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Designing e-learning materials for non-native English speakers in Higher Education: A cognitive theory

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Abstract: A study was undertaken with 90 non-native English speaking undergraduate students at a European Business School. Participants were allocated to one of three groups. Each group used a different multimedia mix of a music e-learning program. The experiment groups were; Redundancy mode (text and narration mix), Modality mode (graphics and narration mix) and Mixed mode (text and graphics mix). Participant's prior level of music learning was assessed, as was their level of knowledge after using the system. Results indicate that the Redundancy mode is most effective for learning, that is, the simultaneous presentation of text and narration enables significantly more optimal learning that modality modes (i.e. Narration and graphics) and Mixed modes (i.e. text and graphics). These findings challenge the currently accepted stance on the redundancy effect in e-learning design.

Keywords: E-learning; interface design; dual coding theory; human memory.

Word count: 4,044.

1. Introduction

Contemporary educational technologies make use of a range of multimedia elements, i.e. text, graphics, video and sound to present pedagogic information. However, these elements are often applied ad-hoc without consideration of which mix of elements will best communicate educational concepts to students (Najjar, 1998). Research into multimedia groupings in interface design for educational technology has led to inconclusive and contradictory results. Some studies report that one multimedia element is more effective for learning, whilst others rooted in antecedents such as dual coding theory and models of working memory, have focused on providing similar (although not identical information) through different multimedia elements. Added to this is the complexity of 'visual/verbal' classifications in the area of cognitive psychology and human memory.

This study extends upon work conducted by Truman & Truman (2006) and Toh et al (2010), which identified that designing interfaces which simultaneously present information via text and narration significantly increases a student's ability to recall pedagogic concepts. Truman & Truman reported this as a consistent outcome across unrelated academic domains. The study presented in this paper extends upon this work by challenging the currently accepted notion of the 'redundancy effect' in multimedia design and by situating the study in the context of non-native English speakers in Higher Education.

The experiments reported here were designed to assess the effectiveness of 'text-only', 'text-narration' and 'pictorial-narration' on learning and information recall. The e-learning program MOLE (Music Oriented Learning Environment), was used as a test platform for this research.

Background Motivation

Human memory and dual Coding theory

It is acknowledged that there are four memory processes within human memory; control, encoding, storage and retrieval. The modal model of memory proposed by Atkinson & Shiffrin (1968) states that there are three sub-stores; sensory memory, short-term memory and Long-term memory. Information perceived via sensory memory can be transferred to short term memory via attentional processes. Information in short-term memory can be transferred to long-term memory through two primary conditions. Peterson & Peterson (1959) state these conditions to be; the rehearsal of material/information in short-term memory, and in-depth information processing (i.e. Craik & Lockhart, 1972). Unlike the infinite capacity of long-term memory, short –term memory is limited in the information is can hold (Miller, 1956).

A more contemporary model of memory (i.e. working memory) was proposed by Baddeley (1992), and purports that auditory and visual processing channels are independent, allowing both visual and verbal representations of information to be held in memory. Two slave sub-systems are encompassed within the working model of memory; the articulatory loop and the visuo-spatial sketchpad. The articulatory loop is responsible for the processing and storage of verbal information, whereas, the visuo-spatial sketchpad is responsible for processing and storage of visual information. The 'Central Executive' component of working memory is responsible for the co-ordination of these sub-systems and allows referential connections to be formed between visual-verbal information. The notion of 'working memory' directly links to Paivio & Csapo's concept of 'dual-coding theory' (1973).

Dual-coding theory asserts that simultaneous multi-channel processing of linguistic information is possible whilst providing a symbolic function to non-verbal objects. This is facilitated by two cognitive representation units; imagens and logogens (Paivio, 1971). Imagens are concerned with processing pictorial information, whilst 'logogens' are responsible for processing verbal information. Educational technologies which utilise dual-modality are effective for enhancing the recall of pedagogic information as they target both the visual and verbal processing channels. This allows the brain to search along two 'paths' during recall, allowing maximization of an individual's response time (Dix et al, 1993).

Interface design and the redundancy effect

To date, studies within the area of multimedia use in educational technology have applied dual-coding theory to pictures and narration owing to the classifications of visual/verbal entities. However, the results arising from the application of dual-coding theory in interface design have been contradictory at best. Whilst numerous studies have stated that a mix of pictorial and verbal (i.e. narration) information has proven most effective for information recall (i.e. Mayer, 2011; Mousavi et al, 1995), other studies have reported significant learnability effects associated with text and narration (i.e. Reed, 1985; Badii & Truman, 2001; Truman & Truman, 2006; Toh, 2010).

Despite the findings from studies mentioned above, the generally accepted assumption in educational technology research is that learning is inhibited when on-screen text and narration containing the same information is presented simultaneously, rather than on-screen text or narration alone. This is referred to as the 'verbal redundancy effect' (Toh et al, 2010). It is argued here that this assumption is incorrect, and this notion is supported by more recent research which has reported learnability gains associated with the simultaneous presentation of text and narration (i.e. Badii & Truman, 2001; Truman & Truman, 2006). This notion is also substantiated by the study conducted by Toh et al, which investigated the redundancy effect in multimedia learning via two instructional modes; redundant mode and modality mode. In 'redundant mode', static pictures and audio narration were presented with synchronised redundant on-screen text. In 'modality mode', only static pictures and audio were presented. Findings from the Toh et al study indicated that learners exposed to the redundancy mode achieved significantly higher comprehension scores than learners exposed to the modality mode. These findings suggest that the reverse redundancy effect does not impede learning; rather it reduces the cognitive load and thereby enhances learning.

Cognitive load theory: redundancy and modality modes

Cognitive load theory is an instructional theory based on relations between short term and long term memory used to generate instructional procedures. The theory asserts that as short term memory is limited in capacity, it is important to ensure that cognitive resources of learners are directed to learning as opposed to irrelevant/redundant features of instructional materials (Clark et al, 2006; Sweller, 1999; Sweller, 2011).

Research related to cognitive load theory reports that pictures and narration that are presented simultaneously with redundant on-screen text increase cognitive load and can impede learning due to the competition of resources in the visual working memory (Moreno & Mayer, 1999; Mousavi et al, 1995; Tindall-Ford et al, 1997). This is often referred to as the redundancy effect. It is important to note that, much of the empirical research validating this principle was based learning of scientific concepts and technical material (i.e. Craig, Gholson, & Driscoll, 2002; Kalyuga, Chandler, & Sweller, 2000, Sweller, 2004). Mayer (2001; 2011) suggests that for optimal learning to occur, information accompanying pictures should be narrated, rather than presented as onscreen text. According to Clark and Mayer (2008) learning is most effective when pedagogic concepts are presented via graphics and narrations as opposed to graphics, narration and onscreen text. Clark and Mayer's reasoning for this is the assumption that when graphics and words are both presented together in visual manner (i.e., as graphics and text), the visual-processing channel becomes overloaded. Numerous studies support this finding, for example, a study conducted by Mousavi et al (1995) reported that students performed better on subsequent tests after learning via audio-visual format as opposed to a visual format. Such results have been replicated in later studies (i.e. Ginns, 2005). However, research into this area has produced conflicting results. This is evident in the studies reported by Toh et al (2010) and Truman & Truman (2006) outlined above.

Challenging visual and verbal classifications

Theories that address the simultaneous reading of text whilst listening to narration refer to these elements as 'verbal entities' (i.e. Baddeley, 1992; Baddeley & Hitch, 1974; Paivio & Csapo, 1973). This is as opposed to graphical images, which are said to relate to visual stores. In the design of multimedia use in educational technology this appears to have been taken literally. Many scholars have adopted the classifications or 'visual' and 'verbal' as stated above. However, in the proposed study it is argued that the classification of visually presented text as a verbal entity is a false

dichotomy as the representation of text is a visual display in itself as one forms an appreciation for the structure of the text. This view is substantiated by Craik & Loockhart's levels of processing theory (Craik & Lockhart, 1972), in which it is suggested that information can be processed in the short-term memory store in a number of ways. This might include information concerning the visual characteristics of printed text, and rehearsing to encode it in terms of semantics. Craik & Lockhart suggest that such processes facilitate learning over longer periods, with deeper levels of processing leading to more effective information retention. In addition, both the written and spoken word are natural forms of communication, and thus, directly encodable

Some scholars assume that simultaneously presenting text visually and aurally can cause interference between reading and listening to the text because the speed of reading is usually faster than that of listening. However, it is argued here that concurrent read and narrated text focuses a learner's attention on pacing through the information as opposed to skim reading and thus imparting a deeper level of learning in line with the depth of processing theory. With regard to educational media design, the studies conducted by Badii & Truman (2001) and Truman & Truman (2006) report that processing of visual and auditory text does not interfere with each other but reinforces learnability.

Language and learning

A number of studies conducted with international students have investigated the ways in which the use of a foreign language for instruction affects teaching and learning. Numerous studies have reported that international students face difficulties in understanding lessons in English (Morell 2004; Crawford & Camiciottoli 2004; Arden-Close, 1993; Othman, 2008). Hellekiaer (2010) argues the need to improve the quality of lessons for students for whom English is not their first language. Our study seeks to provide an effective strategy to support learning for non-native English speakers in Higher Education through dual-modal educational technology design. It is envisioned that designing e-learning materials with a dual-modal design may assist with removing barriers causal of lessons delivered through a second language, and may assist with delivering material at more suitable 'pace'.

Research Aims and Objectives

The purpose of this research is to investigate the area of dual-coding systems with a focus on existing visual and verbal information processing classifications. In particular, this study will focus upon the effectiveness of three presentation modes on pedagogic information recall. The findings from the study will be analysed to provide an interface design strategy to support learning for non-native English speakers in Higher Education through educational technology.

Hypotheses

Based on the above, the following hypotheses will be explored:

- H1) The redundancy mode is an effective e-learning strategy for non-native English speaking students in Higher Education.

- H2) The redundancy effect enhances learning significantly more than modality and mixed modes.

Methods

Participants and experimental procedure

In order to test the hypotheses, an adapted version of MOLE (Music Oriented Learning Environment) was used. This software was adapted from the version used in previous studies by Badii & Truman (2001) and Truman & Truman (2006) to consist of three short interactive lessons relating to music theory fundamentals. MOLE was originally designed in accordance with the Associated Board of the Royal School of Music theory guides.

This research is based upon two assumptions; the dual-channel assumption and the limited capacity assumption and will investigate the hypotheses through three modes. The MOLE software was

adapted into three different prototypes to present multimedia information in accordance with the conditions under investigation. The prototypes used are described in Table 1.

Condition	MOLE Prototype Display	No. of participants	Participant demographic
Redundancy mode	Audio narration and on screen text	Thirty	Non-native English speaking undergraduate students
Modality mode	Static graphics and audio narration	Thirty	Non-native English speaking undergraduate students
Mixed mode:	Static graphics and on screen text	Thirty	Non-native English speaking undergraduate students

Table 1: Experiment groupings

Ninety undergraduate students at a European Business School (n=90) participated in the study. All participants were non-native English speaking students, and were randomly selected and assigned to one of the conditions shown in table 1. Participants were based in a computer lab which accommodated 15 participants at a time All participants were provided with a computer with the MOLE software installed and a set of headphones (where applicable). The effect of the conditions was measured using a pre-test, post-test protocol prior to and following their session with MOLE. This was followed uniformly across all conditions.

Data collection protocols

As participants were selected at random the extent of their prior knowledge of music was unknown upon selection. However, if upon taking the pre-test their level of knowledge was found to be high, they were deselected and replaced by another randomly chosen candidate. This procedure was followed to minimize the incidence of errors and bias. A protocol of pre-experiment and post-experiment testing was used to normalize as far as possible, the effect of any previous music learning that had not been mediated by exposure to the MOLE software.

In order to evaluate the actual learning imparted by the MOLE software, participants completed a paper based pre-test prior to their learning session. This allowed for the assessment of their prior knowledge level of musical concepts. Participants were allotted five minutes to complete the pre-test and fifteen minutes to interact with the MOLE software. Upon completion of the session with MOLE, participants were then given five minutes to complete the post-test paper. The post-test paper included questions from the pre-test arranged in a different random ordering. The pre-test and post-test scores were then compared across the three conditions to ascertain the mode associated with the highest learnability scores. The total participation time was twenty five minutes.

Ethical Considerations

Participation in this study was voluntary and anonymous. Participants were assured that they could withdraw their participation at any time and that participation was not compulsory.

Results

The responses of participants for each of the 11 questions of the pre-test and the post-test were averaged, such that pre-test and post-test generated mean scores. These scores are presented in Table 2, across each of the modes separately.

Condition	N	Pre-test Score M (*SD*)	Post-Test Score M (*SD*)
Redundancy Mode (Narration and text)	30	4.13 (3.32)	9.53 (1.54)
Modality Mode (Static graphics and narration)	30	2.90 (3.13)	6.13 (2.62)
Mixed Mode (Static graphics and text)	30	1.93 (2.46)	4.70 (2.62)

Table 2: Means and standard deviations of pre-test and post-test scores across mode type

As can be seen in table 2, participants in the Redundancy mode attained higher scores in the pre-test and post-test than those in modality and mixed modes. Those in the mixed mode (i.e. text and static graphics) attained the lowest scores on the pre-test and post-test out of all three conditions. A 2(time: pre-test vs post-test) x 3(mode type: redundancy vs modality vs mixed) repeated measures ANOVA was conducted to establish the association between test performance and mode type. Significant main effects were observed with time, in that participants performed significantly better in the post-test compared to the pre-test, $F(1,87)=211.75$, $p=.000$. This indicates that learning was imparted during the e-learning session. This finding is consistent across all three conditions.

In addition, a significant interaction effect was observed between time and mode type, $F(2,87)=9.65$, $p=.000$. Specifically, participants who received the redundancy mode performed significantly greater in the post-test, compared to participants who received the modality mode ($p=.001$), and participants who received the mixed mode ($p=.000$). This indicated that the redundancy effect (i.e. narration and text) was the most effective multimedia mix for imparting learning to participants.

Additional analysis

Additional analyses were computer to examine the role of demographic variables, such as music training, on performance across the pre-test and post-test.

A 2(time: pre-test vs post-test) x 3(mode type: redundancy vs modality vs mixed) x 2(music theory training: yes vs no) repeated measures ANOVA was conducted. A significant interaction effect was obtained between time and music training, irrespective of the mode type they had received. Specifically, individuals with music theory training performed significantly better in the pre-test ($M=4.82$, $SD=3.07$) and post-test ($M=7.80$, $SD=2.80$), compared to individuals with no music theory training (pre-test: $M=1.55$, $SD=2.23$, post-test: $M=5.95$, $SD=3.08$), $F(1,83) =12.19$, $p=.000$, $\eta 2=.12$.

Similarly, a 2(time: pre-test vs post-test) x 3(mode type: redundancy vs modality vs mixed) x 2(music instrument training: yes vs no) repeated measures ANOVA revealed a significant interaction effect between time and music training, irrespective of the mode type they had received. Specifically, individuals with music instrument training performed significantly better in the pre-test ($M=5.06$, $SD=3.05$) and post-test ($M=8.28$, $SD=2.35$), compared to individuals with no music instrument training (pre-test: $M=1.84$, $SD=2.48$, post-test: $M=5.96$, $SD=3.12$), $F(1,84)=7.60$, $p=.007$, $\eta 2=.08$.

No significant differences were identified with regard to gender.

Discussion

With regard to our hypotheses, the results from our study demonstrated that text and concurrent narration leads to a significantly higher level of learning than multimedia mixes of graphics-and-text and narration-and-text for non-native English speaking students in higher education. This finding challenges the currently accepted stance on Cognitive Load Theory and in particular to the 'Redundancy effect'. That is, rather than impede learning, a text and narration mix is significantly conducive to learning. There are a number of reasons for this occurrence. Firstly, we argue that concurrently read and narrated text focuses a learner's attention on pacing through information

rather than 'skim-reading' and imparting a deeper level of learning, thus making processing information in second language more manageable for non-native English speaking students. In addition, both the written and spoken word are natural forms of communication, and thus, directly encodable.

Whereas current understandings on dual-coding theory suggest that 'text' and 'narration' are both categorised as 'verbal entities', we argue that this is a false dichotomy as the representation of text is a visual display in itself. Therefore, the simultaneous presentation of text and narration of identical information within an eLearning system allows for the simultaneous multi-channel processing of linguistic information for the learner. Thus, the material is imparted along two distinct channels in the brain, increasing the learnability of the material. In terms of non-native English speakers, this approach strengthens the associations of the material being learned and is an effective strategy for e-learning design.

Although our results indicated that music theory training and music instrument training led to better task performance, our findings also indicated that all participants performed significantly better in the post-test compared to the pre-test. Thus, this is indicative that learning was imparted during the e-learning session across all conditions.

Conclusion

The impact of this research is that concurrent text and narration is an effective multimedia mix for e-learning for non-native English speaking students. This challenges the accepted stance on Cognitive Load Theory, in that redundancy mode rather than impede learning is actually conducive to learning. This multimedia mix is more significantly effective than mixes of graphics-text and graphics-narration. Future research may include investigating information pacing in concurrent text and narration. This study has also raised implications for the current classifications of visual and verbal entities of dual coding theory.

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