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Learning declarative and procedural knowledge via video lectures: cognitive load and learning effectiveness

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ABSTRACT

Video lectures are being widely used in online and blended learning classes worldwide, and their learning effectiveness is becoming a focus of many educators and researchers. This study examined the cognitive load and learning effectiveness of video lectures in terms of the type of knowledge being taught (declarative or procedural) and instructor visibility. Video lectures with and without an instructor were used to teach each type of knowledge. Sixty Chinese undergraduates were randomly assigned to two of the four lectures. They completed a cognitive load questionnaire and learning tests after viewing the lectures. The results of *t*-tests revealed that adding the instructor in a video lecture increased learners' cognitive load only when learning procedural knowledge; adding the instructor only facilitated declarative knowledge learning. The results suggest that the learning effectiveness of video lectures varies depending on the type of knowledge being taught and the presence or absence of an instructor.

KEYWORDS

Video lectures; declarative knowledge; procedural knowledge; cognitive load; learning effectiveness

Introduction

Video lectures have become a fast-developing trend in online and blended learning classes worldwide. Thousands of video lectures are available online through platforms, such as Coursera, Udacity, EdX, Khan Academy and Tree of Wisdom (Guo, Kim, & Rubin, 2014). In comparison to face-to-face lectures, video lectures can be used to learn without any restrictions in time and space (Winslett, 2014). They can radically decrease educational cost and open the door for a wider variety of learners to succeed in science, so that they achieve educational equity (Fernandez et al., 2011; Yerrick, Ross, & Molebash, 2004). Furthermore, they are thought to be powerful learning tools, as they can present knowledge through vivid visual and audio forms at the same time. Therefore, the learning effectiveness of video lectures is becoming a focus of many educators and researchers (Chen & Wu, 2015; Danielson, Preast, Bender, & Hassall, 2014; Hill & Nelson, 2011; Zhang, Zhou, Briggs, & Nunamaker Jr., 2006). Previous studies in this field have shown that the presentation mode of video lectures influences learning effectiveness (Chen & Wu, 2015; Guo et al., 2014; Pi & Hong, 2016; Wang, Hao, & Lu, 2014). The results suggest that the video lecture with an instructor has positive effects on learners' learning experience (Kizilcec, Bailenson, & Gomez, 2015; Kizilcec, Papadopoulos, & Sritanyaratana, 2014; Lyons, Reysen, & Pierce, 2012) and learning effectiveness (Ilioudi, Giannakos, & Chorianopoulos, 2013; Pi & Hong, 2016).

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According to social agency theory, adding the instructor's image in video lectures has the potential to improve learning effectiveness (Mayer, 2014). Social agency theory addresses how the presence or absence of social cues affects learning. Mayer (2014) postulates the rationale behind the positive effect of the instructor's image is that the instructor's movements, eye contact, and facial expressions activate learners' social response, such as learners working harder to select, organise, and integrate learning content. Learners' social response in turn leads to an increase in active cognitive processing and thereby increases learning effectiveness (Mayer, 2014). However, the instructor's image can also distract and overload learners (Harp & Mayer, 1998). Possible increases in cognitive load may offset or reduce the positive effects of the non-verbal communication provided by the instructor's image. However, the principles for reducing extraneous processing in multimedia learning hold that the benefit of including the instructor's image in video lectures should justify drawing on additional cognitive resources (Mayer & Fiorella, 2014; Sweller, 1994).

Exploring the results of empirical studies, we saw mainly one story: these studies advocated the positive effects of the instructor's image in video lectures (Kizilcec et al., 2015; Pi & Hong, 2016). This sentiment may be related to the learning material in the studies. In the extant studies, the learning material presented in video lectures was mostly based on declarative knowledge. However, declarative knowledge is different from procedural knowledge in many aspects. Declarative knowledge is a type of knowledge that could be described as 'know-what', such as facts, theory and names; procedural knowledge is a type of knowledge that could be described as 'know-how', such as swimming, driving and playing basketball (Anderson, 1982; Schunk, 1996). The main learning process of declarative knowledge is understanding and remembering the knowledge. The main learning process of procedural knowledge is firstly knowing its associated declarative knowledge, and then knowing how to enact the skill via practice. Therefore, learning declarative knowledge is relatively simpler and requires learners' lower cognitive skills than learning procedural knowledge (Anderson, 1995). Some empirical studies have shown that declarative knowledge and procedural knowledge have a different role in video lectures (Hoffler & Leutner, 2007; Shi, 2014).

The results of these earlier studies suggest that the choice to use video lectures should consider the content of what is taught (Winslett, 2014), and they raise a new question: Do video lectures have the same effect on learners when being taught procedural knowledge as when being taught declarative knowledge, depending on whether or not the instructor is present? We assume that when adding the instructor's image in video lectures teaching procedural knowledge, it is easier to overload learners compared with video lectures teaching declarative knowledge. From that perspective, it might be that the advantages of non-verbal communication provided by the instructor's image would be reduced due to additional cognitive resources in learning video lectures. Thus, learning procedural knowledge does not necessarily follow the rule that is derived from learning declarative knowledge in terms of the positive effect of the presentation mode with an instructor.

Our study was designed to examine the cognitive load associated with the presence or absence of an instructor, taking into account the learning effectiveness of video lectures in teaching declarative and procedural knowledge. Based on social agency theory, the principles for reducing extraneous processing and the above literature review, the following hypotheses were formulated:

(1) For declarative knowledge, learners who watch the video lecture with an instructor will not report a significantly higher cognitive load than those who watch the lecture without an instructor; for procedural knowledge, learners who watch the video lecture with an instructor will report a significantly higher cognitive load.

(2) For declarative knowledge, learners who watch the video lecture with an instructor will show greater learning due to the advantages of non-verbal communication provided by the instructor; for procedural knowledge, learners who watch the video lecture with an instructor will not show greater learning, due to a significantly higher cognitive load.

Method

Participants

Sixty undergraduate students (15 male and 45 female) were recruited from Central China Normal University (CCNU). Their ages ranged from 19 to 24 (M = 20.76, SD = .86). They were enrolled in a broad variety of disciplines (e.g. Chinese, English, preschool education, special education, chemistry, bio-science, geography, physical education, history, maths, economics), and none of them was majoring in educational technology. Prior to the study, none of the participants was familiar with the topic presented in the video lectures. All participants gave written informed consent, and received a small gift for participating in the study. The study protocol was approved by the Academic Committee of the School of Psychology at CCNU.

Materials

Video lectures

Declarative knowledge. The video lectures about declarative knowledge included two modes of presentation on the topic of educational technology, as part of an online course at CCNU. The first video lecture did not include the image of the instructor, but included accompanying PowerPoint (PPT) slides. The second video lecture included both the image of the instructor and synchronised PPT slides. The two video lectures were identical, including the size and colour of the words in the PPT slides, and the instructor's audio explanations, however, in the second version an image of the instructor was not present. The video lectures lasted 8 min and 20 s.

Procedural knowledge. The procedural knowledge topic was image processing, specifically making an image with a transparent background in Photoshop. The first video lecture did not include the image of the instructor, but included the Photoshop interface and the process of operating Photoshop. The second video lecture included both the image of the instructor, the Photoshop interface and the process of operating Photoshop. The two video lectures were identical, including the size of the Photoshop interface and the instructor's audio explanations, however, in the second version an image of the instructor was not present. The video lectures lasted 7 min and 6 s.

Measures

Demographic questionnaire. Participants were asked to report their gender, age, year in school, major and experience taking educational technology courses. (None of them reported taking an educational technology course).

Prior knowledge test. Developed for the purposes of the current study, this measure included 10 multiple-choice questions to test participants' prior knowledge of educational technology. No questions asked about the specific learning topic in order to avoid any effects of expectation on learning effectiveness. Each item included four alternative answers. The number of possible correct answers per item ranged from two to four. Participants received 1 point for the item only when all correct answers were selected and all false answers were rejected. The total of the scores was 10. This test had high discrimination (t (58) = 8.35, p < .001, d = 2.03), which means that the test was able to discriminate between participants who had different degrees of prior knowledge.

Cognitive load questionnaire. The cognitive load questionnaire was based on Cognitive Load Subjective Ratings developed by Paas and van Merriënboer (1993). The questionnaire consisted of two 9-point Likert-scale questions, which assessed the degree of task difficulty and the mental effort involved in learning. This questionnaire has high reliability in previous research (internal consistency coefficient = .74; Paas & van Merriënboer, 1993).

The learning test on declarative knowledge. Developed for the purposes of the current study, this test measured the acquisition of declarative knowledge presented in the video lectures. All items were derived from the learning content presented in the video lectures. The test consisted of five multiple-choice items and one open-ended item. For multiple-choice items, the method of rating was the same as the prior knowledge test. For the open-ended item, the full score was 5 points. Two independent raters who were blind to the goal of the study showed high inter-rater agreement on the open-ended item (Cronbach's $\alpha = .72$). Thus, the average of the two ratings was used as the final score on this item. The total score (10 points) for the learning test was the sum of scores from the multiple-choice items and the open-ended item. This test had high discrimination (t (58) = 10.15, $p < .001$, MD = 1.68), which means that the test was able to discriminate between participants who learned differently.

The learning test on procedural knowledge. To measure the acquisition of procedural knowledge presented in the video lectures, participants were asked to process two pictures in Photoshop according to the lectures. The first picture was the same as the one in the lectures, and the second was a different picture. Two independent raters who were unaware of the goal of the study scored the participants' products on five dimensions: unlocking, selecting the area, feather, inverse, and save format. Each dimension was worth one point, meaning five total possible points for each product and 10 total possible points for the learning test. The average of the two raters was used as the final score on each product. The inter-rater agreement was high on the two pictures (Cronbach's $\alpha = .95$; Cronbach's $\alpha = .93$). This test had high discrimination (t (58) = 13.45, $p < .001$, MD = 3.83), which means that the test was able to discriminate between participants who learned differently.

Design

A mixed design was used in this study with the type of knowledge (declarative vs. procedural) as a within-subjects variable and the presentation mode of video lectures (with instructor vs. without instructor) as a between-subjects variable. Thus, half of the participants watched the declarative lecture without the instructor, and the procedural lecture with the instructor; whereas the resting half of the participants watched the declarative lecture with the instructor and the procedural lecture without the instructor.

Procedure

The study was carried out in a computer laboratory. Before starting the study, participants were randomly assigned to one of two groups, each including 30 participants. The two groups were escorted into different computer labs where the study was carried out. Each participant sat at a computer, and participation took approximately 1 h. After granting consent, all participants filled out the demographic questionnaire and prior knowledge test.

First, both groups watched the video lecture on declarative knowledge without pausing. The first group was assigned to watch the video lecture without the instructor, and the second group was assigned to watch the video lecture with the instructor. Participants were then given 10 min to freely review the video lecture according to the learning content in the study. The review period of time was roughly estimated, similar to the real educational settings. After that, participants completed the cognitive load questionnaire and the learning test on declarative knowledge.

Next, both groups watched the video lecture on procedural knowledge without pausing. The first group was assigned to watch the video lecture on procedural knowledge with the instructor, and the second group was assigned to watch the same video lecture without the instructor. Participants were then given 10 min to freely review the video lecture and exercise the operating process in Photoshop. After that, participants completed the cognitive load questionnaire and the learning test on procedural knowledge.

Results

Prior knowledge

Participants had low prior knowledge in both learning content areas (M = 3.35, SD = 1.40). According to a t-test for dependent samples, there was no significant difference between the two groups (t (58) = 1.21, p > .05, MD = .43).

Cognitive load

The hypothesis on cognitive load was addressed first. It was hypothesised that adding the instructor's image in the video lecture would not increase learners' cognitive load when learning declarative knowledge, but would increase learners' cognitive load when learning procedural knowledge. According to t-tests for dependent samples, for declarative knowledge, there was no significant difference between the participants who watched the video without the instructor (M = 10.93, SD = 1.87) and those who watched the video with the instructor (M = 11.07, SD = 1.72), t (58) = .29, p > .05, MD = .13. However, for procedural knowledge, the participants who watched the video without the instructor reported significantly less cognitive load (M = 12.13, SD = 2.68) than those who watched the video with the instructor (M = 13.43, SD = 1.87), t (58) = 2.18, p < .05, MD = 1.30. The results supported our hypothesis and suggested that adding the instructor's image in the video lectures significantly increased participants' cognitive load when learning procedural knowledge, but not when learning declarative knowledge.

Learning effectiveness

Next, the hypothesis on learning effectiveness was addressed. It was hypothesised that adding the instructor's image in the video lecture would benefit participants when learning declarative knowledge, but would not benefit participants when learning procedural knowledge. According to t-tests, for dependent samples, for declarative knowledge, the participants who watched the video with the instructor had significantly higher scores on the learning test (M = 5.50, SD = 1.54) than those who watched the video without the instructor (M = 4.09, SD = 1.66), t (58) = 3.41, p = .001, MD = 1.41. However, for procedural knowledge, there was no significant difference between the participants who watched the video with the instructor (M = 6.23, SD = 2.26) and those who watched the video without the instructor (M = 6.61, SD = 2.20), t (58) = .65, p > .05, MD = .38. The results were consistent with our hypothesis and suggested that for different types of knowledge, different types of video lectures were effective.

Discussion

This study initially examined learners' cognitive load and learning effectiveness in the context of online video lectures either with or without the instructor when learning different types of knowledge. The results confirmed the beneficial effects of having the instructor in the video lectures in some cases: learners performed better and experienced no increase in cognitive load when being taught declarative knowledge, but not procedural knowledge. Thus our results suggest that adding the instructor in video lectures did not always have the potential to improve effectiveness, and the positive potential effects were dependent on the type of knowledge. This study represents unique contributions to social agency theory, the principles for reducing extraneous processing in multimedia learning, and the education literature in that the findings highlight the value of the type of knowledge for designing the appropriate presentation modes of online video lecture. In the remaining part of this Discussion, we consider the main results concerning the differences between learning declarative knowledge and procedural knowledge.

The results of cognitive load questionnaire showed that adding the instructor's image significantly increased learner's cognitive load only when learning procedural knowledge, and the effect was not uniform for declarative knowledge. The results further support the principles for reducing extraneous

processing in multimedia learning (Mayer & Fiorella, 2014). A potential explanation for the different effects on cognitive load is differences in learning processes between declarative knowledge and procedural knowledge. Specifically, in the current study, when learners learned declarative knowledge, they required fewer cognitive resources. Further analysis of the means on cognitive load when learning declarative knowledge found that the participants who viewed the video lecture with the instructor experienced a slightly higher level of cognitive load than those who viewed the video lecture without the instructor, but the small difference did not reach statistical significance. By contrast, when learners learned procedural knowledge, a higher level of cognitive resources was required. The instructor's image increased the cognitive load and may have interfered with learning procedural knowledge.

Furthermore, the results of learning tests showed that the positive effect of the instructor's image was only for declarative knowledge, not for procedural knowledge. There were two possible explanations of the results. The first explanation is that adding the instructor's image activated learners' social responses and meanwhile did not increase their cognitive load when learning declarative knowledge; thus, learners had enough cognitive resources for essential processing, and benefited from the non-verbal communication provided by the instructor's image. However, when learning procedural knowledge, adding the instructor's image activated learners' social responses, but meanwhile it increased their cognitive load; thus the increases in cognitive load reduced the benefits of the instructor's non-verbal communication. The second explanation is that understanding and memorising the learning content was crucial in learning declarative knowledge, while exercising the operating process was very important in learning procedural knowledge (Anderson, 1995). When learning procedural knowledge, learners' practice was more important than paying attention to the instructor. Therefore, the presentation mode of video lectures had more effects on learning declarative knowledge than learning procedural knowledge.

The results of the study are especially important because they provide preliminary evidence in support of social agency theory (Mayer, 2014), the principles for reducing extraneous processing (Mayer & Fiorella, 2014) and the extant studies on video lectures (Hoffler & Leutner, 2007; Shi, 2014). Firstly, to the best of our knowledge, this is the first study to test the effects of the presentation mode and type of knowledge simultaneously. Secondly, we tested the learning effectiveness after 10 min reviewing instead of immediately after viewing the video lectures. The learning phase and reviewing activities were based on the real educational settings in which video lectures are presented. To conclude, these findings indicated that when teaching and learning declarative knowledge, the video lectures with an instructor were more effective. Moreover, when teaching and learning procedural knowledge, the video lectures without an instructor and with an instructor had the same effectiveness. As the type of knowledge in video lectures varies, the effect of the instructor's image should be taken into account. Therefore, the type of knowledge should be informed by pedagogical design principles of video lectures. The findings are particularly important for video lecture designers and teachers.

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Disclosure statement

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