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Emotion and multimedia learning: an investigation of the effects of valence and arousal on different modalities in an instructional animation

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Abstract Previous emotion studies in education have focused mainly on the superiority of positive emotion for learning performance (e.g., enjoyment) over negative emotion (e.g., fear). However, few studies have considered different arousal levels in terms of learners' emotion. For example, the effects of calm positive or negative emotion have not been discussed, when compared to arousing positive or negative emotion. Based on *the limited Capacity model of motivated mediated message processing* (LC4MP), this study investigated how learners' emotional valence and arousal, induced by video clips, influenced their learning performance and mental effort in an animated instruction with different modalities (written-text versus spoken-text). A total of 206 participants were randomly assigned to eight groups: (a) calm positive, (b) calm negative (c) arousing positive, and (d) arousing negative emotions under different modality conditions (written and spoken). The results showed that both arousing groups outperformed calm groups on a recall test only in the written-text group regardless of valence, while emotional valence and arousal did not significantly influence learning performance in the spoken-text group. The results provide partial support for the LC4MP model and imply that the arousing emotional state has the potential to enhance multimedia learning.

Keywords Multimedia learning · Emotion · Motivated cognition · Limited capacity model of motivated mediated message processing · LC4MP

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Introduction

Emotion represents a universal experience everyone feels and is intertwined with motivation and cognitive learning processes (Chen and Sun 2012). Recent studies have demonstrated that emotional experiences during learning influence motivation to learn and learning achievement (e.g., test scores) (Fassbender et al. 2012; Goetz et al. 2007; Pekrun 2006; Pekrun et al. 2009, 2002; Robinson 2013; Trautwein et al. 2009). Several researchers have found that positive emotion (e.g., enjoyment) are superior to negative emotion (e.g., fear) for learning. They suggested that positive emotion increases learners' intrinsic motivation by stimulating their curiosity to explore new knowledge and thus leads to better learning performance (Pekrun et al. 2011; Pekrun and Stephens 2010). However, they have overlooked the positive role of negative emotion or differential effects of emotional arousal (calm versus arousing). For example, negative emotions, such as stress or anxiety, may motivate learners to perform better. Learners may strive to avoid academic failure, and such emotions may be effective for learning (Pekrun et al. 2009, 2007). On the other hand, calm positive emotion is not likely to be as effective as arousing positive emotion (Kay 2008; Linnenbrink 2007).

Emotion studies (e.g., Fassbender et al. 2012; Feldman and Russell 1998; Pekrun et al. 2009, 2011; Russell 2003; Sanchez-Franco 2010) have asserted that emotion consists of two main dimensions, valence and arousal. Valence refers to how positive or negative an emotional experience is, and arousal refers to how calm or arousing an emotional experience is. In this regard, a learner's emotional state can be identified within four categories by valence and arousal: calm positive, arousing positive, calm negative, and arousing negative emotions (Shen et al. 2009). However, there has been little consideration on how coexisting dimensions of emotional valence and arousal interactively influence learners' cognitive learning processes.

This study examines the interrelationships among emotion, motivation, and cognition in a multimedia learning context (i.e., animated instruction) based on *the Limited Capacity Model of Motivated Mediated Message Processing* (LC4MP: Lang 2006) which is a data-driven theoretical model. According to the LC4MP, humans have two fundamental motivational systems: appetitive and aversive. Motivational systems become involuntarily and unconsciously activated in response to the emotional tone (valence and arousal) of mediated content. Emotional valence and arousal can be seen as an opportunity or threat depending on how relevant given content is to an individual. The intensity of this opportunity or threat spontaneously increases the activation level of the motivational system. Humans' emotional experience and cognitive processing can vary depending on which motivational system is activated and how intense the motivational system is (Lang 2006). The LC4MP has been used to explain how individuals interact with the emotional tone of various media platform such as television, radio, computers, and video games in various presentation formats (e.g., advertisements, public service announcements, political messages, and entertainment) (Gibbons et al. 2005; Lang 2006; Potter 2009) and how they encode, store, and receive mediated content, but no study has yet applied this model to a learning media context.

An instructional animation is a multimedia learning material for displaying the continuous and dynamic flow of information through the use of audiovisual components such as pictures, background music, written-text (subtitles), and spoken-text (narrations). The animation allows for the visualization of complex processes (e.g., how a car's braking system works) and invisible or dynamic movements (e.g., how lightning develops) (Mayer and Moreno 2003). The modality principle suggests that an animation with only a narration

is more effective in recalling content than that with written-text (e.g., on-screen text correspondence), because the animation with written-text causes the overload of visual information in the visual channel of working memory (i.e., visual split-attention) (Mayer 2009).

However, no study has explored whether effects of emotion are maintained in the same way under different modality conditions. Since a learner's emotional state diminishes over time (e.g. Um et al 2012) and may be altered by an additional stimulus, effects of emotional induction can be assumed to be intervened by different modalities, such as a narrator's voice in a subsequent instructional animation. Therefore, the current study investigates how learners' valence and arousal, induced by emotional video clips, influence their learning performance (recall test scores) and the efficiency of their mental effort in animated instruction with different modalities (written-text versus spoken-text).

Theoretical background

The capacity of a human's working memory is limited in (a) simultaneously processing different sources of information (i.e., multitasking), (b) retaining particular bits of information in the working memory and (c) purposely retrieving bits of information from long-term memory (Lusk et al. 2009). There may be some cognitive overload if the amount of information required for processing exceeds the limitation of the individual's working memory capacity (Baddeley 1992; Lang 2000). The LC4MP suggests that the emotional tone of mediated content automatically activates the human's motivational system and can enhance his or her cognitive capacity by increasing the amount of cognitive resources allocated to processing. The first section introduces the LC4MP through relevant studies, and the second section discusses previous emotion and modality studies in the context of multimedia learning.

Motivated cognition

Mediated content can convey motivational relevance by containing information on opportunities or threats (Lang 2006). Opportunities refer to beneficial information (e.g., food) for human survival in a given environment, whereas threats refer to harmful information (e.g., snakes). The motivational relevance of information takes the emotional tone of valence and arousal (Lang 2006; Lang et al. 1997). Information considered as an opportunity activates the appetitive system resulting in positive emotion. Threat information activates the aversive system eliciting negative emotion (Cacioppo and Gardner 1999; Lang 2006). Simultaneously, the intensity of an opportunity or threat (i.e., how relevant given information is to human survival) is associated with the level of arousal. For example, a highly intense opportunity (e.g., victory) or threat (e.g., violence) associated with arousing positive and negative feelings is more likely to elicit a higher activation level of appetitive and aversive systems. On the other hand, a less intense opportunity (e.g., flowers) or threat (e.g., trash cans) is more likely to cause a lower activation level of appetitive and aversive systems.

The activation of the motivational system is an automatic response and thus can automatically regulate the amount of cognitive resources for processing mediated content. Because of dissimilar purposes of appetitive and aversive activation, the allocated amount of resources varies. Appetitive activation functions to seek and remember information that

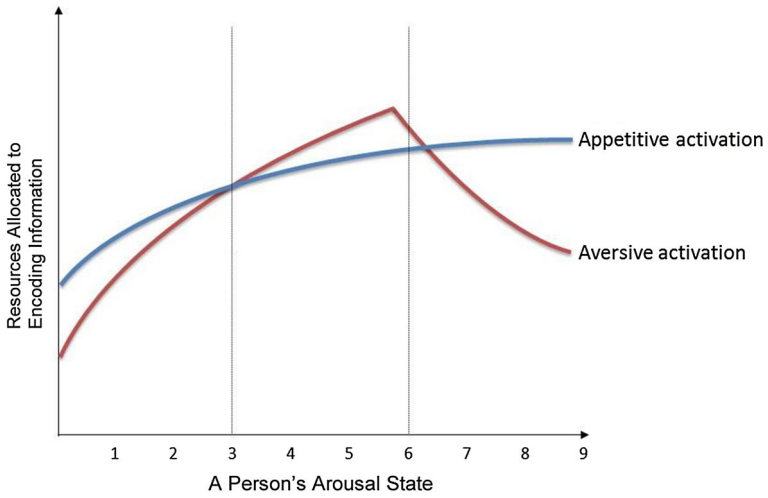


Fig. 1 Empirical evidence on motivated cognitive processing

is beneficial to human survival as much as possible. Aversive activation operates to identify and remember harmful information to protect human survival and keep the individual away from danger as much as possible. Overall, the higher the motivational activation, the more likely the individual is to experience results in more arousing emotions and strengthen memory retention.

However, as shown in Fig. 1, activation rates for appetitive and aversive systems vary. Humans are innately curious and thus seek pleasantness in a neutral or non-threatening environment. With content producing a very lower range of arousal levels (i.e., between levels 0 and 3 in Fig. 1), the resting baseline of the activation of the appetitive system exceed that of the aversive system. In moderate to high ranges of arousal levels (i.e., the detection of a more serious threat; between levels 3 and 6 in Fig. 1), the aversive system is activated more agilely and vigorously than the appetitive system. However, in extremely high ranges of arousal levels (i.e., life-threatening content; between levels 6 and 9 in Fig. 1), the aversive system fails to identify and remember content in the external environment. Instead, it is transmitted for internal retrieval processing from long-term memory to avoid any fatal danger.

Evidence of the aforementioned relationships has been provided in various mediated contexts such as photographs, radio advertisements, televised public service announcements, and in-game advertisements (e.g., Bartsch and Oliver 2011; Gibbons et al. 2005; Lang 2006; Lee and Lang 2009; Potter 2009). However, few studies have considered entertainment and communication media context, and the LC4MP prediction has not been examined in learning environments. Because it is rare to use information in high ranges of arousal levels in a learning context, the current study examined learners' motivated cognition within moderate ranges of learners' arousal levels (i.e., between levels 3 and 6 in Fig. 1).

Emotion and modality in multimedia learning

Previous studies utilized various types of media (e.g., on-screen text, narrations, pictures, videos, and animations) to determine emotional tones that influence learning such as,

pictures illustrating frightened residents fleeing from a hurricane (Park and Lim 2007), cheerful background music in educational games (Fassbender et al. 2012), and colored human-like shapes in animated instruction (Um et al. 2012). Learners' emotional state can be induced by their external mood through various emotional tones (e.g., free gifts, emotional videos, and puzzle game) and maintained during learning (Isen et al. 1987; Isen and Reeve 2005; Um et al. 2012; Wolfson and Case 2000). The induced emotional experiences can influence cognitive processing (Gomez et al. 2009; Um et al. 2012). Emotion studies have found that positive emotion can enhance learners' cognitive interest, motivation, satisfaction, and cognitive achievement (i.e., transfer and comprehension test scores). Positive emotion can help learners pay closer attention to learning content (Park and Lim 2007) and increase their germane cognitive load (i.e., relevance to learning) (Um et al. 2012). However, these studies have discussed relative benefits of positive versus negative emotion without considering different arousal levels (e.g., calm positive or arousing negative) (e.g., Pekrun 2006; Um et al. 2012). Therefore, there is a need to explore different intensity levels of positive and negative emotions.

This study examines how different valence and arousal levels of the emotional state influence multimedia learning with two types of text versions: spoken-text and written-text. Modality conditions play an important role in cognitive processing. According to Baddeley's (1992) model of working memory, auditory processing and visual processing are independent of each other and are different in terms of their cognitive capacity. Therefore, the strategic presentation of multimedia instruction has been suggested to avoid the cognitive overload of one channel (Mayer 2009). The modality principle asserts that multimedia instruction with spoken-text (i.e., a narration) is more effective than multimedia instruction with on-screen text because the simultaneous presentation of visuals and explanatory written-text is more likely to cause the learner's cognitive overload in visual processing (i.e., the split-attention effect) (Mayer 2009; Mousavi et al. 1995). Therefore, the use of multiple modalities (e.g., animations/graphic images for the visual channel and spoken-text for the verbal channel) can help increase cognitive efficiency. Learners' emotional state as well as the modality of learning materials influences their learning. However, few studies have explored the effects of emotions on learning in different modality conditions.

The modality of learning materials may influence learners' emotional state induced before the learning process. For example, spoken-text, such as narration, can convey its own emotional tone by the voice tone (e.g., the pitch or rhythm) (e.g., Cook 2002; Laukka et al. 2005). Thus, the spoken-text during learning may influence the effects of emotional induction provided before learning. On the other hand, written-text may not have this effect on the emotional mood because of the absence of the voice tone. In addition, emotional induction may be less likely to influence the cognitive processing of spoken materials, which require the learner's conscious cognitive effort to pay attention to and understand the meaning of spoken-text (e.g. Hampson and Morris 1996; Lang et al. 1999). Since there is little research that explores the relationship between emotional induction and the different modality conditions, the current study proposes the following research questions and hypotheses:

RQ1 Do valence and arousal have differential effects on learning performance (i.e., recall test scores) between written-text and spoken-text animations?

More specifically, within moderate ranges of arousal (e.g., a learner' arousal state; see Fig. 1), regardless of the type of valence activating appetitive or aversive systems, arousing emotion may produce better learning performance than calm emotion during learning.

Because of the more vigorously increasing activation level of the aversive system, arousing negative emotion may be more effective in learning than arousing positive emotion. However, there may be little difference in learning performance between calm positive and calm negative emotions based on the LC4MP. Further, the aforementioned valence and arousal effects may be better observed when learning with a written-text animation, because a narration in spoken-text may attenuate the learner's emotional state.

RQ2 Do valence and arousal have differential effects on mental effort for the test between written-text and spoken-text animations?

The efficiency of mental effort for tests refers to lower cognitive burden during a test (e.g. Um et al. 2012). Therefore, based on Fig. 1, because arousing emotion can automatically allocate more cognitive resources to the processing of learning content, this study hypothesizes that, regardless of the type of valence, arousing emotion is more likely to reduce the learner's mental effort for the test than calm emotion. In particular, arousing negative emotion may reduce mental effort for the test than arousing positive emotion. However, there may be little difference in mental effort for the test between calm positive and calm negative emotions. Furthermore, if valence and arousal effects of emotional induction disappear with learning from a spoken-text animation (see RQ1), then mental effort scores on test may be higher than those for written-text.

Methods

Participants and the study design

A total of 206 undergraduate students enrolled in a computer literacy course at a large southwestern university participated in this study (female: 134, male: 72; freshman: 24, sophomore: 88, junior: 45, senior: 49). The course had a research module for students to participate in an experimental study about an instructional technology. This study had three between-subjects independent variables: modality (written-text/spoken-text), valence (positive/negative), and arousal (calm/arousing). The participants were randomly assigned to one of eight different conditions: (a) written-text, positive, and calm ($n = 27$), (b) written-text, positive, and arousing ($n = 27$), (c) written-text, negative, and calm ($n = 26$), (d) written-text, negative, and arousing ($n = 26$), (e) spoken-text, positive, and calm ($n = 25$), (f) spoken-text, positive, and arousing ($n = 25$), (g) spoken-text, negative, and calm ($n = 25$), and (h) spoken-text, negative, and arousing ($n = 25$).

Materials

Emotion induction

The participants' emotional state was induced by using 3-min video clips with different emotional tones in valence and arousal, prior to the presentation of learning content (e.g. Um et al. 2012). The contents of the emotional video clips were comparable to that used in the previous study (Gomez et al. 2009): (a) the calm positive video about nature showing a deer walking through the forest with bird sounds and sedate background music; (b) the calm negative video about slum streets showing trash and children sitting around the slum street with gloomy background music; (c) the arousing positive video about sports events

depicting exciting moments in football games including victories and touchdowns as described by sports commentators, and cheering crowd sounds; and (d) the arousing negative video about disasters in nature showing gradual flooding by the tsunami, and its damages to cars and buildings along with disorderly and crushing sounds. Figure 2 shows screenshots of these four emotional video clips. After watching the video clip, all participants were asked to separately rate their emotional feelings for positive valence, negative valence, and arousal for manipulation check.

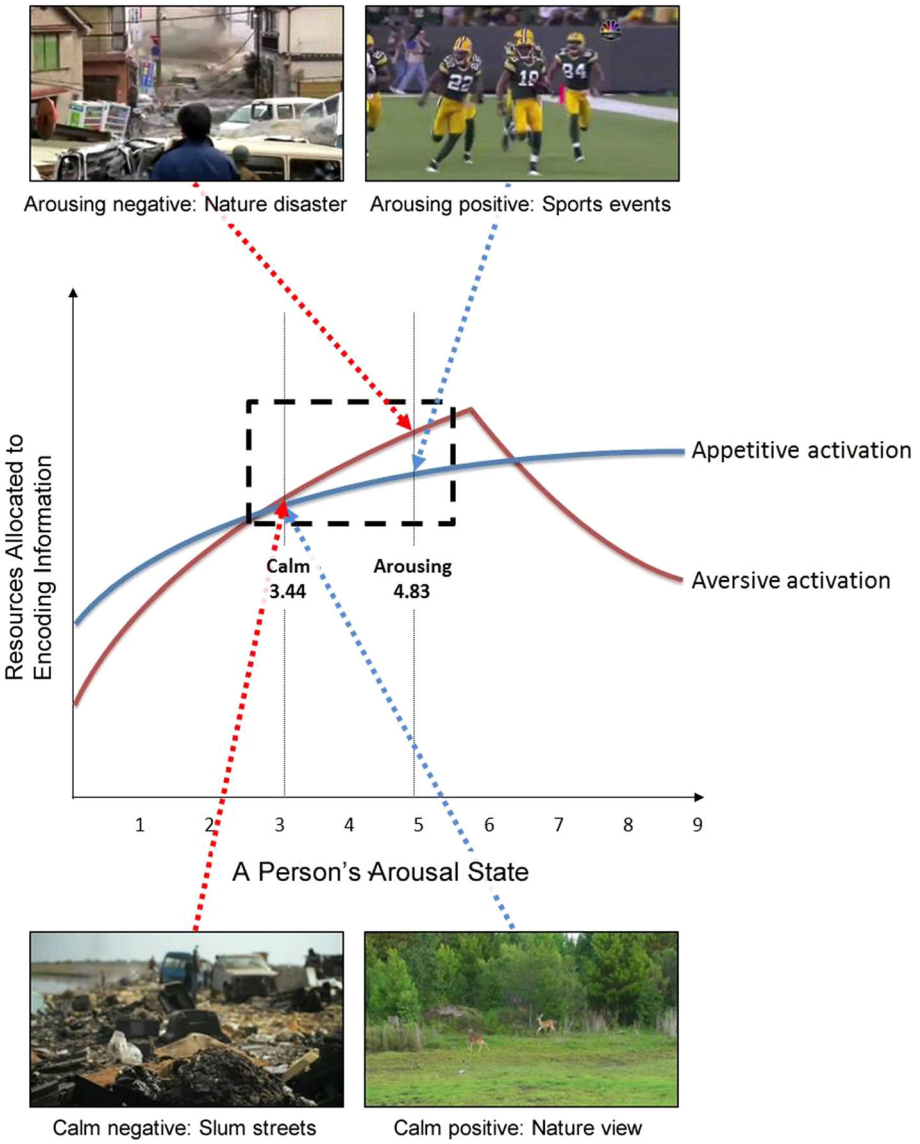


Fig. 2 Emotional video clips for the experiment and hypothesis testing

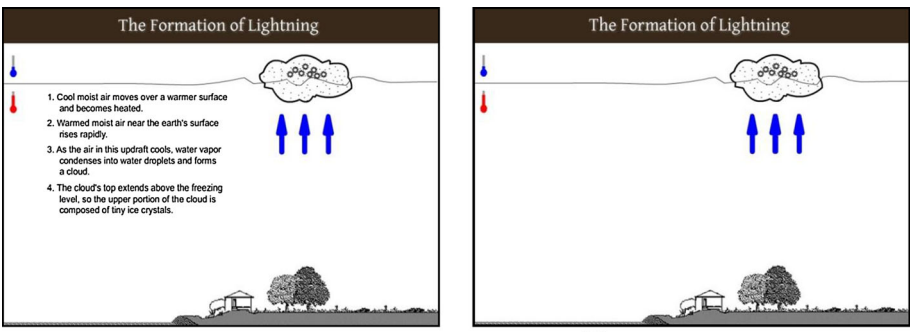
Instructional unit

The learning material was a 40-s instructional animation about the formation of lightning, which was used in previous studies of various principles of multimedia learning (Cheon et al. 2014; Mayer and Moreno1998, 2002). The animation contained information on initial steps of lightning formation. The animation was presented in two types of modality conditions: written-text and spoken-text (see Fig. 3). The written-text condition presented four sentences on the screen (e.g., *Cool moist air moves over a warmer surface and becomes heated*) in sequential order during the animation. The spoken-text condition had only a narration (identical to the written-text) without presenting text during the animation. The time period of on-screen text was equivalent to that of the narration. Both animations were system-controlled and could not be replayed.

Measurements

Emotional responses

Because the type of motivational system and its activation level determine the emotional experience of valence and arousal, previous studies of motivated cognition have measured positive valence, negative valence, and arousal, separately by using separate 9-point rating scales (Bolls et al. 2001; Bradley and Lang 1994; Lee and Lang 2009; Yegiyan and Lang 2010). The self-report measures have been widely used by matching reliably and consistently to physiological responses, such as heart rates or skin conductance (e.g., Ivory and Kalyanaraman 2007; Schneider et al. 2004). The question for positive valence was: "Please rate how positive you felt from the video clip you just watched" (1 = not at all positive, happy, or pleased; 9 = extremely positive, happy, or pleased). The question for negative valence was: "Please rate how negative you felt from the video clip you just watched" (1 = not at all negative, unhappy, or unpleased; 9 = extremely negative, unhappy, or unpleased). The question for arousal was: "Please rate how aroused you felt from the video clip you just watched" (1 = not at all aroused, excited, or awake; 9 = extremely aroused, excited, or awake).



(a) Written-text condition **(b)** Spoken-text condition

Fig. 3 A screenshot of instructional animation

Prior knowledge test

Prior knowledge of meteorology was measured to control individual differences in knowledge about the instructional unit of the study. The eight question items measuring the prior knowledge were adopted from Mayer and Moreno's (1998) study. They were a 7-item checklist (e.g., "I know what a low pressure system is ___") and a self-rating question asking participants to report the degree of their meteorology knowledge on a 1-item 5-point scale (1 = very little; 5 = very much). The reliability test score (Cronbach's $\alpha = 0.749$) of the prior knowledge test was acceptable.

Free-recall test scores

Free-recall test scores for learning content were measured to examine learning performance. The recall test asked the participants to type all information they could recall from the animation they just watched. Consistent with previous studies (e.g. Cheon et al. 2014; Mayer and Moreno 2002), each sentence contained two key concepts and therefore could be scored as 0–2 points. Because there was a total of four sentences, a participant could receive 0–8 points in the recall test. In the pilot test, an inter-rater reliability analysis using the Kappa statistic was conducted to determine consistency between two raters. The inter-rater reliability for the raters was as follows: Kappa = 0.695 ($p < 0.001$), 95 % CI (0.528, 0.862).

Mental effort rating scores for test

A one item 9-point scale was used to measure the amount of mental effort invested during the free-recall test. This scale was obtained from Paas and colleagues (Paas 1992; Paas et al. 2003). The participants were asked to rate their mental effort based on the statement: "Please indicate how much mental effort you invested in this test" (1 = extremely low; 9 = extremely high).

Procedures

Through a click of a survey link, students were randomly assigned to one of eight different experimental conditions. An introduction page informed them that they would learn about the formation of lightning from an instructional animation. They were asked to wear headsets and adjust volume levels (if needed) while watching a sample video for audio testing, which was not related to this study. This study consisted of five phases. First, the participants responded to questions on demographic information (i.e., gender and academic year) and prior meteorology knowledge. Second, they watched a 3-min video clip with a pre-assigned emotional tone. After watching it, they rated their emotional experience of positive valence, negative valence, and arousal with respect to the video clip they just watched. Third, they learned from an instructional animation about the formation of lightning. Fourth, they took a free-recall test that asked them to write in the text-input box on the computer screen how lightning works. The amount of time spent on the recall test was controlled by learner. Finally, they were asked to rate their mental effort levels for the recall test.

Results

Manipulation check

The manipulation check of the emotional tone of video clips was performed by t test analyses. Positive valance was significantly higher for positive video clips ($n = 104$; $M = 6.67$, $SD = 1.77$) than for negative ones ($n = 102$; $M = 2.25$, $SD = 1.43$), $t\,(204) = 19.702$, $p < 0.001$. Negative valence was significantly higher for negative video clips ($n = 102$, $M = 6.68$, $SD = 1.94$) than for positive ones ($n = 104$; $M = 2.38$, $SD = 1.58$), $t\ (194.32) = -17.437$, $p < 0.001$. Arousal was significantly higher for arousing video clips ($n = 103$; $M = 4.83$, $SD = 2.55$) than for calm ones ($n = 103$; $M = 3.44$, $SD = 2.16$), $t\,(204) = -4.218$, $p < 0.001$. Therefore, the manipulation of the emotional tone was determined to be within moderate ranges of arousal levels highlighted by the dashed-line rectangle in Fig. 2. In addition, there was no significant difference in prior knowledge among the participant groups across modality, valence, and arousal conditions, ($F\,(1198) = 1.302$, $p = 0.255$).

Recall test scores and mental effort

To examine RQ1, 2 (Modality) × 2 (Valence) × 2 (Arousal) ANOVA analysis was performed on recall test scores. Table 1 shows the means and standard deviations for all measures. No significant main effect was found in terms of the modality ($F\ (1198) = 0.514$, $p = 0.474$) and valence ($F\ (1198) = 3.769$, $p = 0.054$). However, arousal had a main effect ($F\,(1198) = 5.329$, $p = 0.022$, partial $\eta^2 = 0.03$). There were no significant interaction effects for modality × valence ($F\,(1198) = 0.306$, $p = 0.581$), and modality × valence × arousal ($F\,(1198) = 0.474$, $p = 0.492$). However, a significant interaction effect was found for modality × arousal ($F\ (1,\ 198) = 5.713$, $p = 0.018$, partial $\eta^2 = 0.03$). In sum, the modality and arousal interactively influenced recall test scores although no interaction effect was found between modality and valence.

Based on the results for RQ1, we computed separate 2 (Valence) × 2 (Arousal) ANOVAs and independent t-test analyses in each modality condition (written-text: $n = 106$; spoken-text: $n = 100$) to examine differences between positive and negative

Table 1 Means and standard deviations for all measures

			Written-text ($n = 106$)		Spoken-text ($n = 100$)	
			Arousal		Arousal	
			Calm	Arousing	Calm	Arousing
Recall test scores	Valence	Positive	($n = 27$) 4.04 (1.16)	($n = 27$) 5.19 (1.78)	($n = 25$) 4.48 (2.18)	($n = 25$) 4.12 (1.56)
		Negative	($n = 26$) 3.42 (1.21)	($n = 26$) 4.58 (1.72)	($n = 25$) 3.80 (2.24)	($n = 25$) 4.12 (1.94)
Mental effort scores	Valence	Positive	6.22 (1.40)	6.52 (1.72)	5.92 (1.53)	5.92 (2.20)
		Negative	6.42 (1.42)	6.42 (1.42)	5.56 (1.76)	5.68 (1.91)

Standard deviations are presented in parenthesis

emotions for calm levels only and for arousing levels only. For scores on the recall test in the written-text modality condition, there were significant main effects for valence (F (1, 102) = 4.431, $p = 0.038$, partial $\eta^2 = 0.04$) and arousal (F (1, 102) = 15.719, $p < 0.001$. partial $\eta^2 = 0.13$). However, there was no interaction effect between valence and arousal (F (1102) = 0.000, $p = 0.992$). More specifically, independent t-tests show that recall test scores in the arousing positive group ($M = 5.19$; $SD = 1.78$) were significantly higher than those in the calm positive group ($M = 4.04$; $SD = 1.16$), t (44.749) = 2.812, $p = 0.007$. Recall test scores were significantly higher for arousing negative emotion ($M = 4.58$; $SD = 1.72$) than for calm negative emotion ($M = 3.42$; $SD = 1.21$), t (50) = −2.796, $p = 0.007$. However, there were no significant differences between calm positive and calm negative emotions (t (51) = 1.890, $p = 0.064$) and between arousing positive and arousing negative emotions (t (51) = 1.264, $p = 0.212$). On the other hand, on recall test scores in the spoken-text modality condition, no significant effects were found for valence (F (196) = 0.723, $p = 0.397$), arousal (F (196) = 0.003, $p = 0.960$), and valence × arousal (F (196) = 0.723, $p = 0.397$). In sum, the results suggest that arousal independently influenced recall-test scores regardless of valence only in the written-text condition; however, no effect was found in the spoken-text condition.

RQ2 was addressed by conducting a 2 (Modality) × 2 (Valence) × 2 (Arousal) ANOVA analysis on mental effort levels. Means and standard deviations of the mental effort scores are presented in Table 1. The results showed that modality had a significant main effect (F (1198) = 4.017, $p = 0.046$, partial $\eta^2 = 0.02$). However, no significance was found for valence (F (1198) = 1.383, $p = 0.241$), arousal (F (1198) = 1.195, $p = 0.276$), modality × valence (F (1198) = 0.009, $p = 0.924$), modality × arousal (F (1198) = 0.704, $p = 0.403$), and modality × valence × arousal (F (1198) = 0.045, $p = 0.833$). Valence and arousal did not differently impose mental effort for the test even in different modality conditions.

Based on these results, separate 2 (Valence) × 2 (Arousal) ANOVA analyses in each modality condition were computed on mental effort scores. In the written-text modality condition, no significant effects were found for valence (F (1, 102) = 0.751, $p = 0.388$), arousal (F (1102) = 2.402, $p = 0.124$), and valence × arousal (F (1102) = 0.294, $p = 0.589$). Similarly, the mental effort scores in the spoken-text modality condition were not significantly different in valence (F (196) = 0.648, $p = 0.423$), arousal (F (196) = 0.026, $p = 0.872$), and valence × arousal (F (196) = 0.026, $p = 0.872$). In sum, valence and arousal had no effects on mental effort for the recall test in both modality conditions.

Discussion and conclusion

This study is the first to examine how valence and arousal influence learning performance and mental effort in the context of multimedia learning (i.e., animated instruction). The results fairly support the LC4MP predictions on learners' motivated cognitive processing of instructional animations with written-text.

In the written-text condition, arousing emotions had a significant positive effect on recall scores regardless of the type of emotional valence in comparison to calm emotions. Previous education studies have verified the benefits of only positive emotions for increasing learning performance. In this regard, the present study extends the literature by revealing that arousing negative emotions can also be an effective motivator for learning.

That is, stronger feelings in a learning environment may increase attention to and improved memory for learning content (e.g. Joëls et al. 2006).

The results for the effects of valence on recall test scores provide partial support for the LC4MP. Consistent with the LC4MP, at calm levels, there was no significant difference in recall test scores between calm positive (i.e., nature) ($M = 4.04$) and negative (i.e., slum streets) emotions ($M = 3.42$). However, inconsistent with the LC4MP, at arousing levels, there was no significant difference between arousing positive and negative emotions, although the recall test scores were higher for the positive emotion ($M = 5.19$) than for negative emotions ($M = 4.58$). According to the results, learners' emotional state was induced by emotional video clips presented before an instructional animation. However, the period of this emotional induction varied. For example, arousing negative emotion tended to occur and vanish quicker than arousing positive emotion because of differences in the activation rate and speed between appetitive and aversive systems (e.g., Lang 2006; Rickwood and Price 1988). Thus, we conjecture that the induced negative emotion did not last longer than positive emotion during the processing of a learning task. In addition, valence and arousal effects did not influence mental effort during the recall test. That is, although the arousing emotional experience did not increase efficiency (i.e., reduce mental effort), it did not impose any additional extraneous cognitive load, which is consistent with the findings of (Um et al. 2012).

However, the LC4MP was not applicable to the spoken-text condition as no effect of valence and arousal was found. The human voice has been shown to convey the emotional tone of valence and arousal, and the emotional tone is known to be influenced mainly by the pitch of the voice (Cook 2002; Laukka et al. 2005). In this study, the narration in the spoken-text has a neutral emotional tone because the narration was carefully recorded to have the voice with little change in its pitch tone. Therefore, although learners were previously emotionally induced before learning, their emotional state could be readjusted by the neutral emotional tone of the narration during the learning process (e.g. Piwek et al. 2012). Subsequently, emotional induction did not affect learning performance in the spoken-text condition.

The findings of this study provide important practical implications. In online learning environments, instructional designers have not paid careful attention to the role of learners' emotional state that may occur before or during learning. This study shows that learners' emotional state can be regulated by emotional induction, such as external video clips with the emotional tone of valence and arousal, and the arousal levels would be more important than the valence when prompting learners' emotion. The results show that arousing emotions for both positive and negative emotions consistently entailed better learning performance than calm emotions in the written-text modality. Overall, the findings provide support for Pekrun's control-value theory (e.g. Pekrun 2006; Pekrun et al. 2002), which posits that both positive and negative activating emotions can enhance performance. More specifically, positive activating emotions can facilitate factors such as motivation, elaboration, and critical thinking, whereas negative activating emotions can be beneficial by enhancing focused attention and motivation to carefully process the information. However, emotional induction is not recommended for animated instruction with only some narration, because differences in the emotional tone of the narrator's voice in the animation may reduce benefits of arousing emotional induction. Additionally, the results suggest the use of emotional induction in learning, although it is not directly relevant to learning content. For practitioners such as instructors and designers, such types of emotional induction can be beneficial in easily drawing learners' attention prior to learning. However, although this study provides meaningful findings on emotionally motivated

learning in a multimedia context, future research should design emotional induction to be more instructional or relevant to learning content for the better generalization of results.

This study has several limitations in terms of the manipulation of emotional induction in the experiment. The analysis focused only on a narrow (i.e., moderate) range of the learner's arousal level. According to the LC4MP, resources allocated to processing vary across low, moderate, and high ranges of arousal levels because of differences in the activation tendency of appetitive and aversive systems (see Fig. 1). Therefore, future research should investigate multiple levels of arousal and a broader range of arousal to examine interaction effects of valence and arousal in learning contexts. In addition, the analysis measured the participants' emotional experience based on their self-report rating of emotions. Future research can employ physiological measures such as a facial electromyography techniques, heart rates, and skin conductance to more directly capture dynamically changing responses over time. Further, future research should measure and compare learners' emotional states before, during, and after learning because the narrator's voice in the instructional animation may attenuate the effect of emotional induction. Other limitations are associated with the instructional design of the instructional animation. Because the instructional animation was relatively short in this analysis, more complex animations can be employed to determine the effects of emotions. In addition, this study's video clips consisted of visual and audio information that could have imposed some extraneous cognitive load and thus reduced learning resources (e.g. Um et al. 2012). In this regard, future research can employ other types of multimedia tools demanding a lower cognitive load, including photographs and background music. Finally, the analysis employed emotional induction presented before learning, but future research can use learning content with various emotional tones.

Although many scholars have investigated the interrelationships among emotion, motivation, and cognition, there is little research considering the effects of valence and arousal on multimedia learning. According to the results of this study, only arousal induced higher learning performance for an instructional animation with written-text regardless of valence (i.e., positive or negative). The positive role of emotional induction can be considered to motivate and engage learners in an online learning environment.

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