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ARTICLE

Readdressing The Redundancy Effect: A Cognitive Strategy For E-learning Design

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ABSTRACT

This study challenges understandings on the 'redundancy effect' of cognitive load theory and visual/verbal classifications of dual-coding theory. Current understandings assert that a multimedia mix of narration and text displayed during e-learning leads to cognitive overload, thus, impeding learning[1,2]. Previous research suggests that for optimal learning to occur, the most effective multimedia mix for e-learning presentation is the use of graphics and narration[3-6].

The current study was undertaken with 90 undergraduate students at a British University. Participants were allocated to one of three groups. Each group used a different multimedia mix of a music e-learning program. Participants received learning material electronically, which involved either a mix of narration and text, graphics and text, or graphics and narration. Learning was measured by differences in music knowledge scores obtained before and after receiving the learning material. Results indicate that the combination of text and narration is most effective for learning, compared to combinations of graphics and text and graphics and narration. These findings challenge the currently accepted stance on the redundancy effect in e-learning design.

1. Introduction

Contemporary educational technologies make use of a range of multimedia elements including text, graphics, video and sound to present pedagogic information. However, these elements are often applied in an ad-hoc manner without considering which mix of elements will best communicate educational concepts to students. For example, e-learning platforms may use a mix of narration and text on screen or just narration without a clear rationale for using multiple or a single presentation mode. Alternatively, an emphasis may be given to inclusivity in terms of learning styles, such that the more styles that are addressed the better, without consideration of what is optimal. For instance, on some virtual learning platforms subtitles have become a standard feature that learners have to switch off rather than on. As such, while technology has made it easier and cheaper to use multiple presentation modes, educational designers and learners are not generally informed about the benefits and drawbacks

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of choosing a particular presentation mode.

Studies in e-learning and psychology have produced mixed and contradictory results about the effectiveness of using different modes to present learning content. Some research has supported cognitive load theory, which suggests that conveying excessive information can impede learning because of the limited capacity of working memory [7-9]. The outcome of cognitive load has been coined the redundancy effect, whereby learning is detrimentally affected by the overloading of either the visual or verbal processing channels of memory. Other research, in contrast, has suggested that learning is more effective when multiple channels are used [10,11].

Our research attempts to clarify and explain the inconsistencies in the literature around the use of multiple presentation modes (e.g. text, graphics, narration) in e-learning. In what follows, we show that the inconsistencies in past research may at be attributed to differences in how text is treated, as either a verbal rather than visual presentation mode. Moreover, text is a natural form of communication that is directly encodable and the visual-verbal categorization may not therefore be representative of how text is processed. We argue that text paces narrated information, and therefore, enhances learning rather than competes for limited working memory resources. It may be that there is no redundancy effect when text is involved, as will be shown by our empirical results. Our findings support and help explain the work conducted by Truman & Truman[10] and Toh *et al*[11], who found that e-learning interfaces that present information via text and narration simultaneously significantly increase students' ability to recall pedagogic concepts.

In what follows, we investigate the effectiveness of three separate presentation modes on learning and information recall: 'text-only', 'text-narration' and 'pictorial-narration'. The e-learning program MOLE (Music Oriented Learning Environment) is used as a test platform for the study. We control the effect of several variables that can interfere with the relationship between presentation modes and learning including music theory and music instrument training.

2. Background Motivation

2.1 Human Memory and Dual Coding Theory

Research about the effectiveness of media used in learning contexts is based on assumptions about the operation of human memory. There are four well-established memory processes: control, encoding, storage and retrieval. Furthermore, the modal model of memory proposed by Atkinson & Shiffrin[12] identified three sub-stores of memory: sensory memory, short-term memory and long-term memory. Information perceived via sensory memory can be transferred to short term memory via attentional processes, while information in short-term memory can be transferred to long-term memory through two primary conditions: rehearsal of material/information in short-term memory, and in-depth information processing[1,13]. Unlike the infinite capacity of long-term memory, short-term memory is limited in the information it can hold[14].

In addition, the model of working memory proposed by Baddeley[15] 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 working memory: the articulatory loop and the visuo-spatial sketchpad. The articulatory loop is responsible for processing and storing verbal information, whereas the visuo-spatial sketchpad is responsible for processing and storing visual information. The 'central executive' component of working memory co-ordinates these sub-systems and allows referential connections to be formed between visual and verbal information.

The notion of working memory relates to Paivio & Csapo's 'dual-coding theory'[16]. This 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[17,18]. Imagens are concerned with processing pictorial information, whilst 'logogens' are responsible for processing verbal information. Educational technologies that 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[19,20]. When translated into the context of learning, offering learning materials through the two paths of visual and verbal processing should lead to more effective learning because information recall is enhanced.

2.2 Cognitive Load Theory: Redundancy and Modality Modes

While dual coding theory suggests that using both visual and verbal presentation of learning material enhances learning, other theories of memory imply that memory processes can be overloaded, leading to reduced learning capacity. More specifically, cognitive load theory asserts that as short term memory is limited in capacity, the use of repetitive or redundant features of learning material will overload the cognitive resources of learners, i.e. the visual

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or verbal processing channel identified in the dual-coding theory, culminating in a redundancy effect [7,8,9]. More specifically, visual pictures and verbal narration presented simultaneously with redundant on-screen text increase cognitive load and can impede learning due to the competition of resources in working memory[21-24].

In order to avoid the redundancy effect, Clark and Mayer[3] suggest that learning is most effective when pedagogic concepts are presented via visual graphics and verbal narration as opposed to a combination of graphics, narration and onscreen text[3]. Clark and Mayer's reasoning is that when graphics and words are both presented together in visual manner, the visual-processing channel becomes overused. Numerous studies corroborate this finding [22,25]. In these studies, however, text is considered to be visual information processed through visual memory channels as imagens rather than logogens. Rather, as verbal information, text can be processed by logogens via a verbal-processing channel, alleviating the cognitive overload on the visual-processing channel. It is also important to note that much of the empirical research validating the redundancy principle has been based on the learning of scientific concepts and technical material[26,27,24].

2.3 E-learning Design and the Redundancy Effect

Studies within the area of e-learning design have applied dual-coding theory to the use of pictures and narration in learning situations owing to the distinction between visual and verbal entities[4,5,6,21]. Some studies have found that a mix of pictorial and narration information is more effective for information recall[2,22,3,4,5], whilst other studies have found that a mix of text and narration is more effective[28,29,10,11]. For example, Toh *et al*[11] 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 (verbal overload). In 'modality mode', only static pictures and audio were presented (no overload). Findings revealed that learners exposed to the redundancy mode achieved significantly higher comprehension scores than learners exposed to the modality mode. These findings suggest that the redundancy effect does not impede learning; rather, the use of all of pictures, audio narration, and on-screen text reduced the cognitive load, and thereby enhanced learning.

2.4 Challenging Visual-verbal Classifications

Research about the redundancy effect in learning assumes that text and narration are both verbal logogens. Specifically, the simultaneous reading of text whilst listening to narration are referred to as 'verbal entities'[15,30,16,18]. In contrast, graphical images relate to visual memory stores and processes. Many scholars have adopted the classifications or 'visual' and 'verbal' as literal categories in the design of e-learning. However, in the present study it is argued that the classification of text as a verbal entity and images as a visual entity is a false dichotomy. Rather, like images, the representation of text is visual, as it has a visual structure.

Furthermore, some scholars have assumed that simultaneously presenting text visually and orally can cause interference between reading and listening to the text because the speed of reading is usually faster than that of listening[31,32]. However, we argue here that concurrent reading and narrated text focuses the learner's attention on pacing through the information as opposed to skim reading and thus imparts a deeper level of learning. This view is supported by Badii & Truman[29] and Truman & Truman[10], who report that processing of visual and auditory text do not interfere with each other, they are both naturally and directly encodable as forms of communication, and reinforce rather than impede on learning.

3. Methodology

The purpose of this research is to investigate the redundancy effect in e-learning. In particular, this study will focus upon the effectiveness of three presentation modes on pedagogic information recall: narration and text (referred to as the 'redundancy' mode), graphics and narration (referred to as the modality mode, i.e. visual vs verbal) and graphics and text (referred to as the mixed visual mode).

3.1 Hypotheses

The following hypothesis was explored:

H1) The redundancy mode will be associated with greater information recall compared to the modality and mixed modes.

3.2 Participants and Experimental Procedure

In order to test our hypothesis, 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[29] and Truman & Truman[10] 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. The MOLE software was adapted into three different prototypes to present multimedia information in accordance with the

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conditions under investigation. The prototypes used are described in Table 1.

Table 1. Experimental conditions

Experimental Condition	MOLE Prototype Display
Redundancy mode	Audio narration and on screen text
Modality mode	Static graphics and audio narration
Mixed mode	Static graphics and on screen text

Ninety undergraduate students at a British University (n=90) participated in the study. All participants were randomly selected and equally assigned to one of the conditions shown in Table 1. Participation tool place in a computer lab which accommodated 15 participants at a time. All participants were provided with a computer running the MOLE software and a set of headphones. Learning was captured by participants' scores on a pre-test and a post-test, administered prior to and following their session with MOLE. This was followed uniformly across all conditions.

3.3 Data Collection Protocols

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

3.4 Ethical Considerations

Participation in this study was voluntary and anonymous. Participants were assured that they could withdraw their participation at any time.

4. 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 scores generated mean. These scores are presented in Table 2, across each of the modes separately.

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

Experimental Condition	N	Pre-test Score M (*SD*)	Post-Test Score M (*SD*)	Difference between pre-test and post-test scores
Redundancy Mode (Narration and text)	30	4.13 (3.32)	9.53 (1.54)	5.40
Modality Mode (Static graphics and narration)	30	2.90 (3.13)	6.13 (2.62)	3.23
Mixed Mode (Static graphics and text)	30	1.93 (2.46)	4.70 (2.62)	2.77

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. The reason behind the different pre-test scores across the three conditions can be explained by individual variables in particular music training, as discussed later in detail.

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 interaction with the learning software. Significant main effects were observed 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 across all modes using different combinations of text, graphics and narration.

In addition, a significant interaction effect was observed between mode type and learning performance, F (2, 87) = 9.65, p = .000. Specifically, participants who received the redundancy mode performed significantly better in the post-test, compared to participants who received the modality mode (p = .001), and participants who received the mixed mode (p = .000). The participants in the redundancy condition improved their performance on average by 5.40 points against 3.23 points in the modality condition and 2.77 points in the mixed mode condition. This indicated that the redundancy mode was the most effective multimedia mix for imparting learning.

5. Additional Analyses

Additional analyses were computed 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

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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 theory 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, η^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 instrument 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, η^2= .08. No significant differences were identified with regard to gender.

6. Discussion

With regard to our hypothesis, the results from our study demonstrate that text and concurrent narration leads to a significantly higher level of learning as opposed to graphics-text and graphics-narration modes. This finding opposes views on cognitive load theory, and in particular 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. This concept is substantiated by Moore[33], who states that "*the pace of narration controls the pace of the material*". 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'[15], 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 e-learning 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. This approach strengthens the associations of the material being learned, and is an effective strategy for e-learning design. Our findings support those reported by Badii and Truman[29] and Truman and Truman[10] , who reported that text-and-narration enhance learning performance.

Although all our participants performed better in the post-test compared to the pre-test, our results indicate that previous music theory and instrument training led to better task performance irrespective of the mode through which the material was delivered. As a result, the results indicated that the same mix of learning modes, the redundancy mode, is the most effective one for both novice and expert learners. Sweller[34] argues that information processing is likely to differ markedly between novice and expert learners because expert learners may be more readily able to process material because of its availability in long-term memory. However, our results suggest that there is no difference regarding the effectiveness of learning modes between students who have different knowledge levels. Learning modes do not need to be adjusted for novice and expert learners where information recall is concerned.

However, further research is needed to investigate how the mix of learning materials interacts with different knowledge domains and learning types, i.e. recall vs understanding. As argued by Sweller[35] instructional design should be adapted to the knowledge domain because the domain interacts with the capacity and duration of working memory. Earlier research on cognitive load theory has focused on examining learning in the domain of scientific and technical knowledge [1] [32]. For example, Craig and his colleagues studied learning related to the process of lightning formation as a weather condition[1]. In contrast to the earlier studies pertaining to the learning of scientific concepts, our study concerned another domain of learning, theory of music. Our results are aligned with the findings of other studies that have also investigated learning in the area of music (i.e. Truman & Truman [10] Badii & Truman [29]).

More research is needed to categorise the different knowledge domains and to examine the significance of the domain in explaining the effectiveness of learning materials. Past research has shown that individual qualities influence learning. For example, it has been argued that perception defined as the type of information students like to receive is the most important dimension of learning styles[36]. Sensitive students prefer data and are methodological in their approach, while intuitive students prefer principles and theories (ibid.). Perception and other individual qualities may be linked to the effectiveness of learning modes.

The results of our research have practical implications. As discussed above, the notion of learning styles has been

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criticized in the past because teaching in class rooms has not been adapted to match the diversity of learning styles displayed by learners. Based on our research, e-learning material can be easily adapted to deliver knowledge content through the different modes of narration, text, and graphics. The overall results suggest that the use of text and narration together does not impede on learning, debunking the redundancy effect, and is rather the most effective for learning.

7. Conclusion

The impact of this research is that the use of text and narration simultaneously is an effective strategy for e-learning. This challenges the widely accepted cognitive load theory, in that the representation of text is visual, and uses a visual rather than verbal information processing channel Perhaps for this reason, the use of text and narration simultaneously does not impede on learning, and is actually conducive to learning due to the use of two rather than one learning mode. The use of text and narration together is also more effective than mixes of graphics-text and graphics-narration, perhaps due to the greater ease of encoding communication forms (i.e. text and narration). Instead, the cognitive load appears to occur where graphics are concerned. Future research may include delineating the impact of the use of graphics in learning, in combinations with other forms, as well as 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.

References

[1] Craig, S, Gholson, B & Driscoll, D. Animated pedagogical agents in multimedia education environments: effects of agent properties, picture features and redundancy[J].Journal of Educational Psychology, 2002, 94: 428 – 434.

[2] Mayer, R. Applying the science of learning to multimedia instruction[J].The Psychology of Learning and Motivation: Cognition in Education, 2011, 55.

[3] Clark, R & Mayer, R. E-learning and the Science of Instruction (2nd ed.) [M]. 2008.

[4] Kim, S & Lombardino, L. Exploring the Effects of Narration and Pictures on Learning for Students with Reading Deficits[J]. Clinical Archives of Communication Disorders, 2017,2(2):116 – 127.

[5] Dunsworth, Q & Atkinson, R. Fostering multimedia learning of science: Exploring the role of an animated agent's image.[J]. Computers and Education, 2007, 49(3): 677 – 690.

[6] Mayer, R. Elements of science of e-learning [J]. Journal of Educational Computing Research. 2003, 29(3): 297 – 313

[7] Clark, R, Nguyen, F, & Sweller, J. Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load [M]. 2006.

[8] Sweller, J. Instructional design in technical areas [M]. 1999.

[9] Sweller, J.Cognitive load theory [J]. The Psychology of Learning and Motivation: Cognition in Education, 2011, 55: 38 – 74.

[10] Truman, S & Truman, P. An investigation into the situated learnability effects of single-and dual-modal systems in education: a report of music-oriented learning environment and science computer-assisted studies [J]. British Journal of Educational Technology, 2006, 37(11).

[11] Toh, S, Ahmed, W, Munassar, S & Jaafar, W & Yahaya, W. Redundancy effect in multimedia learning: A closer look[C]. Proceedings of ascilite, 2010.

[12] Atkinson, R & Shiffrin, R. Human memory: a proposed system and its control processes [C]. In K.W spence and J.T Spence (Eds) The Psychology of Learning and Motivation: Advances in Research and Theory, 1968, 2: 89 – 195.

[13] Peterson, L & Peterson, M. Short-term retention of individual items [J]. Journal of Experimental Psychology, 1959, 53: 193 – 198.

[14] Miller, G. The magical number seven, plus or minus two; some limits on our capacity for processing information [J]. Psychological Review. 1956, 63(2): 81 – 97.

[15] Baddeley, A, Working memory [J]. Science, 1992, 255: 556 – 559.

[16] Paivio, A & Csapo, K. Picture superiorty in free recall: imagery or dual coding?[J]. Cognitive Psychology, 1973, 5: 176 – 206.

[17] Paivio, A. Imagery and Verbal Processes [M]. 1971. New York; Holt, Rinehart & Winston.

[18] Paivio, A. Dual coding theory and education [C]. Proceedings of the conference on Pathways to Literacy Achievement for High Poverty Children, 2006.

[19] Dix, Finlay, Abowd & Beale. Human Computer Interaction [M]. 1993.

[20] Sadoski, M. A dual coding theoretical model of reading [C]. In Alvermann, D. E., Unrau, N. J., Ruddell, R. B (Eds.) Theoretical Models and Processes of Reading (6th ed.), 2013.

[21] Moreno, R & Mayer, R. Cognitive principles of multimedia learning: The role of modality and contiguity [J]. Journal of Educational Psychology, 1999, 9(2): 358-368.

DOI: https://doi.org/10.30564/jpr.v1i2.580

[22] Mousavi, S, Low, R, & Sweller, J. Reducing cognitive load by mixing auditory and visual presentation modes [J]. Journal of Educational Psychology, 1995, 87(2): 319–334.

[23] Tindall-Ford, S., Chandler, P., & Sweller, J. When two sensory modes are better than one [J]. Journal of Experimental Psychology: Applied, 1997, 3(4): 257-287.

[24] Larson, M & Lockee, B, Streamlined ID: A Practical Guide to Instructional Design [M]. 2014.

[25] Ginns, P. Meta-analysis of the modality effect [J]. Learning and Instruction, 2005, 15: 313–331.

[26] Hede, A. Integrated Model of Multimedia Effects on Learning [J]. Journal of Educational Multimedia and Hypermedia, 2002, 11(2): 177-191.

[27] Koning, B, Tabbers, H, Rikers, R & Pass, F. Attention cueing as a means to enhance learning from an animation [J]. Applied Cognitive Psychology, 2007, 21(6): 731 – 746.

[28] Reed, S. Effect of computer graphics on improving estimates to algebra word problems [J]. Journal of Educational Psychology, 1985, 77(3): 285 – 298.

[29] Badii, A & Truman, S. Cognitive factors in interface design: an e-learning environment for memory performance and retention optimization[C]. Proceedings of the 8th European Conference on Information Technology Evaluation , 2001.

[30] Baddeley, A & Hitch, G, Working memory [C]. In G.A Bower (Ed) Recent Advances in Learning and Motivation, (1974), 8: 47 – 90.

[31] Mandl, H Levin, J. Knowledge Acquisition from Text and Pictures[M], 1991.

[32] Kalyuga, S., Chandler, P., & Sweller, J. When redundant on-screen text in multimedia technical instruction can interfere with learning [J]. Human Factors, 2004, 46: 567-581.

[33] Moore, C. Do we really need narration? [N]. 2010: http://blog.cathy-moore.com/2010/09/do-we-really-need-narration Accessed: February 2019

[34] Sweller, J. Instructional design consequences of an analogy between evolution by natural selection and human cognitive architecture [J]. Instructional Science, 2004, 32: 9 – 31.

[35] Sweller, J. Original article: Working memory, long-term memory, and instructional design [J]. Journal of Applied Research in Memory and Cognition, 2015.

[36] Felder, R. M. & Silverman, L. K. Learning and teaching styles in engineering education [J]. Engineering Education, 1988, 78(7): 674.

 DOI: https://doi.org/10.30564/jpr.v1i2.580