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## El empleo de técnicas de seguimiento ocular para evaluar materiales educativos en Educación Primaria

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### Abstract

The design of multimedia materials can influence their effectiveness and efficiency as well as the process of teaching and learning itself. Therefore, it is important to evaluate the suitability of different settings or presentation formats when designing this type of resource. It is recommended that a more objective technique such as eye-tracking be used instead of traditional methods such as surveys and questionnaires. This technique can be used to analyse the visual exploration of users and therefore assess objectively which are the most appropriate settings. An experiment was conducted in which the inclusion of distracting elements in a multimedia presentation was evaluated. Thus, this research concluded that a more efficient learning method was achieved when a presentation does not contain elements that divert the attention from the most relevant areas. This configuration favors students in the second course.

**Keywords:** primary education, eye tracking, design of materials, multimedia contents, assessment

### Resumen

El diseño de los materiales multimedia puede influir en la efectividad y eficacia de su uso, así como en el proceso de enseñanza-aprendizaje. Por tanto, es importante evaluar la idoneidad de las distintas configuraciones o formatos de presentación a la hora de diseñar este tipo de recursos. Se propone el empleo de técnicas de evaluación más objetivas, como el seguimiento ocular o eye tracking en vez de métodos tradicionales, como cuestionarios o encuestas. Dicha técnica permite analizar el proceso de exploración visual de los usuarios, para valorar de forma objetiva (fisiológica), cuáles son las configuraciones más adecuadas. Se describe un experimento en el que se evalúa la inclusión de elementos distractores en una presentación multimedia. Como resultado de este trabajo de investigación se concluye que se produce una mayor eficiencia en el aprendizaje cuando una presentación no incluye elementos distractores que desvían la atención de las áreas con información más relevante.

*Palabras clave:* educación primaria, eye tracking, diseño de materiales, contenidos multimedia, evaluación

### Introduction

Technological advances which have occurred in recent years have made resources and multimedia materials increasingly common in the field of education. It is of special interest to assess which resources are most suitable for students in the stages of primary education and, in particular, which configurations provide a more effective acquisition of knowledge (Moreno & Mayer, 1999).

The evaluation of multimedia materials has often been based on the use of questionnaires and surveys, which allows us to know the subjective perspective of users, and the use of techniques of an objective nature, like the eye tracking technique, which is an ideal complement to traditional data collection methods to assess the effectiveness of multimedia materials (Pretorius, Calitz & van Greunen, 2005; Hyönä, 2010). Eye tracking techniques refer to a set of technologies that allows us to track the behaviour of the visual exploration of the subject when looking at the contents displayed on a screen. In this way, we can learn which areas have been focused on more, for how long and the order within the process. This technique enables us to know how and what is produced when the visual analysis of the display takes place. However,

we must also deduce why, that is, to interpret the data obtained properly (Poole & Ball, 2006).

The eye tracking technique has great application potential in a wide variety of disciplines and areas of study: from marketing and advertising to medical research, psycholinguistics, and studies on usability (Hassan & Herrero, 2007). The objective nature of this technique has great potential since it provides physiological information not consciously controlled by participants. This feature is especially useful when used with primary education children, since the information of subjects of this age is sometimes difficult to attain.

This technique allows us to establish the relationship between efficiency, information processing and observation time dedicated to assimilate the contents of a presentation (Cooke, 2006). It also provides an objective assessment of the cognitive load that involves the observation of the information displayed to children (Lin & Lin, 2014). In short, eye tracking is an interesting source of information when evaluating educational multimedia materials (Birkett, Galpin, Cassidy, Marrow & Norgate, 2011).

## **The use of the eye tracking technique in Education**

The educational field presents continuous evolution and exploration of new opportunities to improve the learning experience of students. Each day is of greater interest in the use of data from computer records to improve computing and pedagogical tools (Werner, McDowell & Denner, 2013). In this sense, the eye tracking technique permits us to collect objective data to analyze and report on how to improve resources and multimedia materials.

In recent years, several studies have appeared that use of the eye tracking technique to evaluate multimedia educational materials (Hyönä, 2010; Tsai, Hou, Lai, Liu & Yang, 2012; Ozcelik, Arslan-Ari & Cagiltay, 2010; Jamet, 2014). However, most of these works focus their research on the stages of secondary education and University, paying less attention to younger students (Mason, Tornatora & Pluchino, 2013). Nevertheless, many works involving primary and pre-primary pupils can still be found (Bolden et al., 2015; Wang, Chen & Lin, 2014) (Paulus, Proust & Sodian, 2013), in addition to works that consider pupils with learning difficulties (Boraston & Blakemore, 2007).

The use of eye tracking has shown greater potential in research on the development of instrumental areas. In particular, this technique has been widely used in research in the development of reading processes (Schneider et al., 2008). In fact, this technology was pioneered in the study of reading adapted to screens (Jacob & Karn, 2003) and the global processing of texts (Hyönä, Lorch & Rinck, 2003). Experiences using eye tracking techniques have appeared in recent years in studies in the field of educational technology and particularly in mathematics (De Smedt & Grabner, 2016; Ansari y Lyons, 2016 Anderson et al, 2014). The use of multimedia in teaching mathematics can encourage a more motivating and interesting teaching process (Ogochukwu, 2010). Studies with young adults and college students can be found (Obersteiner & Tumpek, 2016; Ischebeck et al., 2016; Hunt et al., 2015; Rožek et al., 2014; Susac et al, 2014; Chesney et al., 2013), which analyzes the relationship between various metrics of eye tracking and the efficiency of the participants in the resolution of ns. Other not so recent works made use of geometric shapes in experiences with eye tracking (Anderson, Carter & Koedinger, 2000; García-Hernández, 2008; Lin & Lin, 2014). The results obtained have implications not only in the design of multimedia materials within the field of mathematics education, but also in the design of textbook contents used in the teaching of this discipline (Andrà et al., 2009).

The following section shows an example of the application of this technique. It has discussed the inclusion of distracting elements in multimedia presentations created for teaching mathematics in primary education. There have been studies that analyzed the inclusion of redundant information in presentations, mainly in the case of materials aimed at university students (Liu et al., 2011; van Gog et al., 2009). However, this issue has not been analyzed in the case of pupils in primary school, whose attention and distractions are important elements to consider.

## **Evaluating distracting elements in multimedia presentations using eye tracking**

This section will describe the evaluation of multimedia materials using the eye tracking method, the equipment used, the experimental design and the interpretation of obtained results.

## Materials and methods

The device that is used to apply eye tracking technique is called eye tracker, which projects infrared rays into the user's eyes that bounce off the pupil and return to the device, which allows for very accurate calculations where the subject is fixing his gaze at every moment.

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FIGURE I. Device Tobii X60 (eye tracker) and TFT monitor.

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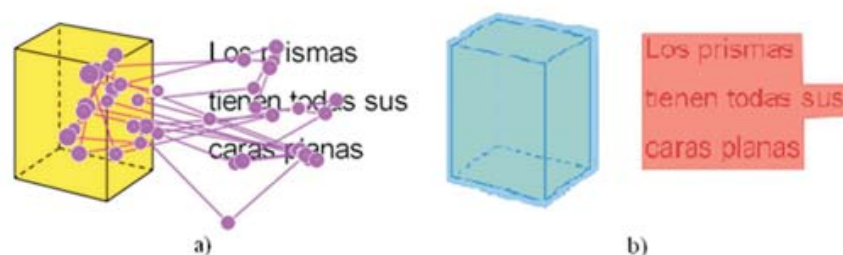
Source: own development

The eye tracker model Tobii X60, made by Tobii Technology, (Figure I) has been used in this research. The eye tracker remains attached under the monitor in this configuration and the user sits opposite to record and track his/her movements by registering the eye tracking data. There is also another eye tracker configuration using glasses. This option is suitable for recording outdoors<sup>1</sup>.

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<sup>(1)</sup> <http://www.tobii.com/>

FIGURE II. Example of scan path (a). Areas of interest (b).



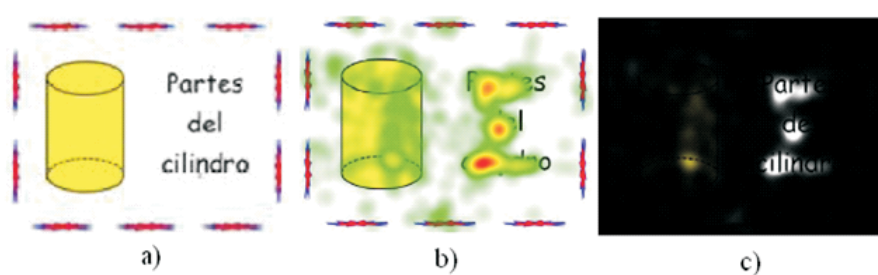
Source: own development

When a scene or image is observed, the ocular trailing does not occur sequentially, but also takes place or has very fast movements called saccades. The distance between saccades is called fixation. During the duration of the fixation period the individual observes the focused area. All generated fixations are recorded during an eye tracking session. The sequence of fixations that a student generates when he or she looks at an image on a screen is shown in Figure IIa. Each circle of the generated graph is a fixation and the size is directly proportional to its duration. The set of generated fixations and the lines that join them (saccades) is called the scan path. This representation allows one to graphically represent the path of visual scanning or ocular trailing while the individual continued to observe the image shown.

Several metrics can be calculated to make a more detailed analysis of the registered information (Poole & Ball, 2006). These metrics may be calculated for the whole image or for specific areas. These areas (that can be defined by the researcher) are called interest areas (AOIs). The AOIs are the areas of the screen in which it is intended to analyse the visual attention of the users (this is, the time spent to look at that area or the number of times that it is consulted). If you want to evaluate multimedia content, AOIs will be created and associated with areas of the screen containing the most relevant information or what is intended to transmit through images and texts (Figure IIb). Analysing the exploration of these specific areas, as well as the amount, duration or sequence of generated fixations, the attention or cognitive load that impose different configurations of the exposed materials can be evaluated or compared.



FIGURE III. Example of (a), heatmaps (b) and gaze opacity (c)



Source: own development

You can also make use of another static representation for the analysis, called heatmaps and, its inverse representation, gaze opacity. In Figure III.a, an example is shown to the subjects. In Figure III.b you can see the heatmap, which clearly shows the areas in which it has generated greater density fixations. These areas are highlighted in red, changing from yellow to green as the number of fixations decreases in different parts of the image. In Figure III.c the gaze opacity is shown, it provides the same information as the heatmap, but in a different way (reverse). When an area has been observed more, it is displayed with greater clarity, while the areas that have not been visualized by the users appear in black.

But the most useful information that is obtained after a session of eye tracking is provided by the metrics that the eye tracker records, which are calculated from the fixations carried out by the participants (Poole & Ball, 2006). These metrics provide more accurate information about how the eye tracking process occurred.

## Experimental design

The objective of this research was to analyse the effect of including distracting elements in a multimedia presentation. This analysis allows for established recommendations or design guidelines of multimedia educational materials for primary education students. In (Navarro, Molina & Lacruz, 2014; Navarro, Molina & Lacruz, 2015) there is a described pilot study which had similar objectives, but using a much lower sample and a less complete analysis.

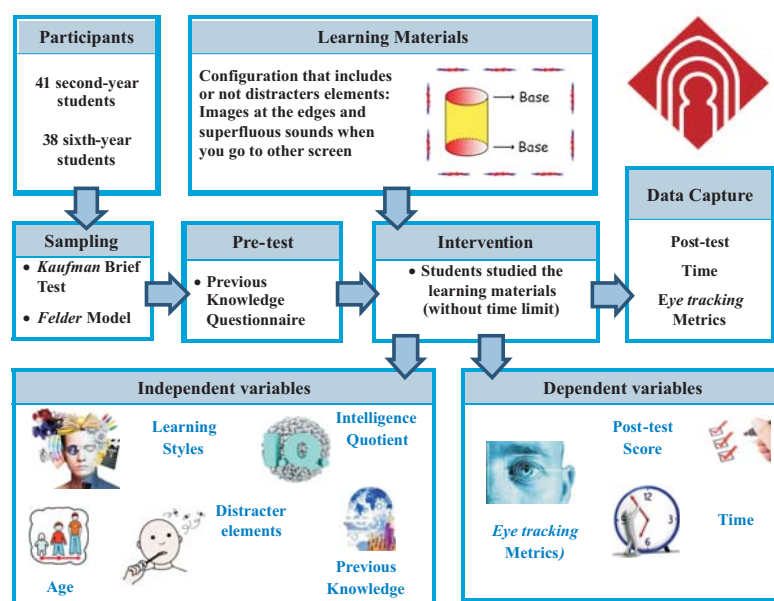


In this case, the experiment was conducted with second and sixth-grade students (7 and 11 years respectively). A different format was shown on screen to two groups in each of these educational levels. The experimental group observed a configuration that included distracter elements (images at the edges and superfluous sounds), while a presentation without these elements was shown to the control group.

The hypothesis on this experience can be formulated in this way: *If unnecessary images at the edges and superfluous sounds are shown in a multimedia presentation, there will be greater learning efficiency (that is, a better comprehension and retention of contents).*

Experimental design is shown in Figure IV. Eye tracking is used to contrast questionnaire data and total observing time of multimedia presentation. 79 primary education students from San José de Calasanz School in Tomelloso (Ciudad Real) participated in the experiment. 41 were second graders, with an average age of 7.38 (SD = 0.33) and 38 were sixth graders, with an average age of 11.56 (SD = 0.42).

FIGURE IV. Experimental design



Source: own development

First of all, two tests were conducted for the sampling stage, *Kaufman* Brief Test (K-BIT) (Kaufman & Kaufman, 2011), to measure verbal and abstract intelligence of students, and *Felder* Model, to know the learning style of each child (Felder & Silverman, 1988). From this data a quota sampling was made to establish two homogeneous groups at every educational level, second and sixth grade of primary education. An experimental group was established and formed by those students who were shown a multimedia presentation with distracter elements. The children in the control group watched a configuration without distracter elements and, theoretically, it favoured learning. Mayer's Coherence Principle was taken into account for the design of the presentation (Mayer, 2005). This principle tells us that adding interesting or entertaining elements that are irrelevant to the instructional goal actually interferes with learning. Gestalt Simplicity Principle also was taken into account (Ware, 2008), which states that every stimulus is perceived in its most simple form.

Afterwards, students completed a test individually. Firstly, they completed a Pre-test that included several open questions. The objective was to establish their previous knowledge about the content shown on screen. After this, the child was placed in front of the monitor for the eye tracker calibration phase. Once prepared, presentations composed by three slides in second grade and four in sixth grade were shown. They included images and text, and some disruptive elements (superfluous images and sounds). The experimental task consisted of students trying to understand and retain the concepts shown in the presentation. The materials and contents to be studied by students was maths and it was adapted to each levels of the primary education official curriculum. As soon as the presentation was finished, the students completed a knowledge questionnaire on the content that they had observed (Post-test).

The total time dedicated to each pupil was about half an hour. Throughout the process we used vocabulary suitable and adapted to the children, using similar activities to those made in the educational centre, and they were quite familiar with. Special attention was given to the explanations and follow-up of the activity for second grade students. They needed more clarification on the process to keep up.

The score of the Post-test, total observation time and eye tracking metrics were processed with Excel and SPSS to perform statistical calculations. A unilateral comparison of means was carried out to perform statistical calculations (Student's t-test).

One of the main realization aspects was the selection of the eye tracking metrics that would be used in the analysis. In this regard, the main disadvantage was the diversity and quantity of measurements that can be used, and there is no unanimity on the most suitable (Hyönä et al., 2003). It is even more important to know how to interpret them. You can find works on the interpretation of these metrics (Jacob & Karn, 2003; Poole & Ball, 2006; Birkett & al., 2011; Mason & al., 2013; Bojko, 2013).

TABLE I. Metrics used in the investigation. \* Measures in image, text or both AOIs

<b>(TFF) *</b>	Time used by the student on to the first fixation of an AOI
<b>(FB) *</b>	Number of fixations before fixating on an AOI for the first time
<b>(AllSc)</b>	Number of total fixations generated on the entire screen
<b>(%Fix)</b>	% of participants who fixated on an AOI at least one time
<b>Fix. density</b>	Number of density fixations on the screen
<b>(TFD) *</b>	Duration for all fixations within an AOI
<b>(FC) *</b>	Number of fixations on an AOI
<b>(TFD/Time)</b>	Percentage of time dedicated to observe an AOI
<b>(FC/AllSc)</b>	Proportion of fixations on AOIs

Source: own development

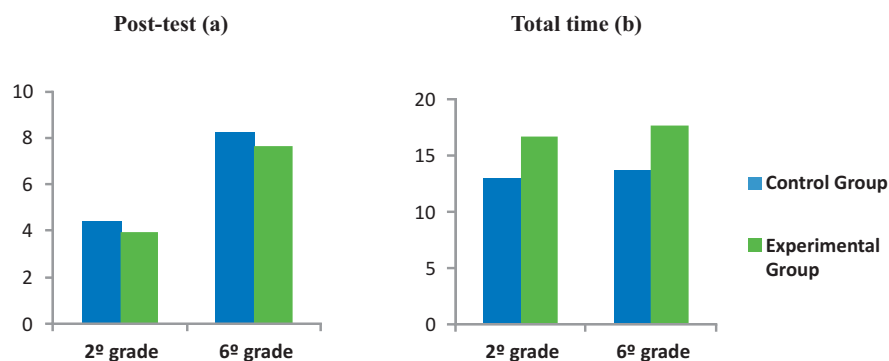
The available metrics which better adapt to the objectives of our research (to measure the efficiency and the cognitive load) were selected. Five of the metrics allowed for the measurement of some of the configurations resulting in greater or less efficiency in locating relevant contents. For instance, less time and the number of fixations until gazes were focused for the first time on an AOI indicated greater efficiency in the search. Also, they are considered efficiency metrics a less total number of fixations, the percentage of participants who fixated at least one time on an AOI or a greater density of fixations. There are other metrics that are interpreted with greater ease in the processing of the information, as

less duration and number of fixations on a particular AOI. Finally, it can be said that an AOI awakens greater interest in the user if they get a major proportion of fixations or a greater percentage of time dedicated to observe an AOI. Table I lists each of the used metrics. In the case of four of these metrics (TFF, FB, TFD, FC), they were calculated for different AOIs (images and text), as well as taking into account both AOIs simultaneously.

## Analysis and results

As indicated above, the presentations appeared with different configurations to two different groups in the experimental task. An image accompanied by the text which was shown to the students of the control group. In the case of the experimental group, they were shown the same image and text but superfluous elements were added (images at the edges and sounds whenever a new slide was appearing). Next there appears graphs that allow us to compare the score obtained by the students in the Post-test (Graphic Ia) and the total time of observation (Graphic Ib), both on the part of the control group (blue) and of the experimental group (green).

GRAPHIC I. Score of the Post-test (a) and Total time spent by the students (b)



Source: own development

The score obtained by the second graders in the Post-test is slightly higher in the case of control group. However, when comparison of means was done, we obtained results of the *Student's t* lower to the critical value, so there are no significant differences. Nevertheless, there is a clear difference in the time dedicated by students to study and retain the information shown on the screen. The calculated value of the *Student's t* relative to Time, with a significance level of 0.05, was of  $t = 1.89$  ( $p = 0.033$ ), greater than the critical value. This indicates that the experimental group looked at the screen significantly less.

Similar data was obtained in the case of sixth graders. As in the case of second graders, the Post-test score is higher in the case of the *Control group*, but practically the same, with no meaningful differences. It can also be confirmed that the time used by the *Control group* is significantly lower, with  $t = 2.96$  ( $p = 1.688$ ) and a significant level of 0.01. Therefore, it can be said for both educational levels, that when the configuration presented to the control group (without distracter elements) is used, the observation is realized in significantly less time.

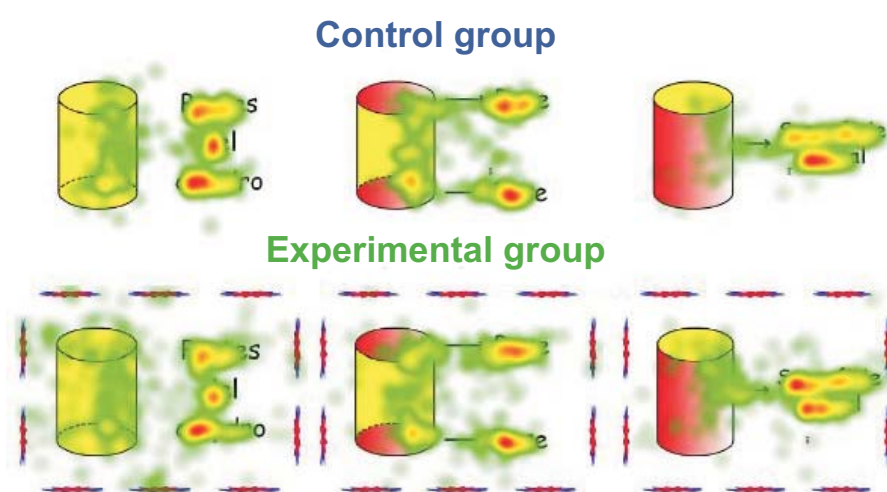
Analysing the generated heatmaps (Figure V), we can see where the student's fixations are concentrated. We can appreciate a similar visual behaviour in both groups. It is observed clearly that if superfluous elements appear, in the case of the experimental group, there is a greater dispersion in fixations, mainly for students of the second grade. The dispersion is greater on the first screens in both educational levels, but is reduced in the following. This effect is known as habituation.

Regarding the metrics provided by the *eye tracker*, differences are observed in most of them, with different levels of significance (Table II).

In the case of the second grade, students of that control group took less time to fix their gaze (TFF), on texts, as well as considering both AOIs, with values of  $t = 3.15$  ( $p = 0.002$ ) y  $t = 2.72$  ( $p = 0.005$ ), respectively. Moreover, they generated less fixations before totally focusing their gaze (FB), on the texts, with values of  $t = 3.01$  ( $p = 0.002$ ) y  $t = 1.85$  ( $p = 0.036$ ), respectively. Additionally, students in the control group generated fewer total fixations on the screen (AllSc), with  $t = 2.49$  ( $p = 0.008$ ), while the percentage of participants who fixated at least one time on an AOI was lower, with  $t = 6.33$  ( $p < 0.001$ ). Regarding the control group, the duration of all the fixations was less (TFD) taking into account both AOIs, with a value of  $t = 1.49$  ( $p = 0.071$ ). Also, for this same group the number of all fixations was lower (FC) on images, texts while considering both AOIs,

with values of  $t = 1.82$  ( $p = 0.038$ ),  $t = 1.38$  ( $p = 0.087$ ) y  $t = 2.35$  ( $p = 0.012$ ), respectively. Finally, the students of the control group dedicated a greater proportion of time on AOIs (TFD/Time), with a value of  $t = 1.37$  ( $p = 0.09$ ).

FIGUREV. Heatmaps



Source: own development

Regarding the sixth graders measurements, the control group students generated a lower overall number of fixations on the screen (AllSc), with  $t = 3.18$  ( $p = 0.002$ ), and a lower percentage of participants fixated at least one time at the edges (%Fix), with  $t = 6.9$  ( $p < 0.001$ ). Where there also appeared a higher proportion of fixations on the AOIs (FC/AllSc), with  $t = 1.42$  ( $p = 0.082$ ).

In the case of the control group, the duration of all fixations was lower (TFD) in texts (only for sixth graders) and all AOIs, with values of  $t = 2.35$  ( $p = 0.012$ ) y  $t = 2.69$  ( $p = 0.005$ ), as well as the number of fixations (FC) in image texts while taking them both into account, with values of  $t = 1.47$  ( $p = 0.075$ ),  $t = 2.43$  ( $p = 0.01$ ) y  $t = 2.98$  ( $p = 0.003$ ), respectively.

TABLE II. Eye tracker metrics obtained in the experiment. \* =  $p < 0.01$ ; \*\* =  $p < 0.05$ ; \*\*\* =  $p < 0.1$ 

		TFF				FB				AllSc	% Fix
		Bor	Im	Tx	All	Bor	Im	Tx	All		
2°	Gr con	6,23	1,25	0,26*	0,09*	0,95	12,29	3,05*	1,33**	44,14*	1,59%*
	Gr exp	2,48	1,10	0,40*	0,18*	13,41	13,09	4,82*	2,18**	62,95*	43,9%*
6°	Gr con	-	0,71	0,27	0,11	-	10,79	3,89	1,47	48,32*	0%*
	Gr exp	2,52	0,76	0,25	0,14	15,58	13,00	3,95	2,16	67,53*	38,2%*

		TFD				FC				TFD / Time	FC / AllSc
		Bor	Im	Tx	All	Bor	Im	Tx	All		
2°	Gr con	0,01	2,78	6,78	9,56***	0,05	9,81**	28,76***	38,62**	0,73***	0,87
	Gr exp	0,65	3,77	7,27	11,69***	3,59	16,27**	34,14***	54,00**	0,70***	0,86
6°	Gr con	0,00	3,88	5,57**	9,44*	0	15,79***	27,95**	43,74*	0,70	0,91***
	Gr exp	0,78	4,43	6,85**	12,06*	3,68	19,37***	36,68**	59,74*	0,71	0,89***

Source: own development

The first conclusion reached by analysing the obtained results is that students obtained scores almost identical in the Post-test in both educative levels (second and sixth grades), but the control group spent less time observing the contents (who observed the configuration that theoretically facilitates the assimilation of contents, because distracter elements were not included). Therefore, it has been achieved in both educational levels a larger learning efficiency when contents are shown without superfluous elements at the edges or unnecessary sounds (as enunciated in the Mayer's Coherence Principle) with a simpler configuration (as expressed by the Gestalt's Simplicity Principle).

These results were confirmed by reviewing the metrics recorded by the eye tracker. The second graders in the control group focused their gaze at lower times and generated fewer fixations, before focusing their attention on the texts and taking into account both AOIs, indicating that this configuration facilitates the perception of the more important contents of the presentation, allowing for a more efficient and direct way



to find these AOIs. The same conclusion is reached by observing that, in the case of the control group, a lower number of total fixations on the screen were recorded and a lower percentage of participants who fixated at least one time on superfluous images at the edges.

In the case of the sixth grade a similar tendency was observed. Students in the control group generated fewer numbers of total fixations and a less percentage of participants who fixated at the edges, so there is also greater efficiency. However, in this case, there isn't fixation on the AOIs before or with a fewer number of fixations, without significant differences existing in this aspect.

Therefore, it is stated that in both educational levels there is more efficient learning in students from the control group, because a similar score was obtained using less time. The students in this group spent almost a third less time (29%), both for second and sixth graders. It is emphasized that the configuration shown to the members of the control group facilitated the quick location of the AOIs, mainly in the texts, in the case of the second graders.

Also in the second course a greater proportion of time dedicated to looking at the AOIs was observed, and a greater proportion of fixations in the AOIs for sixth graders. This indicates that these AOIs present better visibility and arouse more interest in the students, although with low significance levels in both cases. Besides, the control group of second graders dedicated less time to observing the AOIs and a fewer number of fixations were generated, in images, texts, as well as considering both elements. In addition, similar data was obtained in the sixth grade, but adding also total fixation time in the text. All this indicates is that there exists a greater ease in the processing of the information by the control group in both courses.

## Discussion and conclusions

The eye tracking technique presented in this paper is a powerful tool for the evaluation of educational multimedia materials. We propose the combination of traditional techniques (questionnaires) with other innovative methods of an objective nature such as eye tracking.

As a case of application, an experience is described in which we analyze the effect of the inclusion of distracting elements in multimedia

presentations. As a result we can conclude that it is recommended that the presentation of the content that does not include distracting elements (like unnecessary images at the edges or superfluous sounds) that divert the attention from areas with relevant information. Moreover, the study has been conducted considering two different educational levels (second and sixth grade). It has been proven that the use of a format that does not contain distracting elements favors to a greater extent the second grade pupils rather than sixth grade ones. A presentation that includes no distracting items favors children primarily in the control group of the second grade. Lower reading ability of children of this age explains that the inclusion of distracting elements is harmful to a greater extent by focusing faster on the attention in the texts of the members of the experimental group.

Similar conclusions to those reached in this study can be found in previous studies. When inspecting a presentation, the appearance of distracting elements can harm its assimilation (Underwood, Foulsham, van Loon & Underwood, 2005). Graphics should not display more information than required to perform the task (Canham & Hegarty, 2010), because when there is a need for greater processing of information, the learning potential can be lost due to the incorporation of unnecessary content (de Koning, Tabbers, Rikers & Paas, 2009). Therefore, to show non-relevant or redundant information, it should be avoided in presentations and educational content.

A number of problems and limitations have emerged during the research mainly because of the age of the participants. Second grade students require more time and further explanations to perform the entire process and it is necessary to adapt language, display materials and even the size of the images to the inner characteristics of each level of education. On the other hand, only seventy-nine students participated in the present study. A large sample cannot be considered for this study, although it is true that research on eye tracking does not usually employ a great number of participants due to the complexity of the tests, which require activities that require a long time for processing and analysis.

In regards to the follow up lines of this research, we propose the implementation of similar experiences to analyze empirically and objectively other principles of multimedia learning. Besides, this experiment can be completed with others that include distracting elements of a different nature such as advertising banners or elements in motion.

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