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Music Notation Software as a Means to Facilitate the Study of Singing Musical Scores

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Abstract

Introduction. Learning to read music is a complex task which becomes more difficult if it involves students who have different levels of music knowledge. The cognitive load theory maintains that acquiring new knowledge or the development of new abilities imposes a cognitive effort which depends on: a) instructional design; b) complexity of the task and c) previous knowledge.

Method. In the present study eleven students varying in previous musical studies participated in a comparative assessment of music reading exercises using two different kinds of help: usual music instrument and music notation software. Load Cognitive Theory was used as a conceptual framework to determine which interface would be better (imposing low cognitive load) according to both exercises' difficulty levels and students´ previous musical studies. The study involved a mixed factorial experimental design with the following independent within-subjects factors and levels 1) Type of Interface: music instrument and music notation software; 2) Music exercises difficulty: level I and level II. The between-subject factor in this study was: 3) Previous Musical Studies: academic and non-academic music studies.

Results. Results showed that for the most of variables related with cognitive load, music notation software seemed that imposes less additional cognitive load than music instrument when students had no academic music studies and especially when they studied high-level music exercises. In these cases music notation software was a useful help to support music score study.

Discussion or **Conclusion**. The music notation software allows to perceive clearly the relationship between written notation and sound and probably it makes easier the memorization of these pairs. This kind of media could be a useful tool for students with difficulties and for those who didn´t because of the options´ software, which allows music edition, composing, etc.

Keywords: cognitive load theory, music reading, music notation software, musical instrument.

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Resumen

Introducción. El aprendizaje de la lectura musical es una tarea compleja cuya dificultad se acentúa más si su enseñanza ha de adaptarse a un alumnado heterogéneo en cuanto a conocimientos previos musicales. Según la Teoría de la Carga Cognitiva el aprendizaje de contenidos complejos o el desarrollo de nuevas habilidades impone un esfuerzo cognitivo que depende de varios factores: el entorno de aprendizaje, la dificultad del material y los conocimientos previos.

Método. El presente estudio trató de comparar la calidad de lectura musical de once alumnos con diferentes estudios musicales previos que utilizaron dos medios de ayuda durante el estudio: el instrumento habitual y un programa de edición de partituras. La teoría de la carga cognitiva se utilizó como paradigma para determinar cuál de los medios sería el más efectivo según la dificultad de los ejercicios propuestos y el tipo de preparación musical previa de los alumnos. Para ello se realizó un análisis factorial mixto en el que se contemplaron dos variables independientes intra-grupo: 1) el tipo de medio utilizado y 2) la dificultad de las partituras; y una inter-grupo: el tipo de estudios musicales previos.

Resultados. Los resultados sugirieron que, para la mayoría de las variables asociadas a la carga cognitiva, cuando los alumnos no tenían estudios musicales reglados y se enfrentaban a partituras de mayor dificultad, el editor de partituras resultaba más efectivo como ayuda que el instrumento musical habitual. Al parecer, el software de notación musical pudo suponer una menor carga cognitiva adicional en dichas condiciones.

Discusión y conclusiones. El hecho de que el editor muestre de una manera directa la relación entre el código escrito y su correspondencia sonora posibilita que los alumnos y alumnas puedan memorizar de una manera más efectiva esta relación. La inclusión de este tipo de herramientas dentro del currículo podría beneficiar tanto a los alumnos con dificultades como aquellos que tienen amplios conocimientos. Las diferentes opciones que ofrece el software entre las que se encuentran la edición de partituras o la composición inducen a pensar de este modo.

Palabras Clave: teoría de la carga cognitiva, lectura musical, editores de partituras, instrumento musical.

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Introduction

This study attempts to deal with the problem of how to best facilitate the acquisition and development of knowledge and skills related with Western Music notation in classes of students with varied musical backgrounds. Solfège, or the reading of sheet music, is one of the most important subjects of Music Education Teacher degree.

Currently, there is a mix of freshman students enrolled in the aforementioned degree at the University of Seville who have different levels of music studies. While some students have studied formal music training at the Conservatory, others taught themselves to play different instruments by ear, and others have taken non-regulated music training. Finally, other students don't have any knowledge or skills in music. In many cases these students scarcely have the necessary skills to read music scores with fluency.

Any task devoted to the acquisition of learning contents requires certain amount of mental effort, namely co*gnitive load.* Acquisition of complex contents, like those related with music literacy, depends on different variables. Cognitive Load Theory (CLT) maintains that the format instruction is a key factor to reduce *extraneous cognitive load* on working memory storage and then improve effective learning. Over load during learning leads to the new incoming information being missed and not held in long-term memory as cognitive schemata or knowledge because of the limited capacity of human working memory (Schnotz & Kürschner, 2007; Sweller, 2005).

According to CLT, the total amount of cognitive load managed by working memory (WM) depends on three factors (Schnotz & Kürschner, 2007):

1. *Learner's expertise*: The amount of cognitive load is determined by the learner´s previous knowledge in some area (in this case, Solfège). This previous knowledge consists of cognitive schemata which facilitate perceptual chunk in music reading. For expert learners, who don't need process information awareness like the novices, there are more cognitive resources avalaible and the cognitive load decreases.

2. *Task complexity*: The understanding of music scores involves dealing simultaneously with different sound categories: rhythm, pitch, etc… Therefore,

one must understand every single element and also the relationship that exists among them. This is known as *high element interactivity*. When previous knowledge exists, these elements are processed automatically and the cognitive load decreases. In contrast, cognitive load in WM increases if these elements require conscious awareness to be dealt with, and therefore, there wouldn't be available resources to deal with novel information.

3. *Instructional environment*: Some instructional environments include information related with learning content which have to be integrated for comprehension. The same is valid for different information sources which are spatially and temporally separated. In both cases, the extraneous cognitive load increases the total cognitive load in WM, with the result that overloading interferes with the learning. This is what happens when learners who have no previous knowledge use a musical instrument in order to obtain a sound model which could be used as an aid for music reading. As the learner's attention must be split between the musical instrument and the music score, the task of music reading is difficult to accomplish.

It is crucial that inexperienced learners take into account information from both the music score and the musical instrument in order to engage music notation and produce the required sounds.

When studying music score using a musical instrument, inexperienced learners experience a cognitive overload as a result of different factors. Firstly, they have to hold in memory the visual information from the score and turn it into movements. In most cases, the learner's attention is split between two sources of information: the musical score and the musical instrument. Secondly, inexperienced learners have to mentally integrate both visual and aural different kind of information which are temporally separated. This produces an overload which could collapse the cognitive system, thus WM would have no available resources to hold this information.

Until the present time, the most common research strategy to examine cognitive load in designs which use different kinds of interfaces is *divided attention* or *dual-task studies* (Oviatt, 2006, p. 874). This methodology measures cognitive load factually and directly; it is based on human limitations in dealing with two tasks simultaneously (Brünken, Plass & Leutner, 2003, p.57). Inthis sense, outcomes measured from the second task can provide information about the mental resources available to handle the cognitive load w imposed by the interface (Oviatt, 2006, p.874).

In our case, studying music scores involve two tasks: hearing the sound model and performing this model with the voice. Comparing learners´ performances in two conditions - using music notation software or using musical instrument could help to evaluate how much cognitive load they have to invest in each condition. Considering that learner's features and the difficulty of the scores are balanced, results should inform about how much cognitive load is imposed by musical instrument and music notation software.

Brünken, Plass y Leutner (2003) divide cognitive load measures in two main types: objective measures (performance, physiological measures, etc…), and subjective measures (questionnaires, observation, etc…). Paas and van Merriënboer (1994a) suggest that measures based on both performance mental efforts can provide information on: a) the impact of the task on the cognitive load and b) the efficacy of the learning context. Typical cognitive load measures included the time to complete tasks and the correctness of performance (Oviatt, 2006, p.874). In addition, subjective mental effort scales were considered as a promising measures in LCT (Paas, van Merriënboer & Adam, 1994, p.131).

Torgesen (1986) underlines the importance of the automatism developed during the practice of reading music. Indeed, when basic tasks, such as letter or word recognition, are automated, mental effort is reduced, allowing the cognitive system to focus on more complex tasks related to content information. For example, people who cannot decode words with fluency are limited in the understanding of the text . In that sense, Torgesen reviews different studies which show how computer programs can improve reading automatisms through a training based on decoding words, syllables and graphemes.

Some authors draw parallels between verbal language and music (Sloboda, 2005) and for this reason the previously mentioned findings can be applied in music as well. In both verbal language and music, symbols are used in order to represent sound events and in both cases information can be manipulated, created an organized in the mind without external sound events.

Reinking (2005) points out that (the implementation of technology can provide students with presentations of blended modalities, which can help in the decoding process. Therefore, this allows for the perception in real time of events which have different, changing parameters.

Various studies have approached the effects of technology on music reading (Goodwin, 1991; Lemons, 1985; Parker, 1980; Platte, 1981; Prasso, 1997) and also on variables directly related to music reading (Buck, 1991; Chan, Jones, Scanlon & Joiner, 2006; Davis, 2001; Isaak, 1989; Ozeas, 1997). These studies can be classified into two groups according to their main objectives. The first group comprises those studies which compare computer assisted instruction with conventional instruction. The second group is composed of studies which approach computer assisted instruction as a reinforcement of traditional instruction. In all of these studies, previous knowledge was used as a factor to stratify the sample or just as extraneous variable. Despite that, it must be highlighted that previous knowledge is a key factor in determining the efficacy of the instructional environment. Neither type of study measured the effectiveness of the interface with tasks of differing levels of difficulty. Simultaneous double stimuli (visual and aural) were common features of the music software used in the mentioned studies, which seemed to facilitate the process of relating music symbols and music sounds.

It can be therefore postulated that music notation software could be a help in some processes similar to those mentioned. As music notation software can be used to make, edit and print music scores and also to hear the sounds represented on the screen these programs could facilitate the integration of visual and aural information, freeing resources at the WM, which in turn could enable more information to be held and processed in long term memory Encore v.4.5 was the music notation software used in this study. It is characterised by its easy and intuitive interface which provides an easily manageable learning curve.

Multimedia learning theory establishes that an effective training environment should fulfil certain main principles, one of which is congruency. The principle of congruency proposes that information from different sources should be temporally and spatially integrated in order to reduce extraneous cognitive load. T That is, to prevent learners from splitting their attention in order to facilitate the integration of information from multiple sources (Ayres &

Sweller, 2005). This principle is directly related to the main characteristics of music notation software.

Based on the current reviewed literature, it could be suggested that music notation software should simplify the cognitive processes. Under this premise, automatic decoding of music symbols would allow students to focus attention on the relationship between sound and symbol, and thus contribute to effective learning

Objective and hypotheses

Based on the reviewed literature, the main objective of our study was to compare students' achievements in music reading, as a result of the imposed cognitive load, when: a) two different interfaces were used to aid in the process of learning to read music (their usual instrument and music notation software), b) subjects had to deal with different difficulty levels in music scores (I and II), and c) students had different previous musical studies (music conservatory studies and non-conservatory studies).

According to the mentioned literature, it was anticipated that:

1. The greater the cognitive load imposed by the interface, the worse the results would be;

2. The greater the level of difficulty, the worse the results;

3. The lower the previous level of music knowledge, the worse the results as well.

Furthermore, in this study it was also considered pertinent to explore the perceptions and preferences of the participants regarding the two media in terms of usefulness and user-friendliness. [1]

Method

Design

Data was collected through a mixed factorial design (2x2x2) with two within-subjects variables: a) *interface,* music notation software and common instrument, and b) *difficulty level*, I and II; and a between-group variable: c) *previous musical studies*: Music conservatory studies and non music conservatory studies.

[1] The results of this part of the study will be presented in another report.

Participants

The initial sample consisted of 20 student volunteers attending classes in Solfège in the first year of Music Education Degree at University of Seville's Education College. This sample was split according to a between-group variable: 1) Music Conservatory Studies (MC *n* = 13) and 2) Non Music Conservatory Studies (NMC, *n* = 7). The latter group included: a) students who had some musical knowledge because they had received lessons in music schools, b) students who had learnt to play an instrument by ear, without knowledge of musical literacy; and c) students who had no additional musical training than that received in the primary or secondary schools. The former group included participants who had studied how to play an instrument at a high academy of music.

During the oral test, the experimental sample was reduced to 11 participants because of the inability of 9 students from the N.M.C group to complete all sections of the test. Thus, the analysis of variables related to cognitive load was made from data obtained from 11 subjects (MC, *n* = 7, and NMC, *n* = 4) who completed all sections of the oral test (experimental sample).

Materials and Instruments

To measure students' *accuracy in reading music,* two tests were designed by conservatory teachers where participants had to read sheet music with two different levels of difficulty (I and II), corresponding to the content of the Solfège course during the first and second semesters. Student performances were digitally recorded using an Acer Aspire 3000 laptop, the audio editing program Adobe Audition v. 1.5 (Balo et al., 1999), and a SONY ECM-ZS90 microphone. Each of the obtained files was analyzed with the program for phonetic speech analysis PRAAT (Boersma & Weenink, 2002), which allows for the fragmentation and tagging of sound files, and thereby the analysis of the duration and mean frequencies of the different sound events. In each exercise, the interonset intervals (IOI) were extracted, isolated and tagged before being analyzed for frequency and duration. . . The data obtained from this analysis was used to evaluate the the accuracy in reading music according to three criteria: a) the intonation error rate, b) the percentage of rhythmic deviation, and c) the named notes recurrence and/or omission errors.

The intonation error rate was determined by the percentage of intonation errors in each exercise. The intonation of the melodic intervals was considered correct if the frequency difference between two consecutive notes did not exceed a quarter of tone with respect to the theoretical model:. That is, whenever the frequency of the interval didn't depart, by excess or defect, more than a quarter of tone from the theoretical model. The differences between the frequencies of the tones in each exercise were transformed into cents. Accuracy of rhythm performance was measured in relation to the degree of deviation from the relative durations of IOI based on the theoretical model. The average of rhythmic deviation intervals in each exercise was considered as mean for establishing to what extent the interpretation departed from the theoretical model. The repetitions and/or omissions of named notes were measured by counting the number of notes that were repeated and/or omitted.

To ensure the reliability of the results on the accuracy, the sound files obtained from the designed protocol were evaluated by two experts, one of whom did not belong to the research team. Significant correlations were found between the results by both experts for: a) the percentage of tuning errors (r = .89), b) the mean percentage of rhythmic deviation (r = .78), and c) the number of errors (r = .99).

To measure the *perceived mental effort* we used the scale of nine categories by Paas and van Merriënboer (1994b), which was in turn an adaptation of a scale to measure the perceived difficulty of the task by Bratfisch, Borg, and Dornic (1972). The reliability of the instrument was confirmed by Paas (1992) and Paas and van Merriënboer (1994b), with internal consistency coefficients of .90 and .82 when using comparable scales. Paas, Tuovinen, Workshops, and Van Gerven (2003) evaluated the scale as highly valid and sensitive for assessing the overall cognitive load.

The scale was administered twice in each exercise: once just after finishing the the participants studied the music score sheet and again after performing the music (by singing). The data obtained from these two periods was used to measure perceived mental effort during the study and the reading.

SPSS v.15 (IBM, 2009) was used for statistical data analysis, jointly with a spreadsheet to obtain effect size indices adequate to the design.

Procedure

In the first step, the population of students, from which the sample of volunteers was later obtained, was given a questionnaire to collect data about their previous music studies in order to split the sample in two different groups. The questionnaire consisted of different items regarding the academic experience with Solfège, their previous musical experience and prior computer experience. The second step consisted of a training course in basic management of the music notation program Encore v.4.5 (GVOX, 2001).

The third phase of the study (oral test) consisted of a session in which the students had to individually study and read different sheets of music, two for each interface and difficulty level. For each of the exercises the same sequence was followed: 1) study of the music sheet by each participant (during the period of time required), 2) assessment of the perceived mental effort once completed the period of study, 3) performance of the music sheet (oral test) digitally recorded, 4) assessment of the perceived mental effort during the performance, and 5) administration of an opinion questionnaire. The order of the different exercises (music scores) was decided at random. Assigned the variable “interface” was also randomly assigned to groups in the condition “difficulty”.

A pilot study was conducted to check the adequacy of materials, time required and protocols used. Some changes on the original format of the exercises were made according to the results of this previous study.

Results

Previous to the mixed factorial ANOVA developed for each dependent variable, we evaluated the homogeneity of error variances assumption related to the main effect of the previous musical studies with the Levene’s F test. When the assumption was not met, the normal F test was substituted by the heteroscedastic Welch’s test for the main effect of the between-groups variable. For each main and interactive effect we calculated a partial eta squared index, different to the calculated one by SPSS which shows a clear inflation (eg. Bakeman, 2005). We always used the two error terms, between-groups and within-subjects, in the denominator of the equation. These effect size indexes were evaluated according to the criteria proposed by Cohen (1988) for a small, medium, and large effect size (respectively .01, .06, and .14).

Time spent in training

Two interaction effects were statistically significant and reached an effect size near the large level (see figure 1): a) difficulty level by interface, *F* (1,9) = 9.71, *p* = .012, η_p^2 = .12, and b) difficulty level by previous studies, *F* (1,9) = 6.27, *p* = .034, η_p^2 = .12. The mean pattern of these relationships is shown in Figure 1 (see also table 1). As one can see, the difference between the two difficulty levels became larger with the common instrument than with the score editor. Similarly, the difference between difficulty levels was larger in the NMC group than in MC their counterpart.

***Table 1*. Means of variables related to cognitive load by difficulty, previous studies and type of interface.**

Dependent variables	Independent variables			
	Level I		Level II	
	Musical Inst.	Software	Musical Inst.	Software
	Non music conservatory studies (*n* = 4)			
Time (sg.)	272 (154.69)	339.5 (45.58)	934.75 (406.21)	568 (125.11)
% Intonation errors	29.18 (27.73)	26.4 (30.56)	51.9 (18.44)	31.73 (33.17)
% Rhythm deviation	6.27 (2.87)	5.69 (.96)	17.19 (12.18)	2.55 (1.25)
Nº of errors	11 (14.67)	0 (0)	26 (23.02)	13.5 (23.78)
Effort study	1.75 (.96)	1.75 (.50)	6.75 (.96)	4.5 (1.00)
Effort performance	2.5 (1.73)	2 (2)	5.75 (1.5)	3 (1.41)
	Music conservatory studies (*n* = 7)			

Time (sg.)	83.14 (50.43)	196.71 (108.04)	326.71 (327.29)	323.29 (114.35)
% Intonation errors	15.87 (9.29)	7.16 (10)	19.8 (13.96)	23.07 (19.38)
% Rhythm deviation	6.79 (3.59)	3.74 (2.16)	7.84 (11.48)	3.91 (5.3)
Nº of errors	0.14 (.37)	0.57 (0.98)	0.86 (2.27)	0.86 (.90)
Effort study	1.43 (.79)	1.43 (.79)	3.14 (2.19)	3 (1.15)
Effort performance	1.86 (1.21)	2.57 (.98)	3.14 (2.67)	3.71 (1.6)

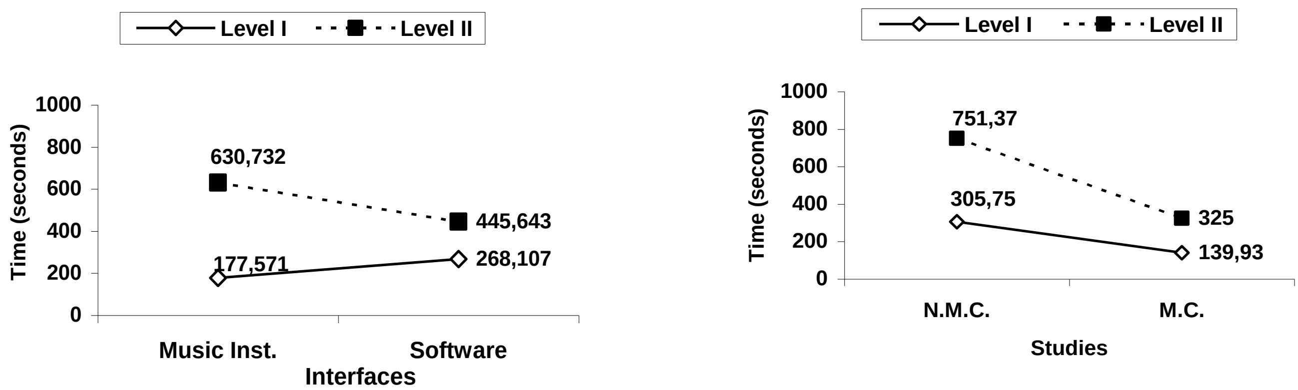

Figure 1. **Time average invested during study by difficulty and interface, and by difficulty and previous musical studies.**

Intonation errors

Blended factorial ANOVA doesn’t show any statistically significant differences or interactions for this variable.

Rhythm deviation

Interface effect was statistically significant and reached a large level effect size (F (1,9) = 5.99, p = .037, η_p^2 = .17). Musical instrument increased the average of rhythm deviation compared to music notation software.

Repeated/omitted-note errors

Interaction effect of previous musical studies by interface was statistically significant (F(1,9) = 15.57, p = .003, η_p^2 = .08) with a medium level effect size. The interaction is shown in fig. 2. It can be observed that the difference between means is greater in the NMC group than in *MC group.*

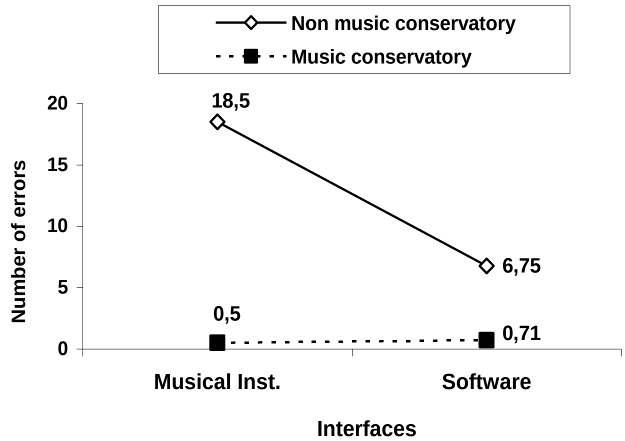

Figure 2. **Means of errors by interface and previous musical studies.**

Mental effort during study

Interaction effect of difficulty levels by musical studies was statistically significant and reached an effect size near to medium (F(1,9) = 6.52, p = .031, η_p^2 = .05). The mean pattern is shown in Figure 3. As we can see there is an interaction between type of interface and score difficulty in NMC group, while there is not in MC group. In the first case, music notation software seems to impose a smaller mental effort during study when students belong to NMC group and when they study high level music scores.

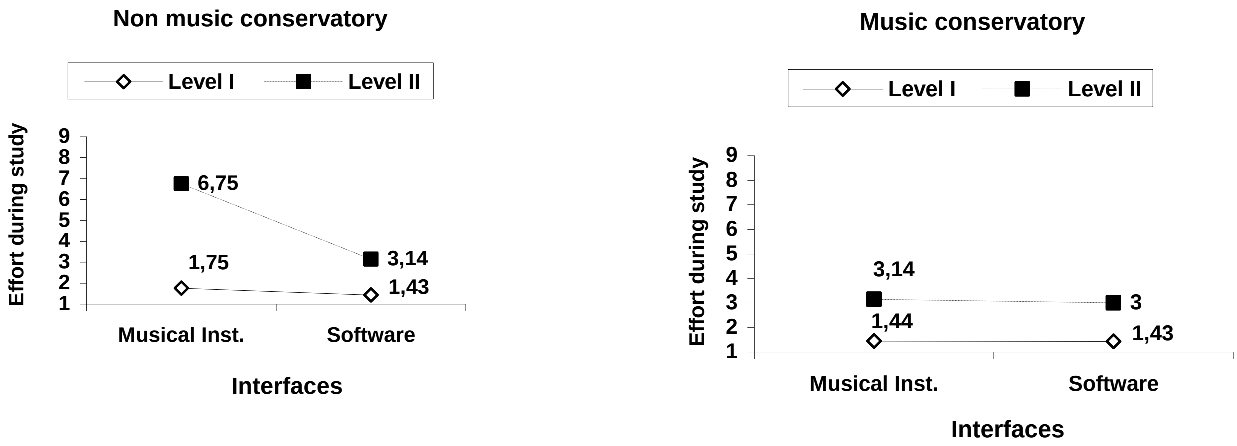

Figure 3. **mental effort average experimented during study by difficulty, previous musical studies and interface.**

Mental effort during performance

The score difficulty effect was statistically significant and reached large level effect size (F(1,9) = 8.21, p = .019, η_p^2 = .21). Also, interface by music studies interaction effect was statistically significant and reached an effect size near to large level (F(1,9) = 5.6, p = .042, η_p^2 = .11). The mean pattern is shown in the fig. 4 and it shows an inverted relationship between the efforts required by each interface and previous music studies.

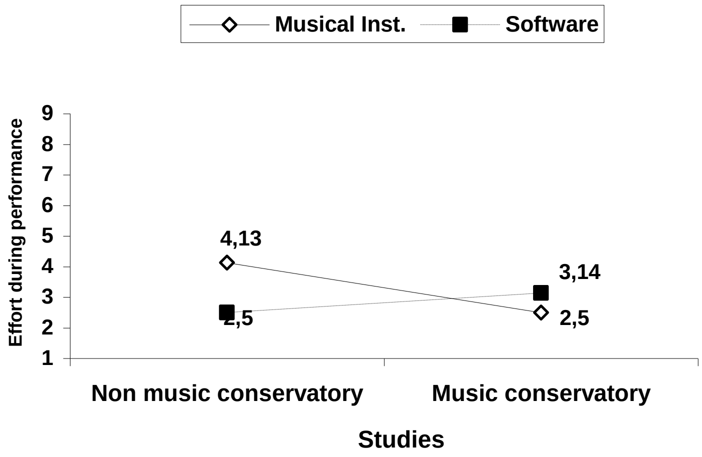

Figure 4. **mental effort average experimented during performance by interface and previous musical studies**

Summarizing, Table 2 shows a contrast between the results of the experiment and the hypotheses.

Table 2. **Results of CLT predictions relative to cognitive load variables**

Variables	CLT predictions		
	Lowest load interface	The greater difficulty → the worst results	The lower knowledge → the worst results
Time (sg.)	Software at level II Musical Inst. at level I	Happened	Happened
% Intonation errors	No differences	Did not happened	Did not happened
% Rhythm deviation	Software	Did not happened	Did not happened
Nº of errors	Software in NMC Musical inst. in MC	Did not happened	Se cumplió
Effort study	Software in NMC No differences in MC	Happened	Happened with the musical instrument. Did not happened with the software
Effort performance	Software in NMC Musical inst. in MC	Did not happened	Did not happened

Discussion

The use of the music notation software produces a lower cognitive load than musical instrument in students who has little previous music knowledge and skills when they approach difficult music scores. This is observed in the data for the majority of variables and it is consistent with the cognitive load principles. These principles predict a high cognitive load when the subjects lack specific mental schemata to approach a material (music score) that embodies a high interaction between its elements.

The cognitive load increased when students used a musical instrument as helping interface for studying high difficulty music scores. Likely, the use of musical instrument imposed an added difficulty and, as consequence, it could have a negative impact on music reading task results. This is consistent with the experiments of Brünken, Plass y Leutner (2003), whom studied the effect of performing two tasks simultaneously. When first task was highly demanded on work memory resources (WM) (in this case, the use of the musical instrument for reading music scores), second task results were highly affected.

Some interfaces and contexts, like music notation software used, would turn into a valid substitute to music schemata or mental representations, reducing the cognitive load and helping to organize music score information in an effective way for learning. In this work, the computer program seems the best help to reduce overall cognitive load in working memory when music score is complex and the students have little knowledge and skills in music reading. Probably, software's capacity to show the relationship between music symbols and related sounds, in a direct and coordinate way, facilitates to construct this association by students. This idea is directly related with time congruence principle of multimedia learning theory (Mayer, 2001), which was developed on a study by Baggett (1984). In this study, the coordination of images and sound during training produced a better learning than the contrary condition. This principle of time congruency was corroborated by Mayer & Anderson (1991).

When students have enough mental schemata to approach the music scores, the use of the two interfaces has different effects on the main variables. It seems that music notation software generated better results related to rhythm accuracy (measured by rhythm deviation) in both groups. That could be seen as music notation software facilitated rhythm accuracy in performance in both groups. On the other hand, it was observed that MC group obtained better results in number of errors and effort during performance by using common musical instrument. That is, the musical instrument facilitated a performance with less number of errors and less effort during score performances. Probably, the computer program could involve redundant information for these variables. The redundancy effect is related to level knowledge or previous experiences in a given domain. The materials presented by computer program were essential to students from NMC condition in order to understand and learn music written code. Otherwise, students with high level music knowledge or previous musical experiences could perceive them as redundant information. Several studies have found that results get worst when there is redundant information (Bobis, Sweller & Cooper, 1993; Carroll, 1990; Mayer et al., 1996).

A selective experimental death happened in the first phase of this work. Some subjects belonged to NMC group could not complete level II of musical scores by using their musical instruments. This fact could help in understanding the double function of the music notation program as a help to study music reading. Firstly, the computer program could have an enabling function for students without previous music instruction: subjects that did not complete the level II musical scores with their musical instruments did it when they used the computer program. According to the cognitive load theory, it can be supposed that computer program reduced the cognitive load and enabled students to tackle the task, an unapproachable task using the musical instrument. Secondly, the computer program could have a facilitating function for the students who obtained better results with the computer program. Probably, music notation software would reduce cognitive load impose by the task thus the effort was less and results got better.

According to the aforementioned, the computer program could be an efficient learning tool when students have few music reading skills. When skills become to develop, it could be useful to introduce other tools –like musical instruments- to enrich music knowledge, to develop some specific music skills and to enable a flexible music reading study. From this approach, it could be interesting for music teachers to expend some sessions to introduce music notation programs in Solfège lessons, given that the use of this programs would be an additional tool for music reading-writing in dictations tasks or even in elemental composition tasks. Students could benefit from the inclusion of these tools, regardless of how much knowledge and skills they have. Moreover, it would be interesting to study in depth of the students understanding processes which are experienced while using both interfaces (instrument and computer program) by a more naturalistic research method. These qualitative data could complete quantitative data in order to build a more comprehensive frame for understanding the role of the interface and its impact in music reading learning.

This study was carried out by using a single experiment to obtain and contrast results of two different helps to study music reading scores. So, only the direct impact of both tools was assessed. It would be interesting to explore the use of these tools in the transference of learning, that is, to study the effects of knowledge and skills acquired or developed by the interface into new situations. A longitudinal hybrid study in the Solfège lessons would be useful to obtain and contrast quantitative and qualitative data in order to get a more complete frame of the real impact of these important music learning tools.

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