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An investigation into the effects of presentation modality and visual representation on recall and cognitive load: learning aspects of electroencephalogram (EEG) net application

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ABSTRACT

The study investigated the effects of text modality and representation on learning in the context of multimedia learning, using a declarative framework based on an EEG net application procedure. The study used a 2x2 between subjects design with modality (narration and text) and representation (video and pictures) constituting the independent variables. It was hypothesized that modality and representation would have an effect on recall (written) and cognitive load (subjective difficulty rating for learning and performance), and that there would be an interaction between type of modality and type of representation, non-directional hypotheses were used due to the conflicting evidence and viewpoints in the literature. Participants were recruited from Psychology and Multimedia classes at the University of Gloucestershire (N=68) and randomly assigned to the four respective conditions. It was found that the effects of modality and representation were non-significant on recall and cognitive load. An interpretation of findings and implications for future research are discussed.

KEYWORDS:	COGNITIVE LOAD	MULTIMEDIA LEARNING	REPRESENTATION	MODALITY	RECALL

Introduction

Establishments involved with teaching, training and learning such as business, manufacturing, engineering, medical and educational institutions have recognised the potential of electronic media for instructional purposes (Holmes, 2006). Through advances in technology there are increasing ways of presenting information for learning (Moreno, 2006). Two such advances are being able to animate material and present it in an alternate modality. A core issue is whether presenting information through two sensory modalities is more effective than a single channel (Tindall-Ford & Sweller, 2006) for learning purposes and the difficulty associated with the learning process (cognitive load). A further issue is concerned with how representational content such as video or pictures can impact upon learning (Lowe, 2004), due to the visuo-spatial and temporal differences between the two formats.

Multimedia as a teaching and learning tool

Multimedia is defined as material that uses different content forms, such as text, audio, narration, still pictures, animation and video. Although the general consensus is that multimedia use is positive (Mayer, 2003), empirical research is needed to examine the cognitive processes that underlie learning from multimedia design (Schmidt, 2008). However with applied research there is the danger that the findings are too specific to be used outside of the domain (Leach, 1991), this is particularly relevant in light of two approaches to studying multimedia learning such as using a technology centred approach or a learner centred approach. The technology centred approach looks to develop new technology (Holmes, 2006). However the aim of the learner centred approach is to aid human cognition (Reed, 2006), focusing on the relationship between design features and information processing.

Multimedia learning is in line with the cognitive approach to learning, and effective instructional presentations should be designed in light of human cognitive architecture (Pass, Tuovinen, Tabbers & Van Gerven, 2003). Human cognitive architecture is description of memory stores, codes and operations (Reed, 2006). Evaluating cognitive architectures can demonstrate the richness of inputs and encoding that can occur in a multimedia environment (Reed, 2006; Sorden, 2005). The two major components are working memory and long term memory. Long term memory represents an unlimited storage capacity and duration (Terry, 2006). The learner centred approach has advocated how important working memory and long term memory are in learning environments (Gathercole, 2008). Without knowledge and results of the relationship between working memory and long term memory, instructional effectiveness is likely to be random (Sweller, 2005). Depending on instructional objectives multimedia instruction needs to be tailored to the type of learning required, declarative learning is the focus of this dissertation. Declarative learning is concerned with the learning of explicit language based information (facts, concepts, events) (Purves et al, 2008), whilst procedural learning is skill based learning (Patrick, 1997; Purves et al, 2008). This learning distinction derives from studies in cognitive neuroscience (Banich, 2004; Hopkins, Waldram & Kesner, 2004).

Working memory

Contemporary research suggests that working memory is not a unitary structure but is comprised of multiple sub systems or processors (Purves, Brannon, Cabeza, Huettel, Labar, Platt & Woldorff, 2008). Furthermore the limitations of working memory are well established (Purves et al, 2008). The working memory model (Baddeley, 1992) consists of the central executive, the phonological loop, the visuo-spatial scratchpad and the episodic buffer (Baddeley, 2007). The central executive controls incoming information and commands attention; the visuo-spatial scratchpad processes visual information (Gyselinck, Ehrilich, Cornoldi, de Beni & Dubois, 2000); and the phonological loop processes auditory information; the episodic buffer organises information for temporal aspects (Baddeley, 2007), as well as multimodal representations. Multimedia learning environments aim to optimize the potential of these slave systems by presenting a mix of visual/verbal and static/dynamic information (Brunye, Taylor, Rapp & Spiro, 2006; Gyselinck et al, 2008). This is supported by a study that identified selective working memory subsystem involvement for alternate multimedia formats (Brunye, et al, 2006). Neuroimaging evidence indicates that different storage material (spatial, verbal, object) require different processing components of working memory (Wager & Smith, 2007).

Multimedia learning theories

As discussed below, there are two central theories that underpin learning from multimedia instruction; these are the Cognitive Theory of Multimedia Learning (Mayer, 2005) and Cognitive Load Theory (Sweller, 1994). Both theories suggest means to overcome working memory limitations by enhancing the presentation method.

Cognitive Theory of Multimedia Learning (CTML)

The Cognitive Theory of Multimedia Learning (Mayer & Moreno, 2003) is based upon three cognitive science assumptions of learning, firstly dual-channel processing, suggests that humans possess separate information processing channels for visual/pictorial representations and auditory/verbal representations (Baddeley, 2007).The second assumption is that there is limited capacity for processing (Mayer, 2003), so that only a restricted amount of information can be processed in one channel at one time (Mayer & Moreno, 2003). Furthermore there is the active processing assumption; active processing entails attentional processes and sense making, and co-ordinating information (Mayer, 2005). Additionally, instruction can be active or passive; active instruction is when the learner is engaged in behavioural activity during learning, whereas passive instruction is when the learner reads a passage or watches a presentation (Mayer, 2009). This study will try and create active processing via passive instruction, to build a knowledge base of EEG net application. Studies have shown support for these processes in multimedia learning (Mayer, 1997). For an illustration of the CTML model see Figure 1.

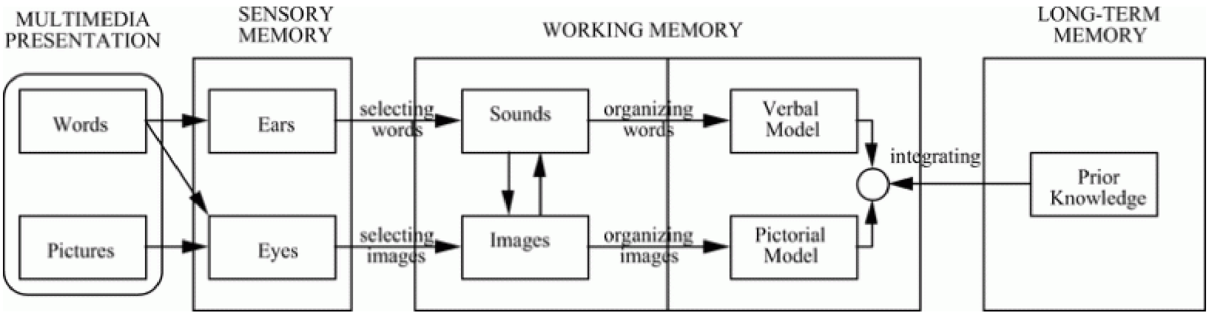

Figure 1: Cognitive theory of multimedia learning, (Mayer & Johnson, 2008).

Key components of the Cognitive Theory are consistent with Cognitive Load Theory. Though, Cognitive Theory of Multimedia Learning elaborates on information processing, such as integrating information into coherent representations (Bartholome & Bromme, 2009; Mayer, Bove, Bryman, & Tapangco, 1996). Cognitive load theory more specifically elaborates on the implications of instructional design upon working memory (Paas, & Sweller, 2004). Consequently Cognitive theory uses cognitive load theory to explain the learning efficacy of different types of learning materials (Brunken, Steinbacher, Plass & Leutner, 2002; Mayer, Moreno, Boire & Vagge, 1999).

Cognitive Load Theory (CLT)

Cognitive load theory adopts the working memory model (Baddeley, 2007) and schema theory. From this view working memory load is a key factor in the efficacy of learning from instruction (Pass, Tuovinen, Tabbers & Van Gerven, 2003).The two key processes that support learning in the CTL model are schema acquisition and automation (Sweller. 1994). Schemas refer to chunks or units of information in long term memory (Chase & Simon, 1973), consisting of declarative or procedural information. Developed schemas allow fluid performance on a task and spare working memory capacity (Sweller, 1998). Furthermore, Renkl (2003) suggests that during the early stages of schema acquisition, actually performing a procedure can be detrimental to learning; this is due to additional cognitive load to an already complex task (Van Merrienboer & Sweller, 2005). The second process, automation refers to knowledge or memory procedures becoming automated through learning and practice (Paas, Renkl & Sweller, 2004); however declarative learning can precede automation of skill learning (Sweller et al, 1998).

Certain instructional approaches ignore working memory limitations, contributing to increased cognitive load (Gathercole, 2008; Sweller, 2005). CLT advocates the use of direct instruction (worked example) over minimally guided discovery learning (Sweller, 2006). Discovery learning is hands on style of learning, the learner has to discover concepts or procedures that could have been communicated directly (Tuovinen & Sweller, 1999). Using a discovery method will likely induce high cognitive load (Kirshner, Sweller & Clark, 2006); particularly for novice learners or for learning novel materials (Van Gog; Paas, Van Merriënboer, 2004; Kirschner, et al, 2006). When dealing with novel information there is no existing schema to organise knowledge (Kalyuga & Sweller, 2004). Direct instruction on the other hand can bring a novice closer to the goal state (Kuhn, 2007), by accommodating for a lack of schema and working memory limitation (Sweller, 2004). Direct instruction can entail delivering information in an explicit, direct and scaffolded manner (Klahr, 2009; Rosenshine, 2009). For task centred learning, direct instruction will be beneficial due the task being broken down into explicit steps (Sweller, 2005), providing organisation of material (Van Merrienboer & Sweller, 2005).

The Cognitive load theory framework entails three types of load, intrinsic, germane and extraneous load (Sweller, 2005); these can be seen as additive to the total workload induced by the material. Intrinsic load is related to the natural complexity of the material (Sweller, 2010). An instructional format with many interacting elements will be seen as high in intrinsic load. A way of increasing intrinsic load would be to use complex sentences, more interacting elements that need to be retained in working memory as well as using more propositions and actions for a task (Paas et al, 2004). Extraneous load is the load that is caused by inappropriate instructional design (Sweller, 2010), such as irrelevant text, distracting pictures and spatially distant material that affect attention. Germane load is the effective cognitive load for schema development (Sweller, 2010); this can be seen as positive effortful learning for schema acquisition. This can be manipulated by the designer of the material to increase learning (Paas & Sweller, 2003). The aim of instruction according to cognitive load theory is to reduce extraneous load and promote germane load (Rikers, 2006). Retention tasks are a way of assessing whether a participant has understood of processed the material, therefore low retention participants are less likely to have engaged in germane processing (DeLeeuw & Mayer, 2008).

In order to promote learning, each dimension can be manipulated in learning tasks according to key design principles. One such design principle is the split attention principle (Schmidt-Weigand, Kohnert & Glowalla, 2010), which states that it is important to avoid formats that require learners to split their visual attention across multiple sources of information (Ayers & Sweller, 2005). Such sources should be physically or temporally integrated to promote essential learning (Mayer & Moreno, 1998).

The modality effect

The modality effect states that working memory capacity can be expanded if some information is presented in a visual mode and other information in auditory mode, rather than when the same information is presented in a single mode (Low & Sweller, 2005), making use of the two different loops, the phonological buffer and the visual-spatial scratchpad. This is necessary to avoid splitting attention across elements, (Schmidt-Weigand et al, 2010), thus increasing capacity for encoding processes (Reed, 2006).The narration directs attention towards the visual stimuli (Mayer & Anderson, 1991). This reduces extraneous cognitive load therefore reducing total cognitive load (Paas et al, 2003).The modality effect occurs when sources of information have to be integrated in order to be understood (Leahy & Sweller, 2003).

Evidence of modality effect

The modality effect has a reported effect size of 1.17 (Mayer & Moreno, 2003); critically this was derived from six studies. Research demonstrates that presenting dual mode presentations such as visual diagrams/images and narration can have a learning advantage over visual diagrams accompanied by visual text (Mayer & Moreno, 2002; Mousavi, Low & Sweller, 1995; Tindall-Ford & Sweller, 1997), as well as decreasing cognitive load.

Strong evidence for the modality effect comes from a meta-analysis (Ginns, 2005). The modality effect was observed across a range of instructional materials and tasks. However it was moderated by variables such as element interactivity which refers to how many pieces of information a participant has to simultaneously process in working memory in order to understand the information (Mayer, 2005) due to the factor of cognitive load (Ayers & Sweller, 2005). With larger effects for high element interactivity materials; however this was only derived from two studies (Ginns, 2005). This suggests that when cognitive load is low there are enough resources to process multiple elements from a single modality. The modality effect was also moderated by the pace of instruction taken from six studies (Ginns, 2005), with larger effects observed for studies which were dictated at a fixed pace, rather than under the control of the participant. Fixed paced conditions are more typical of educational or training practices. The current study will use fixed pace presentations that reflects a training situation.

The modality effect was found for a transfer test in a study that applied multimedia learning to science classrooms (Harskamp, Mayer, & Suhre, 2007). Participants that received narration and illustrations benefited in comparison with participants receiving illustrations and onscreen text. This is an incident of systematic research that pinpoints the conditions in which the modality effect is likely to occur. However the study didn’t include a measure of cognitive load, despite using the theory to make predictions.

The view that dual modality presentation is more effective than single modality presentation has also been explored in several other studies (Mayer and Anderson, 1991, 1992; Mayer and Moreno, 1998, 2002 Rummers et al, 2010). Based upon the findings, participants that received narration (along with presentations depicting how lighting works or how a car’s braking system works) outperformed participants with on-screen text accompanied with the visual demonstration of the car braking system. The measures included recall, item matching and problem solving. Knowledge in training contexts can be highly context dependent so a recall measure can provide the best measure of what has been taught (Patrick, 1997), it reflects deep processing. Results were consistent with the modality coding hypothesis because switching the way information was presented impacted upon learning measures.

Conversely, the modality effect was reversed in a study that used retention tests, transfer tests and a measure of mental effort (Tabbers Martens &Van Merrienboer, 2004). They found that replacing visual text with narration resulted in lower retention and transfer scores. Participants in visual conditions reported investing more effort, although this did not reach statistical significance. However the instructions were at a learner pace.

An interpretation is that task centred information is best presented in text than narration as it allows time for the participant to reflect on the information (Tabbers, Martens &Van Merrienboer, 2004). The reversal of the modality effect has also been found in a more recent study (Leahy & Sweller, 2011). It was hypothesized that this was due to the length of the auditory information exceeding working memory capacity. However the current study will use section breaks in the material which counter this implication. Furthermore simply adding narration to diagrams accompanied by text, doesn't expand working memory capacity, it can actually increase extraneous load as it is redundant information and potentially distracting (Leahy & Sweller, 2003).

Furthermore an audio-visual (narration) format can be a highly efficient medium in terms of volume of material covered; although it is argued that in terms of retained material it is less efficient (Laurillard, 2002). Contrary to the findings, using narration could induce a high cognitive load due to the transitory nature of audio input (Leahy, Chandler & Sweller, 2003). However cognitive processes in multimedia learning are complex and other moderator variables and interactions can provide new implications.

Animation as an instructional strategy

A further variable that can be explored through a cognitive load theory and multimedia learning framework is representation; in the current study this term denotes the use of video or static images.

The concept is often referred to as animation in the literature (Betrancourt, 2005). Lusk &Atkinson (2007) suggest that representation can provide a worked example effect. The worked example effect refers to a method of providing the full solution to a problem, rather than letting learners discover the procedure or solution themselves (Renkl, 2005). This has been found to be an effective form of instruction (Boucheix, & Schneider, 2009; Ayres & Pass, 2007). Especially when the domain is task centred rather than abstract (Hoffler & Leutner, 2007).

Under conditions that involve task centred learning, highly dynamic material could be useful in viewing an isomorphic representation of the task (Hegarty, 1992; Lowe, 2004), this is because it supports the visualisation and mental representation of material (Betrancourt, 2005**;** Chandler, 2004), through enabling and facilitating functions (Schwan & Riempp, 2004; Tversky & Morrison, 2002). A video would thus provide a rich set of cues that allow the participant to build a coherent representation of the topic (Mayer & Moreno, 2002).

Dynamic representations require the participant to continuously and actively update the mental model (Kriz & Hegarty, 2007). However, although providing a temporal indication of the relationship between the elements and showing phenomenal change, it may not give the learner enough time to attend to material (Mayer, Hegarty, Mayer & Campbell, 2005). Reasoning for this is that temporal limitations (duration) of working memory constrain the comprehension of dynamic visual material (Barrouillet, Bernardin, Portrat, Vergauwe & Camos, 2007**;** Boucheix & Schneider, 2009), termed the transient information effect (Van Gog et al, 2009).

Alternatively, the static media hypothesis proposes that static media (pictures) offers cognitive affordances that lead to superior learning (retention and transfer tests), compared with dynamic media (video) (Mayer et al, 2005). Static images allow the learner more time to focus attention on an image, allowing for rehearsal in working memory and integrating it into the mental model (Mayer et al, 2005). Key steps can be depicted using pictures, creating a cueing effect. This can reduce extraneous processing. Participants are therefore encouraged to infer changes from one picture to the next, creating active processing (Mayer et al, 2005). On the other hand, a limitation of statics pictures is that at most, they can present implicit representations of the content (Lowe, 2004). Therefore participants may have to search for the relevant cues, investing more cognitive effort (Kriz & Hegarty (2007). This is because learners have to mentally animate the content themselves, which could lead to incorrect inferences from the material (Cook, Krajick, Varelas, 2006)

Evidence for the effectiveness of animation/representation

A meta-analysis (Hoffler & Leutner, 2007), found that only 6 out of 26 studies used video in contrast to static pictures. For pair wise comparisons animations showed a significant advantage, while for only two pair wise comparisons were static images superior. When the animation was video based, an effect size of d=0.76 was found, generally effect sizes were largest when representational content was used for a procedural-motor domain (d=1.06). Hoffler and Leutner (2007) indicate that the difference between declarative and procedural contexts were non-significant. The effects on declarative and procedural knowledge in such studies are hard to separate as they are intertwined with behaviour (Schneider & Stern, 2010). Furthermore Hoffler and Leutner (2007) suggest that features of animations (video) often combine several declarative and procedural features. Furthermore when animation had an advantage over static images for 7 out of 12 studies this was thought to be due to non-equivalence of the conditions (Watson et al, 2010), however this study will look to control for informational equivalence across conditions by using system paced instruction and using a transcript developed from the narration.

Mixed results for dynamic representation have been found in the literature, Dynamic presentation has been shown to be beneficial (Ayres, Marcus, Chan & Qian, 2009), to have no effect (Hegarty, Kriz & Cate, 2003) and to have a negative effect (Rieber, 1990). Although studies suggest that animations were superior to statics for hand manipulative tasks (Ayres, Marcus, Chan & Qian, 2009; Wong, Marcus, Ayers, Smith, Cooper, Paas, & Sweller, 2009). This may be due to more information being communicated via video, or subjects being able to infer motion in an enhanced way (Amadieu, Marine & Laimay, 2011). Although one study found that increased use of video resulted in higher cognitive load, there was no reduction in learning (Homer, Plass & Blake, 2008). However learning outcomes need to be challenging enough to obtain a potential effect.

It has been argued that animation has not produced an advantage over statics in the literature (Ayres & Pass, 2007). In some learning environments such as learning about mechanical systems, statics have been superior (Mayer et al, 2005). Static images may benefit from matching textual content with the images, as the static media are not as temporally demanding as video (Ainsworth & VanLabeke, 2004), this effect has been produced in research (Mayer & Sims, 1994; Mayer, Hegarty, Mayer & Campbell, 2005). In eight studies it was found that the dynamic group (animation and narration) never scored higher on retention and transfer tests than the static media (pictures and text) group (Mayer et al, 2005). Overall, there was no support for the dynamic media hypotheses or the static media hypothesis. However the studies did not employ a factorial design to systematically alter the independent variables. Furthermore a cognitive load measurement was not administered.

Moreover one study (Boucheix, & Schneider, 2009) found that integrated static pictures, i.e. multiple pictures per frame, were as effective as animation in comprehending a pulley system for students; although animation was superior to sequentially presented static picture and single picture frames, which is described as 'perceptually discontinuous'. This shows how providing a link between frames can benefit understanding, allowing the participant to make inferences between steps. The current study will use two pictures per frame to provide an inferential link.

Regarding participant characteristics, it been found that low prior knowledge participants particularly benefit from diagrams accompanied by audio (Kalyua, Chandler & Sweller, 2000). Prior knowledge was manipulated experimentally in this study, giving this finding value. The current study will look to adapt a novel content domain (EEG net application) to manage this variable.

Key dependent variables in assessing the efficacy of instructional approaches

Recall

Recall has advantages over multiple choice recognition formats because the data is more reliable, as it is a more challenging retrieval process and participants cannot guess the answer (Maki, Willmon & Pietan, 2009), however the qualitative data needs to be quantified. Therefore the experimenter must be internally consistent when coding (Harris, 2008); to ensure internal reliability and ensure demand characteristics do not arise in the study. Furthermore inter-rater reliability should be employed where possible. The recall method has been used successfully in numerous studies (Johnson & Mayer, 2009; Mayer & Anderson, 1992; Reed, 2006), and will be used in the current study.

Cognitive load measurement

Cognitive load is an important aspect of learning that can be defined as multidimensional construct reflecting the load imposed upon the cognitive system for a given task. (Pass, Tuovinen, Tabbers & Van Gerven, 2003). Attempts to measure cognitive load have been numerous (DeLeeuw & Mayer, 2008; Gevins & Smith, 2003). The methods can be classified as direct or indirect. The three classifications of cognitive load measurement are physiological, subjective and task based methods. Attempts to develop a standard methodology for the concept have proven difficult (Wiebe, Roberts & Behrend, 2010).

To evaluate effectiveness of instruction, researchers have used subjective measures to measure cognitive load (Wiebe, Roberts & Behrend, 2010). This assumes that the learner is able to reflect on the learning processes that occurred during instruction;

considerable evidence has supported this method in terms of cognitive load measures (Pass et al, 2003). Subjective measures have been found as reliable, unobtrusive, and more sensitive than physiological methods (Ayers, 2006; Pass et al, 2003). Dual task methodology can attempt to assess cognitive load in terms of working memory limitations as this approach involves making responses to a secondary task that is currently occupied by an aspect of working memory. It has been successful in supporting the assumption that audio-visual formats have lower cognitive load than visual only formats (Brunken, Steinbacher, Plass & Leutner, 2002), although further research is needed to develop suitable secondary tasks in multimedia learning contexts (Pass et al, 2003).

Previous study

Only a single previous study has examined the effect of modality and representation in a factorial design, despite the centrality of the two concepts to appraising learning methods (Kuhl, Scheiter, Gerjets & Edelmann, 2011). Eighty participants from various educational backgrounds took part; the study investigated the influence of text modality (spoken v written) with representation (static v dynamic) for a dynamic domain, namely the physics of fish locomotion. The dependent variables consisted of subjective cognitive load, a multiple choice question set, transfer tasks and pictoral recall task. The study hypothesised that by using narration split attention is avoided, this reduces extraneous load, and information in the visual representations may then be extracted. Although it was proposed that this would lead to a more pronounced advantage for dynamic compared with static visuals with narration, no interaction effect was found (Kuhl, et al, 2011). Furthermore there were no effects for visualisation or modality on verbal factual knowledge. No significant effect of modality or representation was found for cognitive load; however the current study will use a more standardized measure of cognitive load. Furthermore video will be used instead of animation to provide a more extreme manipulation of the independent variable.

Aims of current study

The aim of the study is to inform multimedia learning practices of effective ways of presenting information, so that more content is remembered and cognitive load is reduced. Few studies have explored the effectiveness of instruction for human procedural-motor information; EEG net application will be used to provide a task made up of discrete steps, lending it to recall. The independent variables of modality and representation will be manipulated, to investigate the effects on recall and cognitive load. The intention is to identify whether alternating the sensory modality that information is presented, and altering representation can affect recall and cognitive load. Different combinations of material may complement each other, resulting in a more coherent overall representation (Bodemer, Ploetzner, Feuerlein & Spada, 2004; Tindall-Ford & Sweller, 2006). Many studies have used one dependent variable such as a retention or transfer test, but failed to measure cognitive load. The dependent variables recall and cognitive load are more meaningful when considered together as constructs of 'performance' (Tabbachnick & Fidell, 2007) offering a more comprehensive analysis of a multimedia advantage.

Non-directional hypotheses will be used as the nature of multimedia learning is exploratory, therefore a significant result in either direction would be acceptable to the researcher (Roberts & Russo, 1999). Multimedia learning research can be exploratory due to technological advances in conjunction with learner centred research. Predictions are non-directional based on contradicting evidence in the literature, theoretical distinctions, as well as a lack of prior knowledge about the particular combination of independent variables and their respective levels. As this study is using video which is underused in the literature it is assumed to be more appropriate to use non directional hypotheses, as video and narration could actually be detrimental to learning and induce high cognitive load (Lowe, 2004). This is because of the transitory nature of video and narration (Brunye, Taylor& Rapp, 2007).

Hypothesis one: a significant main effect for modality on the amount of recalled idea units

Hypothesis two: a significant main effect for representation on the amount of recalled idea units

Hypothesis three: There will be significant main effect for modality on the reported cognitive load scores

Hypothesis four: a significant main effect for representation on the reported cognitive load scores

Hypothesis five: a significant interaction effect between modality and representation on the amount of recalled idea units

Hypothesis six: a significant interaction effect between modality and representation on reported cognitive load scores.

Method

Design

This study utilized a 2x2 multivariate between subjects design, the dependent variables were recall, cognitive load, and accuracy. This design allows not only for interactions to be analysed, but what kind of advantages or disadvantages each kind of instructional format can elicit (Mitchell & Jolley, 2004: Tabachnick & Fidell, 2007). This can increase the external validity; furthermore it may give indications about discriminant validity of performance measures (Mitchell & Jolley, 2004). The first independent variable (IV) is modality with two levels (audio and visual): participants were presented with a visual only instructional or an audio-visual instructional. The second IV was representation with two levels (video and pictures). Additionally this study built upon prior suggestions for presenting a series of multiple static frames that depict changes in content (Boucheix & Schneider, 2009; Mayer et al, 2005), so that learners can infer change from step to step.

The modality levels are chosen to provide information in separate sensory channels, potentially expanding or reducing working memory capacity. The representation levels were chosen as polar opposites in terms of continuous motion, this would create different spatial and temporal demands between the two formats (Hasler, Kernsten & Sweller, 2007), animations are suggested to make content more transparent (Gyselinck et al, 2008), yet pictures offer time to study material.

A positive aspect of this study is the control over interactivity, Tversky and Morrison (2002) suggest that one of the key reasons that animation (or video) has been beneficial in many studies is that learners have more interactivity with animation or video, by stopping, rewinding, zooming, simulating etc. In this view it may not be the animation/video that is the cause of learning but the added interactivity. By creating presentations in PowerPoint these features were restricted.

Recall has been used to assess learning in multimedia studies (Mayer & Moreno, 2003); it tests declarative memory (Purves et al, 2008). This variable ensured that a control group/pre-test wasn't necessary, because without the intervention participants won't be able to recall information. The second dependent variable was cognitive load, collected via the NASA TLX, which is a self-report measure. Research has shown participants to prefer the NASA TLX to other subjective methods (Rubio, Diaz, Martin & Puente, 2004), it is also easy to implement and evaluate. This study uses computer supported data collection to eliminate human observer errors, and create standardisation.

Participants

In order to ascertain how many participants were needed for the study a prospective power analysis was carried out. This was based on a meta-analysis that displayed large effect sizes in this area (Hoffler & Leutner, 2007). A similar study used 72 college students as the sample (Hasler et al, 2007); as a result 72 participants were needed to achieve the necessary power at according to Cohen's (1992) power primer.

Participants were recruited via opportunity sampling. Data was collected on 77 (male=29, female=46) students from educational psychology and Multimedia courses at the University of Gloucestershire, ranging from level one to level three. However due to missing data on a couple of variables 9 cases were deleted, therefore 68 participants (male=24, female =42) were used for further analysis, the mean age was (M= 20.88, SD= 2.11). Missing values weren't replaced as this would likely bias the results, due to more than 5% of the cases missing and because of the experimental nature of the study. It was determined that missing data was random and was likely due to computer error rather than non-response, this poses a less serious problem than if missing data forms a pattern (Tabachnik & Fidell, 2007). Participants were from the ages of 18-30. This range was selected as it provides a representation of the target population. Furthermore it is claimed that working memory processes decline with age (Banich, 2004); this has also been tested in the multimedia literature (Echt, Morrell & Park, 1998; Pass, Van Gerven & Tabbers, 2005).

Participants should be selected to maximise profit from intervention (Bausell, 1994). Therefore, psychology and multimedia students are tested as they are familiar with recruitment and testing. Multimedia also integrates cognitive psychology to create multimedia applications. The courses also have practical elements so the content is more relevant. Additionally students at the University of Gloucestershire are also familiar with PowerPoint presentations. This is important as a novel medium may elicit increased motivation, reducing statistical inference to the interventions.

The participants were randomly allocated to four experimental groups; this was achieved by setting up each instructional format in serial order and directing participants to choose a laptop station. The four groups were video and narration (n=18), pictures and narration (n=17), video and text (n=17) and pictures and text (n=16). Participants were tested in groups of 2-6.

Furthermore they were also novices in terms of EEG net application, and couldn't have substantial knowledge of the technique or be engaged in research, therefore eliminating prior knowledge as an extraneous variable and, and eliminating the need for pre-testing. This would also reduce potential outliers from analysis.

Materials

Independent variables

EEG net application was chosen as it uses human procedural motor information; this can be seen as concrete information. Therefore this can be evaluated against other research that uses representational/concrete information. The domain is restricted to task centred information; participants can view this demonstration with no prior experience. However, EEG net application is complex, so attention is needed to learn the content. It is argued that to assess performance for cognitive tasks assembling an expert model is necessary (Patrick, 1997). This is particularly important in a domain that imposes restrictions on what actions or procedures can be performed. Therefore a DVD from an official supplier of EEG nets is used.

The materials used in the study were the Electrical Geodesic Inc (EGI) DVD instructional, section 'applying the EEG net'. The net used for demonstration is the 'Hydrocel Geodesic Sensor Net'. The DVD contained several sub sections in which an assistant demonstrates how to apply an EEG net to a participant. The subsections include; preparing the subject, applying the net (preparing the net), initial positioning, strap adjustment, electrode positioning and removing the net. The DVD portrays underlying themes relating to participant safety, careful positioning of the net and identifying aspects of net.

The DVD was used to create separate presentations in Microsoft PowerPoint which has been used as simple medium in a past study (Wiebe, Roberts & Behrend, 2010). The way in which to create multimedia content was guided by design principles (Clark & Mayer, 2002). Various editing programs were required to develop the materials; however these programs were only selected for pragmatic reasons and not for any theoretical basis. By taking screenshots from the DVD, static pictures were created depicting key steps in the procedure (see Figure 2). Two images were presented on each slide, to show progression.

Figure 2: Example of images from a single slide, taken from EGI instructional

Furthermore, the DVD was converted into a sound file for narrated presentations. The audio file was transcribed to text to produce content for the visual only presentations. This process ensured informational equivalence across groups. Toshiba laptops (15 “, 4GB RAM, 2.53 GHz) were consistently used to in the study, to ensure internal validity.

Recall

In order to test recall memory and understanding, a recall questionnaire was developed. This measure has been used successfully in numerous studies (Brunye, Taylor, Rapp & Spiro, 2006; Mayer& Anderson, 1991). A pilot test was ran on a group of undergraduates (N=10) in order to assess the usability and reliability of the questionnaire. The basis for the questions was taken from the instructional content. This ensured that the participants weren’t going beyond the information, but were exclusively recalling what was shown to them, this ensured content validity. The questions were clear and concise. The recall questionnaire contained 11 questions that required short answers. An example question:

How would you position your hands to apply the net?

Correct idea units entail:

Place the hands underneath the face straps (1)

Count two electrodes out from the nasion (1)

Hands outside net (1), using thumbs and pinkies (1)

Whereas on a multiple choice measure participants can potentially guess the correct answer and reach a score of 100%, recall doesn’t permit this. This reduces random error. Furthermore the operational definitions of agreement were used, acceptable and unacceptable answers were evaluated to check the scoring rubric. Reliability analysis on the pilot data showed that there was a high inter-rater correlation.

Order Verification Task

An order verification task was created to test the mental model and perceptual skill learning, and would be used as a second task in which cognitive load would be assessed. This measure has been used in studies such as (Brunye et al, 2006). The order verification task was created using alternate screenshots from the DVD; to avoid confounding variables screen shots weren't taken from the picture presentations.

Figure 3: Images in incorrect temporal order 'locating the nasion'(EGI DVD).

Figure 4: Images in correct temporal order, 'adjusting the eye electrode band', (EGI DVD).

These were then inserted into e-prime, a cognitive experimental computer program. Sixteen pairs of pictures were used as trials relating to aspects of the procedure.

Cognitive load

The computer version of the NASA task load index (TLX) (http://www.nrl.navy.mil/aic/ide/NASATLX.php) was used to assess cognitive load. Cognitive load is subjective measure of difficulty in completing a task, the participants are required to evaluate their cognitive load for the recall and order verification task. This scale is considered to have high face validity and has been used in vast array of laboratory studies (Rubio, Diaz, Martin & Puente, 2004); including a study that examined the effect of instruction type (Sawin & Scerbo, 1995). Furthermore, a study that examined evaluated three subjective workload measures including the NASA TLX (Rubio et al, 2004); results suggest that convergent validity correlations were positive and statistically significant. There are six subscales that make up the cognitive load; the subscales of the construct show significant inter-correlation (Cao, Chintami, Pandya & Ellis, 2009). Test- re test reliability has been found to be 0.77 (Rubio, et al, 2009). The NASA TLX is reported to be sensitive to changes in task demands, reflected by higher scores, this shows the diagnostic power of the instrument. Importantly outcome variables should be reliable and sensitive to change (Bausell, 1994).

The computerised version was used for this study, as this was seen as more convenient. A high correlation of .0.94 has been found between the computerised version and the paper and pencil version (Cao et al, 2009). This also allowed for paired comparisons to be used to weight the responses; this requires the participant to rate which of two factors was more important for the study, producing an individualised cognitive load score for each participant.

Procedure

The learning environment should itself be taken into account when trying to design a powerful learning environment (Rikers, 2006). Therefore, the study was conducted in a controlled laboratory setting, to eliminate potential extraneous variables (Harris, 2008). Although participants were instructed as to the nature of the study, they would be unable to determine what kind of data would be collected. The pilot study gave an indication that demand characteristics weren't prevalent in the study.

The initial step of the study involved participants signing a consent form (for ethical guidelines) to acknowledge that they are giving consent for data collection and their participation. The participants were seated at a computer to begin the study. The participants were given some background information on EEG and a set of standardised instructions that guided them through the study.

The participants then watched a multimedia presentation; the presentations differed depending on the condition allocated. Participants watched the presentation for the duration of twelve minutes. Headphones were provided to prevent distractions, and deliver audio if required.

The participants initially completed the recall questionnaire; no time limit was set for this task, although the pilot suggested that participants would take approximately 10-15 minutes. The following order verification task involved the participant identifying whether the pair of pictures are in the correct or incorrect temporal order. Participants responded via keyboard 'Y' for correct and 'N' for incorrect. Each trial involved the first picture being presented for four seconds; the second picture would remain on screen until the participant responded.

The final task required the participant to indicate their subjective cognitive load scores, this involved marking a score on 6 subscales and then making 15 comparisons relating to what the participant believed was the more influential type of demand during the study. Data is then automatically collected via the NASA TLX (US navy) and produces an Excel spreadsheet. The participants were then given a de-brief slip in order to inform them as to the nature of the study as well as given contact details to discuss further issues, this process is deemed important (British Psychological Society, 2006).

Results

Descriptive statistics
Recall

A key idea unit was taken as the standard measurement of recall. Thus if a participant recalled the idea unit, a point was scored, exact terminology wasn't required based upon previous studies (Mayer & Anderson, 1991); although an attempt at the actions and terms were necessary to justify a point. An example of an idea unit response to a question is: Q. How is the eye electrode identified? A. *A pink bead.* This is a question of low element interactivity; questions vary in terms of interacting elements. The idea unit scoring system enabled the quantification of qualitative data, this combined with blind scoring procedures reduced the potential for observer bias (Mitchell & Jolley, 2004); increasing objectivity. Table 1 shows the means and standard deviations of the key idea units recalled by participants in each group and as main effects. Results indicate that participants that received audio scored higher than participants that were presented with text Furthermore participants that received pictures scored marginally higher than participants that received video (see Table 1).

Table 1
Means and standard deviations for amount of recalled idea units for main effects and individual groups

Modality	Representation	*M*	*SD*	*n*
Audio	**Video**	12.61	5.39	18
Audio	**Pictures**	10.65	4.66	17
	Total	11.66	5.07	35
Text	**Video**	9.18	4.68	17
Text	**Pictures**	11.31	5.43	16
	Total	10.21	5.09	33
	Video	10.94	5.28	35
	Pictures	10.97	4.98	33

Cognitive load

The score used for cognitive load is the total score from the NASA TLX scale. This is derived from the six sub scales and fifteen pairwise comparisons. A score from 0-100 is produced by multiplying the weighted sub scale, summing across scales and dividing by the total number of paired comparisons. Results indicate that participants that received audio reported lower cognitive load scores than participants that received text (see Table 2). Participants that received video reported higher cognitive load than participants that received pictures (see Table 2).

Table 2
Means and standard deviations of cognitive load scores derived from NASA TLX, main effects of variables and individual groups

Modality	Representation	*M*	*SD*	*n*
Audio	**Video**	56.38	13.01	18
Audio	**Pictures**	59.43	12.26	17
	Total	57.86	12.56	35
Text	**Video**	62.47	15.64	17
Text	**Pictures**	58.34	9.26	16
	Total	60.47	12.92	33
	Video	59.34	14.47	35
	Pictures	58.90	10.75	33

Assumptions and data screening

As MANOVA is sensitive to outliers data screening was carried out. Extreme scores can lead to the inflation of type 1 or type 2 errors (Coolican, 2004). Box plots suggest that although there are several outliers there were no extreme scores, outliers should not be in excess of 3.29 (Tabachnick & Fidell, 2007). This was achieved by examining standard scores and box plots. No scores exceeded the criterion (z= 3.3), suggested by Tacbachnick and Fidell (2007). Multivariate outliers were calculated using Mahalanbois distance, χ^2 (4) <.001, critical $\chi^{2=}$ 13.82. There were no multivariate outliers present.

To assess whether the data is suitable for a multivariate analysis of variance (MANOVA) the data was checked against parametric assumptions for multivariate designs. The assumptions include 1) That data is interval or ratio level, 2) that data are drawn from normally distributed populations, 3) that there is homogeneity of variance, 4) Independence, this was met as it is a between subjects design, 5) Avoidance of multicollinearity, in that there are linear relationships among the DV's. Furthermore when assessing variance it is important that sample sizes are as close to equal as possible. This makes further analysis easier to interpret and ensures the analysis is more robust.

Interval level data is that in which there is equal distance between scores (Coolican, 2004), it is argued that distances on scales may not be truly equal. However if the measures are supported as reliable and valid then data can be assumed as interval level (Tabachnik & Fiddell, 2007). The recall measure and NASA TLX measure can be classified in this way due to supported literature and reliability testing.

With regards to the second assumption, normality was checked via histograms. The histograms displayed normal distributions. Furthermore, each group were checked against the dependent variables to assess skewness and kurtosis. The skewness statistic and kurtosis are divided by the standard error, for skewness the calculation cannot exceed +2.58, the kurtosis the statistic cannot exceed plus or minus 2 (Diamantopolous & Schlegelmilch, 2000). Recall and cognitive load met the assumption, this was also further supported by a Shapiro- Wilk test of normal distribution p. >0.05. This is considered a more robust test of normality.

3) Thirdly data must have homogeneity of variance, so that within each cell the spread of scores is similar (Tacachnick & Fidell, 2007). This offers assurance that data is not skewed and can be treated as reliable (Field, 2005). Box's M test was satisfied assuring homogeneity of variance (Box's M=6.30, sig=.739). Levene's test of equality of error variances was used to assess univariate statistics for each DV. The results were non-significant therefore the assumption was met.

Regarding linearity, it is necessary to avoid variables that show a very strong or no relationship. Giles (2002) suggests that in order not to violate this assumption correlation coefficient variables should fall between 0.3 and 0.6. Alternatively it is argued that DV's should be strongly negatively correlated (Tabachnick & Fidell, 2007). This assumption was violated (see Table 3). Therefore the data cannot be analysed with an MANOVA as this will result in a loss of power. The dependent measures can be seen as conceptually independent and thus analysed separately; this is acceptable as the response variables have been analysed in univariate contexts (Huberty & Morris, 1989).

Table 3
Multicollinearity assumption: Small negative correlation

		Recall	CL
Recall	**Pearson Correlation**	1.000	-.160
	Sig. (2-tailed)		.191
	N	68.000	68
CL	**Pearson Correlation**	-.160	1.000
	Sig. (2-tailed)	.191	
	N	68	68.000

Analysis of variance (ANOVA)

As MANOVA is an extension of ANOVA, the assumptions for using ANOVA are met. Two-way unrelated ANOVA's were computed at the 0.05 significance level; however Bonferroni corrections were applied to control for the increased chances of a type 1 error. Type III sums of squares are used in SPSS when using unbalanced designs (Field, 2005).

To test whether modality and type of representation had an effect on recall, a two-way between subjects 2 (modality: narration v text) x 2 (representation: video v pictures) ANOVA was conducted. The analysis yielded a non-significant effect of modality F (1, 64) = 1.27, p> 0.05, demonstrating a small effect size, partial □□ı□and low observed power =.199. The main effect of representation was non-significant F (1, 64) = .005, p>.0.05, demonstrating a low effect size, □□, and low observed power =.05. There was a non-significant interaction effect between modality and representation F (1, 64) = 2.79, p.>0.05, indicating a low effect size partial □□□□and low observed power =.38.

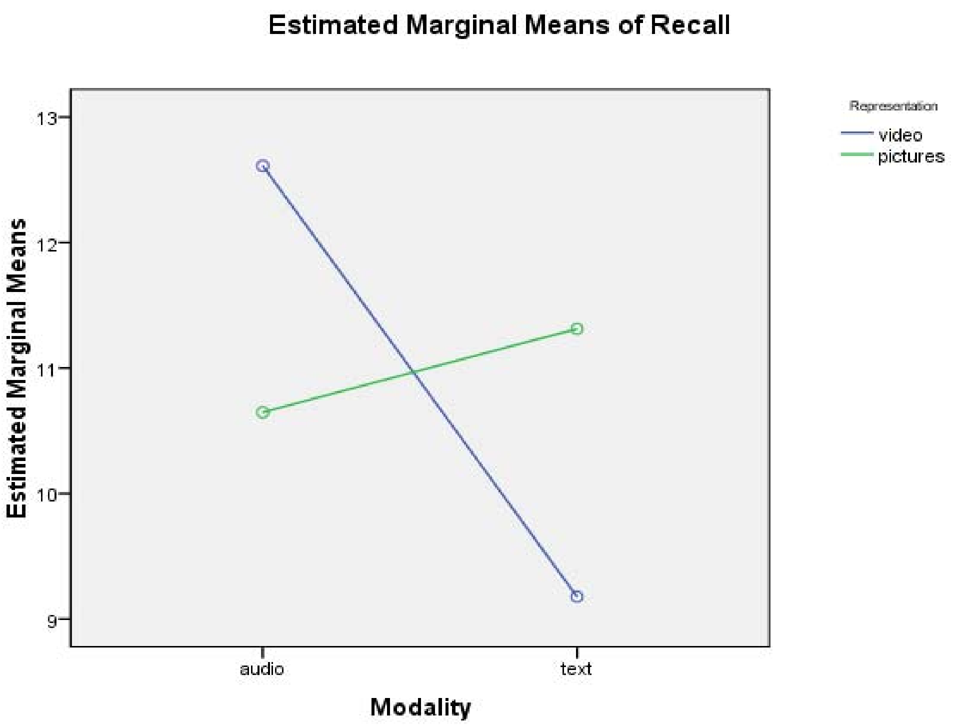

Figure 5: Plot showing interaction between independent variables using estimated marginal means for recall

To test whether modality and type of representation had an effect on cognitive load, a two-way unrelated ANOVA was conducted on NASA TLX scores. Analysis revealed a non-significant main effect of modality F (1, 64) =.65, p> 0.05, indicating a low effect size, □□ıand low observed power □ı□□ The main effect of representation was non-significant F (1, 64) =.030, p>0.05, □□and low observed power□53Finally, there was a non-significant interaction effect, F (1, 64) = 1.33, p>0.05, demonstrating a small effect size □□□and low observed power =.206. Results indicate no significant effects of modality or representation on recall and cognitive load.

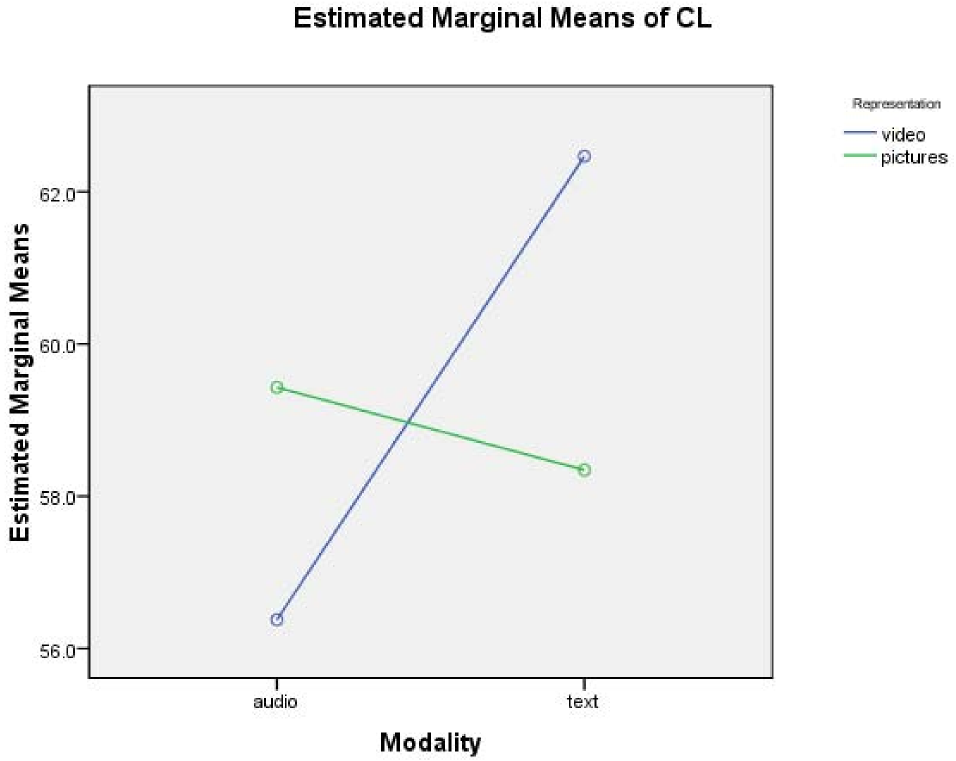

Figure 6: Plot showing interaction between independent variables using estimated marginal means of cognitive load

Discussion

It was predicted that there would be a significant difference between presentation modality, and visual representations on recall and cognitive load. Results indicate that modality did not have a significant effect on recall and cognitive load, despite participants receiving narration scoring marginally higher on recall and reporting lower cognitive load. Therefore, H1 and H3 are rejected.

Representation had a non-significant effect on recall and cognitive load; therefore H2 and H4 are rejected. The results suggest that participants with static pictures found the tasks no more difficult than learners with video in terms of cognitive load. No interaction effects were discovered; therefore, H5 and H6 are rejected.

The marginal differences in means and fairly large standard deviations indicate that there was unlikely to be a significant effect in either direction. Furthermore, the ANOVA's indicated low power to detect an effect. This is surprising given the reported effect sizes for the modality effect (Ginns, 2008), as well as representation; in adherence to instructional design guidelines. This study also had sufficient sample sizes according to priori power analysis.

Modality

The absence of a modality effect in support of narration is in line with Tabbers et al, (2004). However, this was an interesting finding as the presentations were under fixed pace in which the modality effect is suggested as being more prevalent (Ginns, 2005). Suggestions as to why this may have occurred can be explained by the attempt to provide informational equivalence, as each PowerPoint presentation was equal in length this may have actually provided an advantage to the participants who received text, due to temporal contiguity (Mayer, 2005). Whereas, the audio was transitory it could not be accessed again by the participant, text could be read several times if permitted by representational format. In working memory the phonological loop is given less opportunity to rehearse information. The results are consistent with Leahy and Sweller (in press) and Kuhl, et al (2011) in which no modality effect was found.

Representation

Although CTML and CLT overlap in several assumptions outlined in the introduction such as 1) dual- channel processing, and 2) limited processing capacity, they differ in relation to some aspects of multimedia learning. For example CTML and CLT suggests that animation or video will assist learning (Mayer & Moreno, 2002); achieved through cognitive processes that allow the learner to internally animate the material, create inferences and build a more accurate mental model of the content (Cook, Krajick, Varelas, 2006; Lowe, 2004). Alternatively others using a CLT framework suggest that using video can create additional cognitive load, due to the transitory disposition of the material (Leahy & Sweller, in press; Van Gog et al, 2009), thus participants can miss key aspects. In perspective, if participants cannot form coherent representations of the material the following steps in the EEG procedure may not make sense. Static pictures may have only provided implicit representations of a dynamic domain (Lowe, 2004), for statics it may be that novices are unaware of important spatial features, whereas video imposed temporal constraints (Ainsworth & VanLabeke, 2004). This may have led to processing biases. Therefore, the complementary processes and constraints imposed by the manipulations may have cancelled out the difference in effectiveness. The non-significant effect of representation is in line with (Boucheix & Schneider, 2009), in which multiple statics were equivalent in effectiveness to video.

Participants requiring EEG net training may benefit from instruction, allowing for appropriate extraction of information and development of correct mental models. This is because the learners need to understand the relationship between the representation and the domain (EEG) (Ainsworth, 2006); as Kriz and Hegarty (2007) suggest that learning from animation involves a complex interplay between top down and bottom up processes.

Interaction

The pattern of data for recall and cognitive load indicates a cross over interaction, although this was non-significant. The cognitive load interaction plot (see Figure 6) indicates that representation had larger variation than modality. Perhaps showing how the apprehension principle and split attention principle influenced recall and cognitive load. (Tversky & Morrison, 2002) This is indicated by the pattern of data, video and text resulted in higher cognitive load than video and narration participants. The combination of video and text elicits a split attention effect and a transient information effect (Leahy & Sweller, in press) this may explain why this group had the lowest scores for recall. The transient information effect (Van Gog, Paas, Marcus, Ayers & Sweller, 2009) may also have played a role in cognitive load. This is also indicated by the fact that pictures and text participants reported lower cognitive load than pictures and narration. However, less variation was seen with the main effect of pictures in both recall and cognitive load possibly due to the static disposition of the material, allowing more attention to text or narration. The split attention may have caused a detrimental effect on learning, although this didn't reach significance. Therefore although significance isn't reached, the pattern of results suggests that the underlying theory may explain small variations in data.

The results are in line with prior studies that found video and pictures to be equivalent in their effectiveness, such as (Mayer et al, 2005; Hegary et al, 2003; Kriz & Hegarty, 2007). A possible reason for this can be explained in terms of the amount of slides contained within the presentations. By providing a high frequency of static pictures this may have provided not only key steps in the EEG net application procedure but some of the micro steps (Arguel & Jamet, 2009). So far the literature hasn't suggested a way of managing how many steps should depict a given concept of domain area.

Limitations

It is clear participants across conditions found recall difficult, as scores were far removed from the maximum score attainable. Using cued recall as an outcome measure may have resulted in increased cognitive load at retrieval. A potential drawback of the study is that recall may not be an appropriate measure with novices, as recalling material that is passively processed maybe difficult in this context. By choosing recall over recognition attempts were made to achieve high validity over power.

This study used a laboratory based experiment, using an experiment can provide control over variables if well designed (Harris, 2008). However, it is hard to generalize to applied settings and participants with a deeper knowledge base (Leach, 1991). Participants in applied settings requiring training may be more motivated to learn and may need to perform well on outcome measures to achieve a specified goal. Suggesting that learners with more prior knowledge and novices may respond differently to the instruction (Kalyuga, Ayers, Chandler & Sweller, 2003; Valcke, 2002), particularly in terms of perceiving relevant aspects of the material and identifying underlying themes. Goal orientation is likely to be a key individual difference (Clark & Feldon, 2005). Participants that are concerned about their performance may invest more effort and attention, suggesting that this factor could impact on recall and cognitive load (Pass, Tuovinen, Van Merrienboer & Darabi, 2005). In the context of external validity, generalizations of empirical findings become problematic because CLT allows different and contradicting possibilities to explain some empirical results (Schotnz & Kurschner, 2010).

Perhaps participants who were confident in their ability to answer could give more effort in attempting answers. Although the NASA TLX used a rating of own performance, this is only one subscale. Using individual subscales for analysis may provide the researcher with more information about meta-cognitive processes in the study. A further interpretation of the NASA TLX is that participants may interpret the meaning of the scale description in different ways and differ in reflective processes; this is partially because participants in this study are unfamiliar with the NASA TLX whereas in aforementioned studies the NASA TLX is used frequently. The use of a physiological measure of cognitive load would avoid this confounding error variance, although there are ethical boundaries with physiological measures and this may be impractical.

Practical implications

On balance, participants could have been made aware of the instructional objectives. If they knew specifically that recall was used as the retention test they could have prepared for this during the instruction, by allocating more attention and cognitive processes to the material. Of course the objective of assessing cognitive load differences between groups needs to remain concealed. Large effect sizes might have occurred in support of video if a researcher presented a limited number of static pictures. However this study has shown that by providing multiple pictures per frame, learners using static instruction can perform as well as learners using dynamic content. Moreover participants may treat video as nothing more than a movie and given it little attention and thought (Hasler, Kernsten & Sweller, 2007). Therefore a measure of motivation could be administered to control for this variable.

Future directions

Future research could look at cognitive load not only in retrieval but at the encoding stage also. This could be achieved by administering the NASA TLX at several intervals to discriminate between the impact of cognitive load at encoding and retrieval stages. Furthermore, it is recommended that physiological methods or neurophysiological measures of cognitive load be used in conjunction with self-report methods if possible (Gevins & Smith, 2003). Using heart rate variability or EEG (for an alternate focal topic) would allow for a clearer picture of how the participant responds to instruction (Lamberts,Van den Broek, Bener, Egmond, Dirksen & Coenen, 2000). The concept of cognitive load could subsequently be modelled in multimedia learning contexts. It is also important to assess whether separate measures of cognitive load are correlated and consistent with each other, in conjunction with learning outcomes. Furthermore within subjects designs could be used to increase power and avoid the possibility of a type II error (Mitchell & Jolley, 2004). Within subjects designs would allow participants to make comparisons of mental workload using the NASA TLX for different media formats, however careful design is needed to avoid participants guessing the hypothesis.

The results shouldn't be interpreted that video or static media are ineffective in all content areas of frameworks, giving the learner control over the pacing of the materials may provide the necessary benefit of learning at a preferred pace. Furthermore given the design of the study, if the same study were replicated in a procedural paradigm with participants requiring EEG net training, as opposed to a declarative context, the effectiveness of the video or pictures may emerge. This would require the participant to actually apply the net; in which a task analysis could be used to assess performance (Patrick, 1997), and use verbal commentary if desired, requiring the participant to describe what an expert is doing at a given time. However there is a degree of subjectivity with such methods. Future studies could also integrate a learning efficiency formula into the analysis to calculate the cognitive cost of retrieval (Kalyuga, 2007).

The cognitive affordances of dual modality and video/pictures may materialize when the participant is required to actively use the information presented to perform a transfer task such as identifying errors in a net application. It is argued that transfer tasks can test the real effectiveness of instruction as they target higher order processes. However if recall is the required outcome measure, instructing the participant to recall information at section breaks during the instruction may be more appropriate, this is because the length of the procedure may result in a decay of information when tested at the end of the presentation.

Educational environments are well equipped to offer multimedia materials to explore ways of developing instructional effectiveness (Schmidt, 2008). There is also no fundamental difference between education and training and both entail various forms of systematic instruction in different contexts (Patrick, 1997). However, it is recommended that multimedia learning studies are conducted in applied settings to attain external validity, and provide motivation for engagement with the instruction, therefore selecting participants that could be more likely to profit from treatment (Bausell, 1994), although results could not generalize to novices. This could provide practical significance of research findings. Future research could look at reliable, valid and sensitive ways of measuring cognitive load, in order to challenge the construct itself and model the construct in learning environments. Combining subjective with objective measures is needed to achieve this. This could also increase power.

Conclusion

The study has contributed to underpinning cognitive mechanisms involved with multimedia learning. It can be seen that providing the information in separate modalities or through the use of video or pictures isn't sufficient to detect a significant effect, other variables such as motivation and prior knowledge may influence outcome measures. The results from the current study cannot provide support for either position due to non-significant results. Consequently the treatment could have no significant effects in relation to other instructional conditions, or demonstrate a failure to find an effect; due to a number of factors (Mitchell & Jolley, 2004). However the study aimed to enhance the potential of both video and pictures according to design principles and evidence in the literature. Future studies should look to replicate the study in applied settings and transfer to a procedural context to assess whether the design and materials can elicit significant effects on the response measures. An effective method of instruction that can be generalized to other electronic based instructions could be very valuable, but the right questions need to be asked to assess whether methods and mediums for presentation are effective (Mayer, 1997). Otherwise multimedia interventions may hinder learning. This study showed that video and pictures were equivalent in their effectiveness, narration and text were also equivalent in their effectiveness.

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