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Emotional Design in Multimedia Learning

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Can multimedia learning environments be designed to foster positive emotions that will improve learning and related affective outcomes? College students (N = 118) were randomly assigned to 4 conditions created by 2 factors related to learners' emotion: *external mood induction* (positive vs. neutral emotions) and *emotional design induction* (positive vs. neutral emotions). A computer-based lesson on the topic of immunization was used as multimedia learning material. Results indicate that applying emotional design principles to learning materials can induce positive emotions and that positive emotions in multimedia-based learning facilitate cognitive processes and learning. Controlling for the germane load of the materials, the internal induction of positive emotions through design of the materials increased comprehension and transfer, whereas the external induction of positive emotions through mood induction enhanced transfer but not comprehension. Positive emotions induced through mood induction significantly increased the amount of learners' reported mental effort, whereas positive emotional design reduced the perceived difficulty of the learning task. Positive emotions increased motivation, satisfaction, and perception toward the materials. Mediation analyses suggest that the effect of positive emotions induced externally was mediated by both motivation and mental effort but found no mediators for emotion induced via emotional design, suggesting that positive emotional design has a more direct impact on learning than externally induced emotions. The study suggests that emotions should be considered an important factor in the design of multimedia learning materials.

Keywords: emotion, multimedia learning, cognitive load, motivation, instructional design

Can multimedia learning environments be designed to foster positive emotions, and will such positive emotions improve learning and affective outcomes? In academic settings, learners experience a broad variety of emotions that are related to important predictors of learning, such as motivation, learning strategies, and self-regulation, as well as to academic achievement (Pekrun, Goetz, Titz, & Perry, 2002). When it comes to educational experiences, the question of how the design of the materials impacts learners' emotions, and how these emotions may affect learning outcomes, has not received sufficient attention. In the present study, we investigate whether multimedia learning environments can be designed to induce positive emotions in learners and whether these positive emotions enhance comprehension of the content of the multimedia materials and facilitate the construction of mental models that allow for the transfer of the new knowledge to different situations.

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Positive Academic Emotions

A common view of emotions is that they are generated by people's judgment about the world and initiated by an individual's appraisal in response to and interaction with a stimulus, such as the material with which the individual is learning (Desmet, 2002; Frijda, 1993; Lazarus, 1991; Oatley & Johnson-Laird, 1987; Ortony, Glore, & Collins, 1988). Alternative models, such as *core affect*, have also been proposed to describe a person's emotional life (Russell, 2003). This model is a response to research suggesting that a distinction between emotion and mood may not be meaningful and that affect, activation, and mood appear to describe the same phenomena (Yik, Russell, & Feldman Barrett, 1999). Russell's (2003) model captures valence as well as arousal in a two-dimensional system, with activation/deactivation as one dimension and pleasure/displeasure as the other, orthogonal dimension. For the purpose of this article, we therefore use the terms *emotion* and *mood* interchangeably, as our focus is on the general valence of learners' affect (positive–negative) and not on specific emotions.

We are interested in emotions experienced during learning (i.e., academic emotions). Academic emotions describe affect directly linked to learning, instruction, and academic achievement in formal and informal settings (Goetz, Pekrun, Hall, & Haag, 2006; Pekrun et al., 2002). Pekrun et al. discuss two dimensions of emotions that impact performance, the valence of the emotion (positive–negative) and activation (Pekrun, 1992; Russell, 2003). Positive emotions can be activating (happy, hopeful) or deactivating (satisfied, calm). Likewise, negative emotions can be activating (anxious, angry) or deactivating (hopeless; Pekrun et al., 2002; Pekrun & Jerusalem, 1996). Therefore, facilitating effects of emotions may be expected for those positive emotions that have an activating property, such as happiness, but also for certain negative activating emotions, such as anxiety. Furthermore, according to Pekrun (2006), positive emotions strengthen motivation, whereas negative emotions can be detrimental to learning. The relationship between motivation and deactivating positive emotions (e.g., relaxation) and activating negative emotions (e.g., anger) is more complex. For example, anxiety can reduce intrinsic motivation to learn and simultaneously increase extrinsic motivation to avoid failure (Pekrun, 2006). For the purpose of this research, we investigate the effect of activating positive emotions as facilitating agents that impact learning and motivational processes as mediating mechanisms.

Emotions and Learning

The findings from research on emotions and learning suggest that positive affect can enhance cognition in a broad variety of ways. Positive emotions have a crucial effect on diverse cognitive processes that are relevant for learning, such as information processing, communication processing, negotiation processing, decision-making processing, category sorting tasks and even the creative problem-solving process (Erez & Isen, 2002; Isen & Baron, 1991; Konradt, Filip, & Hoffman, 2003). Early research in this area found a positive effect of emotion on memory, where a positive emotional state improved recall and positive emotions served as effective retrieval cues for long-term memory (Isen, Daubman, & Nowicki, 1987; Isen, Shalker, Clark, & Karp, 1978). Research also suggests that cognitive processes may be more flexible as a function of positive affect, which may also result in greater creativity and improved problem-solving ability (Isen et al., 1987). Research on the relation of emotions and learning has also found effects on variables such as effort-related metacognitive experiences, such that more positive emotions resulted in a higher readiness to invest effort in the learning task (Efklides, Kourkoulou, Mitsiou, & Ziliaskopoulou, 2006).

Research conducted in the classroom with authentic learning tasks reveals a more complex relation of emotions and learning. In a study on the impact of affect on college students' comprehension of a reading passage on Newtonian physics, Linnenbrink and Pintrich (2002b) found inconsistent effects of positive emotions on conceptual change and strategy use. Studies on mathematics learning conducted with middle school students revealed a similarly inconsistent picture (Linnenbrink & Pintrich, 2002a). A study on solving a 15-min series of math problems revealed that students' reported emotions were unrelated to learning outcomes. However, self-reported arousal (tired–excited) was positively related to students' regulation of their effort, such as persistence despite not wanting to work on the assigned task. Both self-reported arousal and self-reported valence (sad–happy) were positively related to cognitive regulation processes, such as planning tasks, monitoring task achievement, and checking answers. In reviewing their studies, Linnenbrink and Pintrich noted that their inconsistent findings may have been due to methodological problems of the research. In particular, the self-reports of affect may have been impacted by students' self-perception of how well they did on the assigned posttests, and the studies did not involve experimental manipulation of emotion.

Another line of research investigates emotion in the context of intelligent tutoring systems, such as *AutoTutor* (Graesser, Chipman, Haynes, & Olney, 2005). These studies have shown that students experience a broad range of emotions during learning and that their affective state as coded by observers predicted 27% of the variance in learning measures (Craig, Graesser, Sullins, & Gholson, 2004). Learning gains in this study were positively related to flow and confusion. Using progress in research on affective computing that allows computers to recognize human emotion and express emotion in response (Burleson, Picard, Perlin, & Lippincott, 2004; Picard, 1997), Graesser, D'Mello, and colleagues have begun to investigate the question of whether a system can detect learners' affect through conversational cues, gross body language, and facial features and respond accordingly could enhance learning (D'Mello & Graesser, 2010). A study that incorporated affect sensing into the *AutoTutor* system showed that under some conditions, low-prior-knowledge learners benefitted from an empathic and encouraging animated agent, whereas high-prior-knowledge learners did not (D'Mello et al., 2010).

Although promising, these results of existing studies on the relation of emotions and learning highlight the need for additional research. There are some basic research questions that have not yet been addressed in the context of learning from authentic materials, such as how to best induce positive emotions in learners and how such positive emotions affect learning outcomes in multimedia learning environments. Linnenbrink and Pintrich (2002a) noted, for example, that the experimental research on the effects of emotion on cognition mostly used mood-induction tasks, rather than environmental features, to induce positive affect. In the present study, we are therefore interested in comparing the effects of traditional mood-induction tasks with the effects of inducing positive emotions through the design of the learning environment itself. We are further interested in using learning materials that more closely resemble academic learning tasks, such as multimedia learning materials.

Emotions in Multimedia Learning

Many design features of multimedia materials, such as colors, shapes, and sounds, are likely to have an impact on learners' affect, yet few theoretical models of multimedia learning consider the effect of emotions on learning. *Multimedia learning* can, for the purpose of this research, be defined simply as learning from pictures and words (Mayer, 2001). The *cognitive theory of multimedia learning* describes, based on the dual channel assumption of *dual coding theory* (Paivio, 1986), how multimedia information is processed in separate channels for verbal and visual information (Mayer, 2001). *Learning* is considered a generative process in which learners select relevant visual and verbal materials, organize these visual and verbal mental representations in coherent structures in working memory, and integrate the visual and the verbal mental representations with one another and with prior knowledge (Mayer, 2005). Complementing this process model, the *cognitive load theory* provides a capacity model of multimedia learning (Plass, Moreno, & Brünken, 2010; Sweller, 1988). The theory defines three types of cognitive load: *intrinsic* cognitive load, which describes the complexity of the information; *germane* cognitive load, which describes the amount of mental effort invested by the learner in comprehending the materials; and *extraneous* cognitive load, which describes processing demands of information that is not directly related to the learning task and which are a result of the instructional design of the materials (Kalyuga, 2010).

In the context of these two models, emotions are typically viewed as a source of extraneous cognitive load that should be reduced as far as possible (Harp & Mayer, 1998). An alternative approach suggests, however, that emotions may impact learning in a positive way, for example, by increasing learners' interest and motivation.

Emotions as Extraneous Cognitive Load

The *emotions as extraneous cognitive load* hypothesis suggests that the introduction of any elements aimed at inducing positive emotions in instructional materials will impose extraneous cognitive load, which will, in turn, hurt learning. This hypothesis is consistent with the *coherence effect*, which suggests that adding unimportant but interesting elements to expository texts impedes the learning of the main points in the text (Harp & Mayer, 1997, 1998; Mayer, 2005; Moreno & Mayer, 2000). The strategies to induce positive emotions or interest in learners used in these studies include the addition of interesting text, visual information, music, or sounds to the learning materials. Proponents of this hypothesis claim that the processing of these additional elements makes demands on learners' limited working memory capacity and competes with the processing of the essential information. In other words, they claim that the relative benefit of these additional affective elements, geared toward increasing the learners' interest and motivation, is not high enough to compensate for the added processing demands and therefore will not result in enhanced learning.

The extraneous load hypothesis is grounded in studies in which experimentally induced emotions impeded encoding and retrieval of information (Ellis, Thomas, & Rodriguez, 1984; Ellis, Thomas, McFarland, & Lane, 1985). The authors explained these results within the framework of a resource-allocation theory, asserting that emotions can both quantitatively reduce the amount of task-relevant processing by the participant and produce a differential allocation of processing resources or capacity during encoding. Emotional states are viewed as conditions that regulate the allocation of capacity or resources in cognitive tasks. A disruptive emotional state is considered as generating task-irrelevant thinking that interferes with the encoding as well as the output of information, because it requires cognitive capacity that would normally be allocated to the process of encoding the task (Pekrun, 1992; Pekrun et al., 2002). Other results indicate that emotions may negatively impact cognition by placing demands on working memory and therefore interrupting processing of a cognitive task (Seibert & Ellis, 1991b). Emotions have also been found to suppress the cognitive processes in convergent or analytic tasks, such as deductive reasoning (Oaksford, Morris, Grainger, & Williams, 1996). The extraneous load hypothesis therefore predicts that the use of design features to induce positive emotions in learners will result in decreased learning and increased extraneous cognitive load, as well as lower satisfaction with the learning experience and lower perception about their learning achievement.

Emotions as Facilitator of Learning

The *emotions as facilitator of learning* hypothesis is an alternative approach to the impact of emotions on learning. This hypothesis suggests that experiencing positive emotions during the learning process can enhance learning outcomes, either through direct impact and learning or through mediating variables, such as interest and motivation. The impact of learners' interest and motivation on learning is described by models such as the ARCS model, which suggests strategies for attention, relevance, confidence, and satisfaction of the learner (Keller, 1987). Strategies to enhance positive emotions (specifically, sympathy and pleasure) and reduce negative emotions (specifically, fear, envy, and anger) to facilitate learning have been proposed by Astleitner (2000). Astleitner argued that emotions affect learning and that instructional designers therefore need to optimize learners' emotional states during the learning process. However, there is limited empirical support available for this approach. Most recently, Moreno and Mayer (2007) proposed an extension to the cognitive theory of multimedia learning that incorporates motivational and metacognitive factors as mediators of multimedia learning.

The facilitator hypothesis is grounded in a series of research studies that has suggested that positive emotions have a crucial effect on diverse cognitive processes, such as information processing, communication processing, negotiation processing, decision-making processing, category sorting tasks, and even the creative problem-solving process (Erez & Isen, 2002; Isen & Baron, 1991; Konradt et al., 2003). Isen and her colleagues identified two mechanisms in support of the facilitation hypothesis. One mechanism is related to long-term memory, where positive affect can serve as a retrieval cue for positive material from long-term memory (Isen et al., 1987, 1978). The second mechanism involves the way information is processed, rather than how it is retrieved. Positive affect has been found to influence cognitive organization and creativity, providing cues to the positive material and influencing cognitive organization by altering the context in which cognitive activity take place (Isen & Daubman, 1984; Isen, Johnson, Mertz, & Robinson, 1985). Cognitive processes may be more flexible as a function of positive affect, which may also result in greater creativity and improved problem-solving ability (Isen et al., 1987). The facilitator hypothesis therefore predicts that the use of design features to induce positive emotions in learners will result in increased learning, increased germane cognitive load, increased motivation, and higher satisfaction with the learning experience and higher perception about their learning achievement.

Toward a Theoretical Model of Affect in Multimedia Learning

To advance research on the impact of emotion on multimedia learning it would be necessary to integrate cognitive theories of multimedia learning and theories describing the relation of affect and learning into a cognitive–affective theory of learning with media. Likely theories for such an integrated model are Mayer's (2005) cognitive theory of multimedia learning and Pekrun's (2000) control-value theory of achievement emotions. As a first step, such an integration would include emotions as a construct affecting the cognitive processes of multimedia learning. As a next step, constructs that might be mediators of this relationship of affect and cognitive processing should be considered, such as learners' motivation and invested mental effort (Goetz et al., 2006; Pekrun, 2000; Plass et al., 2010).

An immediate contribution of Pekrun's (2000) theory to an understanding of the role of affect in multimedia learning stems from the *activation* dimension of emotion (Pekrun, 1992; Russell, 2003). The inconsistent effects of positive emotions on learning found in the research reviewed above may be due to the fact that few of these studies considered whether the emotions observed were activating or deactivating. One of the most important factors impacting this activation dimension is the way in which emotions were induced. Following Linnenbrink and Pintrich's (2002b) suggestion to consider inducing positive emotions through environmental factors, we next discuss two different approaches to the induction of positive emotions that were used in the present study.

Two Methods of Inducing Positive Emotions

An important consideration for our study on the impact of positive emotion on multimedia learning is the way in which emotions will be induced. Previous experimental work usually induced positive emotions using procedures such as viewing films or giving a free gift before the task (e.g., Isen et al., 1987). However, there are limitations when applying these methods in a multimedia learning environment. Most important, it is unclear what duration an emotional state that is induced before a learning task will have. Lab research on emotions often used short tasks that are typically completed within 5–10 min after the emotion state has been induced, which is shorter than a typical learning task in multimedia environments. Furthermore, if the learning process impacts the users' emotional state, it is uncertain as to how long the learner can maintain the initial emotional state as learning proceeds. In addition, it is of limited practical relevance for educators in schools that small gifts, given before the learning task, may enhance learning.

An alternative approach is to induce emotions through the multimedia learning environment itself. Various studies of multimedia learning have implied that different aesthetic designs can induce emotions and that these emotions affect users' performance and cognitive process (Harp & Mayer, 1997; Mayer & Moreno, 1998; North & Hargreaves, 1999; Szabo & Kanuka, 1998; Tractinsky, Katz, & Ikar, 2000; Wolfson & Case, 2000). In addition, users' positive perceptions about learning in multimedia environments suggest that positive emotions were produced by the design of various multimedia elements, such as the visual design, design layout, color, and sound (Tractinsky et al., 2000; Wolfson & Case, 2000). Although design principles have been proposed that improve the appeal of design on a visceral level (Lidwell, Holden, & Butler, 2003; Norman, 2004), such principles require a designer's artistic sense and have not been employed along with direct measures of positive emotions. It is therefore desirable to use a set of design principles for the induction of positive emotion through the learning environment that is theory-based and empirically validated.

Our approach to induce positive emotions in multimedia learning therefore uses manipulations of the design of the environment that do not add significant amounts of new information to the material. To that end, we use established effects that have been empirically validated in their impact on learners' positive emotions. These effects include the use of specific color combinations and of specific visual shapes, and we refer to the combined application of these visual design effects as *positive emotional design*.

Color Combination

Various studies showed that people's feelings are affected by colors, and colors can generate positive feelings and arousals of emotions, such as pleasure and excitement (e.g., Berlyne, 1970; Tucker, 1987). Warm colors elicit greater feelings of arousal than do cold colors (Bellizzi & Hite, 1992; Wolfson & Case, 2000). Results from research on advertising indicated that higher levels of chroma (saturation) and value (degree of darkness or lightness of the color) influence feelings of excitement and relaxation, and these feelings, in turn, create positive attitude toward the materials (Gorn, Chattopadhyay, Yi, & Dahl, 1997; Thompson, Palacios, & Varela, 1992). There is indication that the color red may impair performance in high-stakes tests (Elliot, Maier, Moller, Friedman, & Meinhardt, 2007). Although our learning environment does not constitute such an achievement task, we largely avoided the use of the color red. Therefore, the positive emotional design treatment used saturated and analogous bright warm color combinations including yellow, orange, and pink for the design of the multimedia materials.

Visual Shapes

A well-established effect describing the impact of visual shapes on emotion is the *baby-face bias*. The baby-face bias describes how people or things with round features, large eyes, small noses, and short chins are perceived as baby-like (Lorenz & Generale, 1950). In contrast to shapes with sharp edges, these round features evoke baby-like personality attributes, such as innocence, honesty, and helplessness, which induce positive affect in the learner. Similar effects have been reported in research on *anthropomorphism*, which studies the attribution of uniquely human characteristics and qualities to nonhuman beings, inanimate objects, or natural or supernatural phenomena (Dehn & van Mulken, 2000; Disalvo & Gemperle, 2007; Hongpaisanwiwat & Lewis, 2003; Reeves, & Nass, 1996). The positive emotional design treatment therefore uses illustrations and characters with round shapes instead of square shapes.

In the present study, we ask whether positive emotions in multimedia learning environments facilitate or suppress learning. In particular, we are interested in how the *internal* induction of positive emotions (induction *during* learning, through the positive emotional design of learning materials) would affect learning outcomes, cognitive load, and motivation compared with an *external* induction of positive emotions (induction *before* a learning task, through an emotion induction procedure). We were also interested in learners' perception of their learning achievement and level of satisfaction with their learning experience.

Method

Participants and Design

The participants were 118 students who were enrolled at a large private university in the northeastern United States. There were 49 male and 79 female participants, and all of them were over 18 years old (M = 24.9, SD = 6.4). Each participant was compensated $10 for his or her participation. Participants were randomly assigned to one of four treatment conditions, which were created by two design factors with two levels each. These factors were the *external* induction of positive emotions by means of a self-referencing mood-induction procedure (positive [PE] or neutral [NE] emotions) and the *internal* induction of positive emotions by means of the emotional design of the learning materials (positive [PD] or neutral [ND] design). As a result, the control group (NEND group) received the neutral mood-induction procedure (NE) and the material with neutral design (ND). The PEPD group received the positive mood-induction procedure (PE) and material with positive emotional design (PD). The PEND group received the positive mood-induction procedure (PE) and the material with neutral design (ND). The NEPD group received a neutral mood procedure (NE) and the material with positive emotional design (PD).

Materials and Apparatus

Emotion-induction procedure. To induce positive or neutral emotions in the participants, a self-referencing mood-induction procedure, developed by Seibert and Ellis (1991a), was used. This procedure was designed for use in laboratory settings and has been successfully used for induction of emotions in prior research on emotion and cognition with college students (Seibert & Ellis, 1991b). Of the three emotional states the procedure can be used to induce (happy, sad, and neutral), the present study used only the *happy* and the *neutral* mood-induction procedures. Each procedure involves reading 25 statements in a predetermined sequence; the program provided tones in 10-s intervals as signal when to advance to the next statement. In the neutral mood-induction procedure, participants were instructed to read each statement to themselves, then read it out loud and to advance to the next statement when they heard a tone. Sample items from the *neutral* emotion-induction procedure are, “There are sixty minutes in one hour” and “Apples are harvested in the Fall.” In the positive emotion-induction procedure, participants were instructed to read each statement to themselves and then read it out loud. They were told that these statements represented an emotional state and asked to feel and experience each statement as if it applied to them. They were instructed to advance to the next statement when they heard a tone. Sample items from the *happy* emotion-induction procedure are, “It doesn’t get any better than this” and “It’s great to be alive!” Each of these two procedures was presented on a computer screen using a computer program developed in Adobe Flash (Professional Version 8).

Design of learning material. A computer-based lesson covering the topic “how immunization works” was used as multimedia learning material. The first author developed this multimedia program using Flash animation and HTML. The program consisted of six sections, entitled “Infection and Disease,” “Immune System,” “How the Immune System Works,” “Immunization,” “Active Immunization,” and “Passive Immunization.” The content was presented as animation with some integrated labels and a narration, which is the recommended form of integrating text and animation, according to the well-established *modality principle* (Mayer, 2005). Three instructional design professionals reviewed the content and instructional design of the materials. To manipulate affect, two different versions of emotional design were used. The *neutral emotional design* (NE) was developed in monochromatic grayscale and with rectangular shapes. The *positive emotional design* (PD) applied the color and shape effects discussed above to induce positive emotions without changing the learning content of the materials (see Figure 1).

In particular, the positive emotional design treatment used saturated and analogous bright warm color combinations including yellow, orange, and pink for the design of the animation and visual design elements and round shapes, instead of square shapes, for illustrations and characters related to the content. These manipulations were chosen because their emotional impact had been established in previous empirical research and because they allowed for the design of a variant of the treatment that did not add any new learning content that would confound the results.

To make sure that changes to the visual design only affected aspects of the color and shape of the represented information, the positive and the neutral design materials both had the same amount

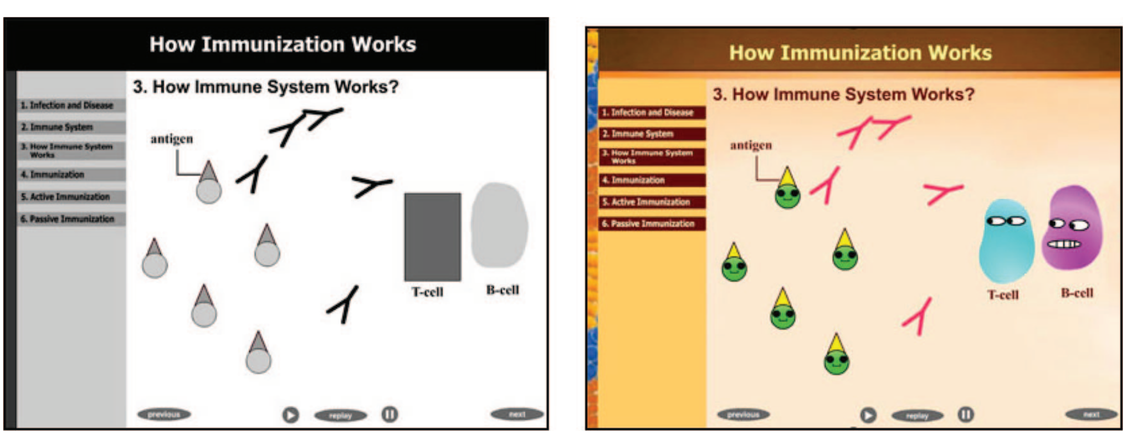

Figure 1. Screen shots of multimedia learning materials: neutral emotional design (left) and positive emotional design (right).

of learning content, user control options, and duration and applied the same multimedia learning design principles (Mayer, 2005).

Measures

As a manipulation check of emotion induction, the Positive Affect Scale (PAS) from the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1998) was used. The PAS asks respondents to indicate the degree to which they experience 10 different feelings related to positive affect (interested, excited, strong, enthusiastic, proud, alert, inspired, determined, attentive, active), using a 5-point Likert-type scale ranging from 1 (*very slightly or not at all*) to 5 (*very much*; coefficient $\alpha = .84$). The total score for each participant was obtained by adding the 10 responses. The subscales have a high internal consistency (coefficient $\alpha = .89$ for PA, .85 for NA) and are independent of one another when used to assess current, past, or general mood (Crawford & Henry, 2004).

Prior knowledge was assessed using a seven-item self-report checklist in which learners indicated their level of knowledge of the topic of the learning material, immunization. Participants received one point for each item that they reported, which span from "I can explain what antibodies are" to "I can explain what phagocytes are." The total score for each participant was obtained by adding points from all seven items.

To assess the learning outcome (performance) of the multimedia instruction, *comprehension* and *transfer* tests were administered. The comprehension test measured learners' understanding of key concepts of the materials and was composed of 15 multiple-choice questions. For example, we asked, "Which cells are producing antibodies? (a) Macrophages, (b) Phagocytes, (c) B cells, (d) T cells, or (e) Antibodies"; "Choose the right words for A & B: 'Immunity results from the production of (A) to a given (B).' (A) Antigens/antibodies/B cell/T cell, or (B) Antibody/antigen"; and "Which cells are recognizing antigens and activate B cells? (a) Antibodies, (b) Macrophages, (c) T cells, (d) antigens, or (e) phagocytes." Participants received one point for each question they answered correctly.

The transfer test measured participants' ability to apply the concepts learned to solve problems and consisted of four questions. For example, we asked, "HIV, Human Immunodeficiency Virus, destroys T cells in immune system. Explain the consequences of this infection by describing the role of T cells in the process of immune system" and "Explain why a person who has already been infected with chicken pox does not need the vaccine for future infection of chicken pox." Participants received one point for each acceptable answer on each of the four problem-solving transfer sheets and the total score on each of the tests was obtained by adding points received for the individual items on the test. A second rater scored all answers, and differences in scores among the raters were discussed until they were resolved.

To measure the *cognitive load* experienced by learners, participants completed a 9-point Likert-type Cognitive Load Subjective Experience Questionnaire targeting invested mental effort (germane cognitive load), asking, "How much mental effort did you invest in studying the previous material?" (Paas, 1992). Participants also completed a 7-point Likert-type survey on their perceptions of task difficulty (extraneous cognitive load), asking, "How easy or difficult was the material to understand?" (Kalyuga, Chandler, & Sweller, 2000).

One 7-point Likert-type question was used to measure users' *satisfaction with their learning experience* of using the computer-based multimedia lesson, asking, "How much you did like the 'immunization' learning material?" In addition, one 7-point Likert-type question was asked to measure users' *perception about their learning achievement,* asking, "How well do you think you did in the preceding tests?"

Learner's *motivation* was measured using a self-report instrument consisting of an eight-item questionnaire with 7-point Likert-type items developed by Isen and Reeve (2006) for measuring intrinsic motivation. Participants were asked to rate how interesting and enjoyable they found the experience (1 = *strongly disagree*, 7 = *strongly agree*; e.g., "It is enjoyable"). One point was assigned for each item, and each participant's total score, obtained by adding responses from the eight items, was used for the data analysis.

Procedure

The entire procedure, including the learning material and responses to the questionnaires, was administered through a computer system. The questionnaires were built in Survey Monkey (http://www.surveymonkey.com), a web-based survey program, and linked with other materials in the order of the study procedure. Each participant was individually tested in a laboratory setting. Participants were randomly assigned to one of the four groups, and each participant worked in an individual session for about 1 hr.

After receiving a brief overview of the study procedure, each participant was seated in front of a computer. The participants received an introduction to the computer-based procedures and were asked to follow the instruction on the screen. After spending approximately 5 min completing the background questionnaires soliciting demographic information, 25 statements of either the positive or the neutral mood induction were displayed in 10-s intervals on an individual computer monitor. Participants were instructed to first read each of the statements to themselves and then read the statements aloud. This procedure lasted for approximately 6 min. To check whether the mood-induction procedure affected participants' emotions, the participants then completed the first positive affect schedule (PAS1). Next, the multimedia instruction with either neutral or positive design of the material was presented to the participants on the computer. They were told that they would be tested on the content of the material after the treatment. Participants were instructed to study the learning material for 15 min. After completing their learning task, participants were given approximately 25 min to complete the questionnaires of mental effort and perceived task difficulty, the second PAS (PAS2), and self-report measure of intrinsic motivation, learning performance (comprehension and transfer tests), perception of achievement, and satisfaction with their learning experience. Participants were then thanked and debriefed. During the entire procedure, we followed American Psychological Association guidelines for the ethical treatment of human research participants.

Results

The aim of the present study was to investigate whether positive emotions in multimedia learning environments facilitated or suppressed learning and whether such emotions can be effectively induced using materials designed following emotional design principles. We used two controls groups in which positive and neutral emotions were induced using an established procedure of mood induction.

After initial preliminary analyses, we conducted a manipulation check to verify that the mood-induction procedure had the desired effect of inducing positive versus neutral emotions. To answer our research questions, we then compared the level of change of emotions as result of the treatment. We next analyzed learning outcomes and experienced cognitive load for the four treatment groups. We then compared the results for motivation, satisfaction with the learning experience, and perception of achievement of the treatment groups. Last, we explored motivation and mental effort as mediators of the effect of positive emotions on learning outcomes.

Preliminary Analyses

Descriptive statistics for the independent and dependent variables involved in analyses are presented in Table 1. The alpha reliabilities for those measures with multiple items were as follows: PAS1, $\alpha = .94$; PAS2, $\alpha = .94$; comprehension, $\alpha = .74$; transfer, $\alpha = .85$; and motivation, $\alpha = .95$. We conducted bivariate correlational analyses (see Table 1) between the scores of independent and dependent variables to assess the need for multivariate statistical approaches. These preliminary analyses revealed a moderate association ($r = .57$, $p < .001$) between the learning outcomes, comprehension, and transfer. Also of interest were the moderate associations between motivation, satisfaction, and perception of learning, which ranged from $r = .38$ to $.68$ ($p < .001$). These associations indicate a need for multivariate approaches when investigating the effect of positive emotions on learning and attitudes about learning (Tabachnick & Fidell, 2007). Also of interest is the increase in the magnitude of correlations evident between the transfer scores and the PAS before ($r = .19$, $p = .040$) and after ($r = .25$, $p = .007$) the learning materials and emotional manipulation. This increase in association suggests that that there may be a relationship between changes in affect in the learning environment and transfer test performance.

Preliminary analyses were conducted to investigate possible gender differences in response to emotional manipulations and performance on outcome measures. Men and women differed significantly in performance on the second administration of the PAS, $t(116) = 2.17$, $p = .032$ ($M = 32.35$, $SD = 7.48$ for men, $M = 28.67$, $SD = 9.29$ for women). Accordingly, we controlled for gender in the subsequent analyses involving the PAS2. No gender differences were evident in other measures.

Manipulation Check of Mood Induction

Evidence of positive mood induction. An indication of a successful mood induction would be a significantly more positive emotional state of learners in the positive mood-induction groups (PEND and PEPD), compared with learners in the neutral emotion groups (NEND and NEPD) before the learning treatment began. An independent-samples *t* test on the scores of the first PAS test by mood-induction condition (neutral, positive) revealed that after the mood induction, the positive emotion groups ($M = 35.3$, $SD = 9.0$) rated their emotions significantly more positively than the neutral emotion groups ($M = 24.9$, $SD = 7.8$), $t(116) = 6.64$, $p < .001$, Cohen's $d = 1.24$. This suggests that the mood induction was successful, and the intended neutral versus positive emotional states were induced before the learning treatment.

Evidence of positive emotional design. An indication of a successful positive emotional design would be a significant effect of group on the change in affect ratings over the course of the learning treatment. An analysis of covariance with repeated measures (RM-ANCOVA) with treatment as between-subjects factor and PAS scores on the first and second PAS tests as repeated-measures variable, controlling for gender, indicated main effects for group, $F(3, 113) = 14.46$, $p < .001$, and gender, $F(1, 113) = 4.22$, $p = .042$. These main effects were qualified by an interaction effect between the change in PAS scores and group, $F(3, 113) = 4.37$, $p = .006$. No interaction effects between gender and group were evident. Follow-up analyses revealed that the PAS scores of two groups changed significantly over the course of the treatment (see Figure 2). These two groups were PEND (positive emotions and neutral design group), $F(1, 28) = 4.981$, $p = .034$, partial $\eta^2 = .15$, for which positive emotions decreased significantly from PAS1 ($M = 36.7$, $SD = 8.7$) to the PAS2 ($M = 33.2$, $SD = 8.2$), and NEPD (neutral emotions and positive design group), $F(1, 28) = 6.733$, $p = .015$, $\eta^2 = .19$, for which positive emotions increased significantly from PAS1 ($M = 26.9$, $SD = 6.9$) to PAS2

Table 1
Means, Standard Deviation, and Bivariate Correlations Between Measures

Measure	*M*	*SD*	2	3	4	5	6	7	8	9	10
1. Prior knowledge	2.37	1.60	.01	.19*	.19*	.10	−.01	−.35**	.21*	.25**	.12
2. PAS1	30.25	9.98	—	.62**	−.10	.19*	.42**	.01	.34**	.33**	.25**
3. PAS2	29.92	8.86		—	.06	.25**	.35**	−.14	.56**	.49**	.39**
4. Comprehension	11.53	2.93			—	.57**	.10	.23*	.25**	.16	.35**
5. Transfer	11.55	5.53				—	.33**	−.20*	.35**	.30**	.56**
6. Mental effort	6.07	1.78					—	.07	.32**	.45**	.36**
7. Perceived difficulty	3.13	1.05						—	−.25**	−.09	−.19*
8. Motivation	34.26	9.59							—	.67**	.38**
9. Satisfaction	5.04	1.37								—	.47**
10. Perception	4.47	1.43									—

Note. PAS = positive affect schedule.
* $p < .05$. ** $p < .01$.

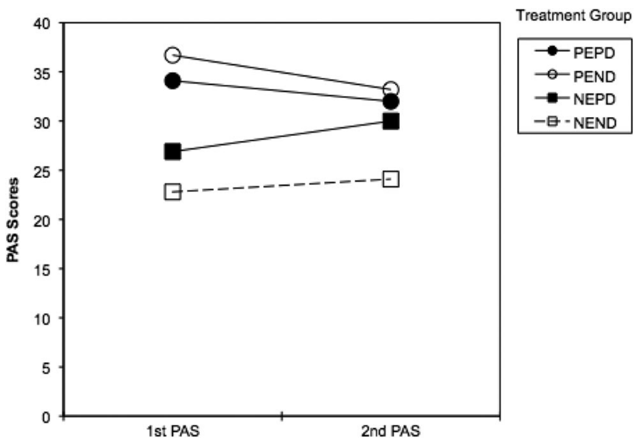

Figure 2. Positive affect schedule (PAS) scores by treatment conditions before learning (1st PAS) and after the learning (2nd PAS). NEND = neutral mood-induction procedure and neutral emotional design of material; PEPD = positive mood-induction procedure and positive emotional design of material; PEND = positive mood-induction procedure and neutral emotional design of material; NEPD = neutral mood procedure and positive emotional design of material.

($M = 30.0$, $SD = 8.0$). Post hoc tests (Tukey honestly significant difference) revealed significant differences between the group NEND and two of the three other groups: PEPD ($p < .001$) and PEND ($p < .001$). The difference between the NEND group and the NEPD was significant at the $p = .056$ level. These findings suggest that groups PEPD, PEND, and NEPD had more positive emotions than the control group NEND, which stayed in a neutral emotional state.

These results indicate that the positive emotions induced externally, before the learning task, tended to decrease during learning when the emotional design was neutral. However, the internal induction of positive emotion, through the positive emotional design of the learning material, helped maintain the positive emotions and even increased the positive emotions during learning for those learners who had neutral emotions at the beginning of the learning task. These findings support our hypothesis that positive emotions can be induced through the learning material by applying emotional design principles.

Learning Outcomes

We were interested in how the *internal* induction of positive emotions (induction *during* learning, through the positive emotional design of learning materials) would affect learning outcomes compared with an *external* induction of positive emotions (induction *before* a learning task, through a mood-induction procedure).

We first determined whether there were differences in self-judged prior knowledge among the four treatment groups. A one-way analysis of variance (ANOVA), with prior knowledge as dependent measure and treatment as factor, did not reveal statistically significant differences, $F(1, 114) = 1.89$, $p = .135$. Prior knowledge was therefore not included in further analyses.

Given the moderate correlation between comprehension and transfer measures, a multivariate analysis of variance was conducted to determine the effect of the two different manipulations on learning outcomes. We computed a 2 $\times$ 2 multivariate analysis of covariance with emotional design (neutral, positive) and mood induction (neutral positive) as between-subjects factors and comprehension and transfer scores as dependent measures, controlling for mental effort (germane cognitive load). The analysis revealed a significant main effect for mental effort, $F(2, 112) = 5.66$, $p = .005$, $\eta^2 = .09$, emotional design, $F(2, 112) = 8.22$, $p < .001$, $\eta^2 = .13$, and a main effect for mood induction, $F(2, 112) = 3.72$, $p = .027$, $\eta^2 = .06$. There was no interaction effect for the two factors, $F(2, 112) = 0.86$, $p = .428$. Follow-up ANCOVAs for each outcome measure are reported below.

Comprehension. Means and standard deviations of the comprehension scores of the four treatment groups are reported in Table 2. To further investigate the effect of the two different manipulations of emotions on learners' comprehension of the multimedia materials, we computed a 2 $\times$ 2 ANCOVA with emotional design (neutral, positive) and mood induction (neutral, positive) as between-subjects factors and comprehension test as dependent measure, controlling for mental effort. The analysis revealed a significant main effect for emotional design, $F(1, 113) = 11.56$, $MSE = 90.77$, $p = .001$, $\eta^2 = .09$. No main effects

Table 2
Mean Scores and Standard Deviations for Each Group on Comprehension, Transfer, Mental Effort, Perceived Difficulty, Satisfaction, Perception, and Motivation

	NEND (controls)		PEPD		PEND		NEPD	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Comprehension	10.4	3.0	12.9	1.9	10.8	2.9	11.8	3.4
Transfer	7.9	4.9	14.5	5.3	11.7	5.4	11.7	4.6
Mental effort	5.6	1.9	6.4	1.5	6.6	1.9	5.7	1.6
Difficulty	3.4	1.2	3.0	1.0	3.2	1.3	3.0	0.7
Satisfaction	4.4	1.3	5.4	1.3	5.3	1.2	5.0	1.5
Perception	3.8	1.4	5.1	1.5	4.5	1.3	4.5	1.4
Motivation	28.9	10.0	36.8	8.4	35.0	9.2	35.0	9.2

Note. NEND = neutral mood-induction procedure and neutral emotional design of material; PEPD = positive mood-induction procedure and positive emotional design of material; PEND = positive mood-induction procedure and neutral emotional design of material; NEPD = neutral mood-induction procedure and positive emotional design of material.

were found for mental effort, $F(1, 113) = 0.63$, $p = .431$, or mood induction, $F(1, 113) = 1.48$, $p = .226$, and there was no interaction effect for the two factors, $F(1, 113) = 0.60$, $p = .439$. As predicted, learners whose positive emotional state was induced internally, through the emotional design of the learning materials, performed better on comprehension test than controls (neutral design, $M = 10.61$, $SD = 2.88$; positive design, $M = 12.39$, $SD = 2.74$; $d = 0.63$). The effect on comprehension test performance was not found for the external induction of positive emotions through the mood-induction procedure (neutral induction, $M = 11.12$, $SD = 2.20$; positive induction, $M = 11.92$, $SD = 2.64$).

Transfer. Means and standard deviations of the transfer scores of the four treatment groups are reported in Table 2. To determine the effect of the two different manipulations of emotions on learners' transfer of the multimedia materials, we computed a 2×2 ANCOVA with emotional design (neutral, positive) and mood induction (neutral, positive) as between-subjects factors and transfer test as dependent measure, controlling for mental effort. The analysis revealed significant main effects for mental effort, $F(1, 113) = 10.32$, $MSE = 245.02$, $p = .002$, $\eta^2 = .08$; the external mood induction, $F(1, 113) = 7.44$, $MSE = 176.64$, $p = .007$, $\eta^2 = .06$; and the internal emotional design, $F(1, 113) = 13.64$, $MSE = 323.96$, $p < .001$, $\eta^2 = .11$. Learners whose positive emotional state was induced externally, through the mood-induction procedure, performed better on transfer test than controls (neutral induction, $M = 9.84$, $SD = 5.08$; positive induction, $M = 13.15$, $SD = 5.50$; $d = 0.62$). Likewise, learners whose positive emotional state was induced internally, through the design of the learning materials, performed better on transfer test than controls (neutral design, $M = 9.82$, $SD = 5.46$; positive design, $M = 13.16$, $SD = 5.13$; $d = 0.63$). There was no interaction effect for the two factors, $F(1, 113) = 0.24$, $p = .623$. These results showed that both internal and external induction of positive emotions increased learners' performance on the transfer test.

In summary, these findings show that, controlling for the germane load invested by the learner, the internal induction of positive emotions through emotional design of the materials was able to increase comprehension and transfer, whereas the external induction of positive emotions through a mood-induction procedure enhanced transfer but not comprehension.

Cognitive Load

Cognitive load was next explored as an outcome variable. We measured two different types of cognitive load: invested mental effort (germane load) and perceived difficulty of the learning task (extraneous load). Means and standard deviations of these variables for the four treatment groups are reported in Table 2. For each of these measures, we computed a 2×2 ANOVA with emotional design (neutral, positive) and mood induction (neutral, positive) as between-subjects factors.

The ANOVA computed on *mental effort* scores revealed a main effect for the external mood induction, $F(3, 114) = 7.52$, $MSE = 22.85$, $p = .007$, $\eta^2 = .06$. Learners who received a positive mood induction reported a higher amount of invested mental effort ($M = 6.49$, $SD = 1.71$) than learners who received a neutral mood induction ($M = 5.61$, $SD = 1.75$; $d = 0.51$). There was no main effect for emotional design (neutral design, $M = 6.07$, $SD = 1.98$; positive design, $M = 6.07$, $SD = 1.58$), nor an interaction effect of the two factors.

The ANOVA computed on *task difficulty* scores revealed a marginally significant main effect for emotional design, $F(3, 114) = 3.62$, $MSE = 3.95$, $p = .060$, $\eta^2 = .03$. Learners receiving the internal induction of positive emotions through emotional design rated the difficulty of the learning material as lower ($M = 2.95$, $SD = 0.84$) than learners in the neutral emotional design condition ($M = 3.32$, $SD = 1.21$; $d = 0.36$). There was no main effect for mood induction (neutral induction, $M = 3.19$, $SD = 0.97$; positive induction, $M = 3.07$, $SD = 1.12$), nor an interaction effect of the two factors.

In summary, positive emotions induced before the multimedia learning task through mood induction significantly increased the amount of reported mental effort learners invested during learning. Positive emotions induced during the learning task through emotional design, on the other hand, reduced the perceived difficulty of the learning task.

Learners' Motivation, Perception of Learning Achievement, and Satisfaction With Learning

Means and standard deviations of scores for motivation, learners' perception of their learning experience, and learners' satisfaction for the four treatment groups are reported in Table 2. Given the moderate correlations between motivation, perception of achievement, and satisfaction, a multivariate analysis of variance (MANOVA) was conducted to determine the effect of the two different manipulations on learning outcomes. We computed a 2×2 MANOVA with emotional design (neutral, positive) and mood induction (neutral positive) as between-subjects factors and motivation, perception of achievement, and satisfaction as dependent measures. The analysis revealed a significant main effect for Mood Induction, $F(3, 112) = 3.53$, $p = .017$, $\eta^2 = .09$. The effect for emotional design, $F(3, 112) = 2.50$, $p = .064$, $\eta^2 = .06$, was marginally significant. For each of these measures, we computed a 2×2 ANOVA with emotional design (neutral, positive) and mood induction (neutral, positive) as between-subjects factors.

The ANOVA computed on the *satisfaction* scores revealed a significant main effect for mood induction, $F(3, 114) = 6.56$, $MSE = 11.58$, $p = .012$, $\eta^2 = .05$. Learners receiving the positive mood-induction procedure reported a higher satisfaction with their learning experience ($M = 5.34$, $SD = 1.25$) than learners receiving the neutral mood induction ($M = 4.72$, $SD = 1.42$; $d = 0.46$). No differences were found for emotional design (neutral, $M = 4.84$, $SD = 1.31$; positive, $M = 5.23$, $SD = 1.41$), and there was no interaction effect for the two factors.

The ANOVA computed on learners *perception of learning achievement* scores revealed a significant main effect for mood induction, $F(3, 114) = 7.06$, $MSE = 13.32$, $p = .009$, $\eta^2 = .06$, and for emotional design, $F(3, 114) = 5.69$, $MSE = 10.73$, $p = .019$, $\eta^2 = .05$. Learners receiving the positive mood-induction procedure reported a higher perception of their learning achievement ($M = 4.80$, $SD = 1.38$) than learners receiving the neutral mood induction ($M = 4.12$, $SD = 1.40$; $d = 0.46$). Likewise, learners whose positive emotional state was induced internally, through the design of the learning materials, reported a higher perception of their learning achievement than controls (neutral design, $M = 4.84$, $SD = 1.31$; positive design, $M = 5.23$, $SD =$

1.41; d = 0.29). These results indicate that both methods of inducing positive emotions increased learners' perception of their learning achievement.

The ANOVA computed on the *motivation* scores revealed a significant main effect for the external mood induction, $F(1, 114) = 6.54$, $MSE = 554.72$, $p = .012$, $\eta^2 = .05$, and a significant main effect for emotional design, $F(1, 114) = 4.20$, $MSE = 356.30$, $p = .043$, $\eta^2 = .04$. Learners receiving the positive mood-induction procedure reported a higher motivation (M = 36.34, SD = 8.75) than learners receiving the neutral mood induction (M = 32.04, SD = 10.01; d = 0.46). Likewise, learners whose positive emotional state was induced internally, through the design of the learning materials, reported a higher motivation than controls (neutral design, M = 32.47, SD = 10.17; positive design, M = 35.93, SD = 8.76; d = 0.36). This result indicates that both internal and external methods of inducing positive emotions increased intrinsic motivation during learning.

In summary, learners' satisfaction with the material was significantly increased only by positive emotions induced before the multimedia learning task through mood induction. Learners' motivation and their perception of their learning achievement were significantly increased by both positive mood induction and positive emotional design.

Effect of Positive Emotions as Mediated by Motivation and Mental Effort

To assess the extent to which motivation and mental effort might be mediating the relationship between positive emotions and learning outcomes in the two manipulations, we conducted series of mediation analyses using the procedure outlined by Preacher and Hayes (2004).

Comprehension. We first ran a series of regression analyses to explore the role of motivation in mediating comprehension outcomes. The mood-induction treatment failed to have a direct effect on comprehension (β = 0.79, p = .142), suggesting that there was not a unique effect of externally induced emotions to be mediated by motivation or mental effort. Positive emotions induced internally by the emotional design of the learning materials had a direct effect on comprehension (β = 1.78, $p < .001$) and a direct effect on motivation (β = 3.46, p = .049). The effect of motivation on comprehension, controlling for emotional design, was also significant (β = 0.06, p = .023). Last, there was a direct effect of emotional design on comprehension, controlling for motivation (β = 1.56, p = .003), suggesting partial mediation as defined by Baron and Kenny (1986). However, results from the Sobel test (Sobel, 1982), which was employed to directly assess whether the effect of emotional design on comprehension is significantly reduced upon the addition of motivation as a mediator to the model, suggested no mediation (z = 1.43, p = .153). An alternative approach to testing the significance of an indirect or mediated effect is bootstrapping, a nonparametric technique that employs resampling and re-estimating to create a sampling distribution of the indirect effect that defines confidence intervals (Preacher & Hayes, 2004). Using 1,000 bootstrap resamples, the 95% confidence interval for the indirect effect of the mediator was –.04 to .61; given that this interval includes zero, the indirect effect does not differ significantly from zero. We can therefore conclude that the addition of motivation does not significantly reduce the direct effect of emotional design on comprehension. Therefore, motivation was not found to mediate the effect of internally induced positive emotions on comprehension.

We next explored the role of mental effort in mediating the effect of emotional design on comprehension. As previously established, positive emotions in the emotional design treatment had direct effect on comprehension (β = 1.78, $p < .001$). Emotional design did not have a direct effect on mental effort (β = –0.005, p = .989), nor was there an effect of mental effort on comprehension, controlling for emotional design, (β = 0.16, p = .268). The direct effect of emotional design on comprehension, controlling for motivation, remained the same (β = 1.78, $p < .001$), further suggesting no mediation by mental effort. The Sobel test (z = –.01, p = .992) and the bootstrap results (95% confidence interval [CI] = –.16 to .14) support the claim that the effect of emotional design on comprehension is not mediated by mental effort.

Transfer. Next we ran a series of regression analyses to explore the role of motivation and mental effort in mediating transfer outcomes in the two manipulations. Positive emotions in the mood-induction treatment had direct effect on transfer (β = 3.31 p = .001) and a direct effect on motivation (β = 4.31, p = .014). The effect of motivation on transfer, controlling for mood induction, was also significant (β = 0.17, $p < .001$). Last, there was a direct effect of mood induction on transfer, controlling for motivation (β = 2.56, p = .009), suggesting partial mediation, as defined by Baron and Kenny (1986). Results from the Sobel test, which assesses the indirect effect of motivation on the relationship between mood induction and transfer, also suggest mediation (z = 1.97, p = .049). The bootstrap results, using 1,000 bootstrap resamples, produce a 95% CI for the indirect effect of the mediator of 0.11 to 1.58, suggesting that the indirect effect of motivation on transfer is greater than zero. Therefore, motivation mediates the effect of externally induced positive emotions on transfer outcomes.

Internally induced positive emotions also had direct effect on transfer (β = 3.34, $p < .001$) and a direct effect on motivation (β = 3.46, p = .049). The effect of motivation on transfer, controlling for emotional design, was also significant (β = 0.18, $p < .001$). Last, there was also a direct effect of emotional design on transfer, controlling for motivation (β = 2.72, p = .005), suggesting partial mediation as defined by Baron and Kenny (1986). However, results from the Sobel test suggest no mediation (z = 1.69, p = .092). The bootstrap results, using 1,000 bootstrap resamples, produce a 95% CI for the indirect effect of the mediator of –0.006 to 1.51. Given that this interval includes zero, we can conclude that the addition of motivation does not significantly reduce the direct effect of emotional design on transfer. Therefore, motivation was *not* found to mediate the effect of emotions induced internally on transfer outcomes.

Finally, we ran a series of regression analyses to explore the role of mental effort in mediating transfer outcomes in the two manipulations. Externally induced positive emotions in the mood-induction treatment had a direct effect on transfer (β = 3.31 p = .001) and a direct effect on mental effort (β = 0.88, p = .007). The effect of mental effort on transfer, controlling for mood induction, was also significant (β = 0.84, p = .003). Last, there was a direct effect of mood induction on transfer, controlling for mental effort (β = 2.57, p = .009), suggesting partial mediation, as defined by Baron and Kenny (1986). Results from the Sobel test, which assesses the indirect effect of mental effort on the relationship between external induction and transfer, also suggest mediation ($z = 1.99$, $p = .047$). The bootstrap results, using 1,000 bootstrap resamples, produce a 95% CI for the indirect effect of the mediator of 0.10 to 1.83, suggesting that the indirect effect of mental effort on transfer is greater than zero. Therefore, mental effort was found to mediate the effect of externally induced positive emotions on transfer outcomes.

As discussed above, positive emotions in the emotional design treatment had a direct effect on transfer ($\beta = 3.34$, $p < .001$). However, emotional design did not have a direct effect on mental effort ($\beta = -0.005$, $p = .989$). There was an effect of mental effort on transfer, controlling for emotional design, ($\beta = 1.02$, $p < .001$). The direct effect of emotional design on transfer, controlling for mental effort, remained the same ($\beta = 3.34$, $p < .001$), suggesting no mediation by mental effort. The Sobel test ($z = -0.01$, $p = .989$) and the bootstrap results (95% CI $= -0.72$ to 0.68) support the claim that the effect of emotions induced by design on transfer is *not* mediated by mental effort.

In summary, the results from mediation analyses suggest that the effect of external induction of positive emotions on transfer outcomes was mediated by both motivation and mental effort. In contrast, these processes do not mediate the effect of internal induction of positive emotions through design on comprehension and transfer. The effect of positive emotions through design features seems to impact learning outcomes directly, as opposed to externally induced emotions, the effect of which is partially mediated by motivation and mental effort.

Discussion

Our results indicate that applying emotional design principles to learning materials can induce positive emotions and that positive emotions in multimedia-based learning facilitate cognitive processes and learning. We examined the effects of internally and externally induced positive emotions on learning performance, cognitive load, and other affective experiences. We also examined possible mediating effects of motivation and cognitive load on the effect of emotion on comprehension and transfer.

Positive Emotional Design

Our data demonstrate that positive emotions can be induced through the quality of the design of the learning material. Several studies have suggested that positive emotions were produced by different designs of multimedia elements, such as visual design principles, design layout, color, and sound (e.g., Tractinsky et al., 2000; Wolfson & Case, 2000). The visual design principles, bright warm colors and baby-face-like shapes, were chosen because their emotional impact had been established in previous empirical research and because they can be implemented in the visual interface of most learning materials without adding any new learning content.

The positive emotional design that incorporated these principles maintained the positive emotional state and increased positive emotions of those learners who had a neutral emotional state in the beginning of the learning process. As expected, our study found that the effect of externally induced positive emotions significantly decreased toward the end of the learning. In contrast, the internal induction of positive emotions through the design of the learning materials maintained the positive emotional state until the end of the learning task. At the end of the learning task, learners in three of the four treatment groups were in a positive emotional state, and only the learners in the control group that received the neutral mood induction and neutral design of the materials remained in a neutral emotional state.

Learning Outcomes

Results showed that learners who studied the materials that were designed to induce positive emotions performed better on the comprehension test than learners who received the neutral design. In addition, inducing positive emotions externally or internally increased participants' performance on the transfer test. These results support the facilitator hypothesis that a positive emotional state enhances learning outcomes. Our findings are in line with previous work indicating that positive emotions can serve as effective retrieval cues for other positive materials in memory and influence cognitive organization by altering the context in which cognitive activity takes place (Isen & Daubman, 1984; Isen et al., 1978). The transfer findings in particular support the idea that positive emotions promote cognitive organization and creativity (Isen & Baron, 1991; Isen & Daubman, 1984; Isen et al., 1985, 1987). Our research helps to resolve the contradiction between the extraneous load hypothesis and the facilitator hypothesis: When positive emotions are induced through aesthetic design of key elements, rather than through extraneous means, they have a facilitating effect on learning.

The current findings also lend insight into the process by which externally and internally induced emotions impact learning. Results from mediation analyses indicate that emotions induced by emotional design of the learning materials, as suggested by Linnenbrink and Pintrich's (2002b), have a more direct impact on learning. In contrast, the influence of externally induced positive emotions is at least in part via motivation and mental effort. Our data show that design features inducing positive emotions have a more immediate and broader impact on learning, both in terms of comprehension of content and transfer of knowledge, relative to externally induced positive emotions.

Cognitive Load

Our results also showed that positive emotions before the learning task resulted in a higher learner-reported mental effort investment, or germane cognitive load. In addition, we found that emotions induced through a positive emotional design resulted in a lower reported task difficulty, or extraneous cognitive load. Our findings were therefore inconsistent with the extraneous load hypothesis, which would suggest that positive mood increases the load on working memory (Seibert & Ellis, 1991b). Furthermore, we did not find support for the notion that externally induced emotions result in increased perceived task difficulty (Seibert & Ellis, 1991a). We found that learners reported lower extraneous load in the positive emotional design condition, suggesting that our goal to enhance the emotional design of the material without adding extraneous cognitive demands was successful.

Motivation, Satisfaction, and Perception

Our results also showed that both externally and internally induced positive emotions increased intrinsic motivation during the learning, consistent with previous work (Erez & Isen, 2002; Isen & Reeve, 2006). It is interesting that the emotional design of the learning material increased the motivation without hurting the learning performance. This result is consistent with Park's (2006) finding that seductive graphics positively affected students' level of interest without hurting the learning performance.

This study also found that the positive emotions induced before the learning increased the satisfaction toward the same learning material and experience. This result is consistent with several previous studies that found that positive emotions are direct or indirect factors in changing people's affective experiences, such as attitude, judgment, evaluation, and satisfaction (Isen et al., 1978; Isen & Patrick, 1983; Petty, Schumann, Richman, & Strathman, 1993; Weiss & Nicholas, 1999). Furthermore, both external and internal methods of inducing positive emotions increased learners' perceptions of their own learning.

Limitations

As is the case for all empirical studies, there are some limitations to the generalizability of our findings. The limiting variables include the population used for this research, which included students at a highly selective university; the subject matter used, which focused on science learning; and the type of learning materials used, which consisted of a computer-based multimedia program with limited interactivity. Further research needs to investigate whether our findings can be applied to other populations, subject matter areas, and types of learning materials. The prior knowledge self-report measure does not provide the same insights as a prior knowledge test and therefore limits the claim that groups were truly equivalent after randomization. As we used a combination of established design principles to induce positive emotions, we cannot make claims as to the individual contributions of each of these methods; this will be the subject of our future research. Further, for this initial study on the effect of emotion on multimedia learning, we focused on the effect of positive emotion in general. Future research should investigate the effect of specific positive emotions on multimedia learning, both immediately and in a delayed test administration.

Conclusion

The results of this study provide initial evidence that positive emotions can facilitate learning and suggest that positive emotions be considered an important factor that should be incorporated into instructional design, especially for multimedia learning environments. This research has important theoretical as well as practical implications.

On the theoretical side, we were able to show that positive emotions not only affect cognition, as found in previous research, but that they also increase learning outcomes. In this study, the emotional design method we used did not increase the extraneous cognitive load induced by the learning materials and did not have any negative effect on learning performance and is therefore inconsistent with the extraneous load hypothesis (Ellis & Ashbrook, 1987; Oaksford et al., 1996; Seibert & Ellis, 1991a). The results of this study are consistent with previous studies supporting the facilitator hypothesis of positive emotions, suggesting that positive emotions facilitate long-term memory retrieval and working memory processes, including creative problem-solving skills (Erez & Isen, 2002; Isen & Baron, 1991; Isen et al., 1987; Isen & Patrick, 1983; Petty et al., 1993; Weiss & Nicholas, 1999). Also, we showed that the emotional design of the learning environments provides a more effective and longer lasting positive emotional state than mood-induction procedures administered before the treatment (Seibert & Ellis, 1991b). Furthermore, the emotional design of such environments seems to have a direct effect on learning, unique from processes of motivation and mental effort.

Most important, this study provided initial data in support of the development of a theory of multimedia learning that includes affect. Our findings show that such a cognitive–affective theory of learning with media should consider emotion induced by the design of the learning environment as a factor that directly affects learning outcomes, rather than being mediated by motivation or mental effort. This is in direct contrast to findings from lab research using external methods of inducing emotions (Isen et al., 1987).

On the practical side, this research provides empirical support for the need to consider emotional design effects in multimedia learning environments. Learners studying materials with the improved emotional design had better comprehensive and knowledge transfer, a more positive perception of and better motivation toward learning. The study provides instructional designers with methods to improve the emotional design of multimedia learning materials that can induce positive emotions without adding additional information that would distract learners from the educational content. Armed with this method for positive emotional design, instructional designers are in a position to enhance learning outcomes from multimedia learning environments.

References

Astleitner, H. (2000). Designing emotionally sound instruction: The FEASP-Approach. *Instructional Science, 28,* 169–198. doi:10.1023/A:1003893915778

Baron, R. M., & Kenny, D. A. (1986). The moderator–mediator variable distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Social Psychology, 51,* 1173–1182. doi:10.1037/0022-3514.51.6.1173

Bellizzi, R., & Hite, E. (1992). Environmental color, consumer feelings, and purchase likelihood. *Psychology and Marketing, 9,* 347–363. doi:10.1002/mar.4220090502

Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Perception & Psychophysics, 8,* 279–286. doi:10.3758/BF03212593

Burleson, W., Picard, R., Perlin, K., & Lippincott, J. (2004). A platform for affective agent research. In A. Paiva, R. Aylett, & S. Marsella (Eds.), *Proceedings of the AAMAS workshop on empathetic agents*. New York, NY: Columbia University Press.

Craig, S., Graesser, A., Sullins, J., & Gholson, B. (2004). Affect and learning: An exploratory look into the role of affect in learning with AutoTutor. *Learning, Media and Technology, 29,* 241–250. doi:10.1080/1358165042000283101

Crawford, J. R., & Henry, J. D. (2004). The Positive and Negative Affect Schedule (PANAS): Construct validity, measurement properties and normative data in a large non-clinical sample. *British Journal of Clinical Psychology, 43,* 245–265.

Dehn, D. M., & Van Mulken, S. (2000). The impact of animated interface agents: A review of empirical research. *International Journal of Human-Computer Studies, 52,* 1–22. doi:10.1006/ijhc.1999.0325

Desmet, P. (2002). *Designing emotions.* Doctoral dissertation, Delft University of Technology, Delft, the Netherlands.

Disalvo, C., & Gemperle, F. (2007, December 20). *From seduction to fulfillment: The use of anthropomorphic form in design.* Retrieved from http://www.anthropomorphism.org/pdf/Seduction.pdf

D'Mello, S., & Graesser, A. C. (2010). Multimodal semi-automated affect detection from conversational cues, gross body language, and facial features. *User Modeling and User-Adapted Interaction, 20,* 147–187. doi:10.1007/s11257-010-9074-4

D'Mello, S., Lehman, B., Sullins, J., Daigle, R., Combs, R., Vogt, K., . . . Graesser, A. C. (2010). A time for emoting: When affect-sensitivity is and isn't effective at promoting deep learning. In J. Kay & V. Aleven (Eds.), *Proceedings of 10th International Conference on Intelligent Tutoring Systems* (pp. 245–254). Berlin/Heidelberg, Germany: Springer. doi:10.1007/978-3-642-13388-6_29

Efklides, A., Kourkoulou, A., Mitsiou, F., & Ziliaskopoulou, D. (2006). Metacognitive knowledge of effort, personality factors, and mood state: Their relationships with effort-related metacognitive experiences. *Metacognition and Learning, 1,* 33–49. doi:10.1007/s11409-006-6581-0

Elliot, A. J., Maier, M. A., Moller, A. C., Friedman, R., & Meinhardt, J. (2007). Color and psychological functioning: The effect of red on performance attainment. *Journal of Experimental Psychology: General, 136,* 154–168. doi:10.1037/0096-3445.136.1.154

Ellis, H. C., & Ashbrook, P. W. (1987). Resource allocation model of the effects of depressed mood states. In K. Fiedler & J. Forgas (Eds.), *Affect, cognition and social behaviour* (pp. 25–43). Toronto, Ontario, Canada: Hogrefe.

Ellis, H. C., Thomas, R. L., McFarland, A. D., & Lane, J. W. (1985). Emotional mood states and retrieval episodic memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 363–370. doi:10.1037/0278-7393.11.2.363

Ellis, H. C., Thomas, R. L., & Rodriguez, I. A. (1984). Emotional mood states and memory: Elaborative encoding, semantics processing, and cognitive effort. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 470–482. doi:10.1037/0278-7393.10.3.470

Erez, A., & Isen, A. M. (2002). The influence of positive affect on the components of expectancy motivation. *Journal of Applied Psychology, 87,* 1055–1067. doi:10.1037/0021-9010.87.6.1055

Frijda, N. H. (1993). Moods, emotion episodes, and emotions. In M. Lewis & J. M. Haviland (Eds.), *Handbook of emotions* (pp. 381–403). New York, NY: Guilford Press.

Goetz, T., Pekrun, R., Hall, N. C., & Haag, L. (2006). Academic emotions from a social-cognitive perspective: Antecedents and domain specificity of students' affect in the context of Latin instruction. *British Journal of Educational Psychology, 76,* 289–308. doi:10.1348/000709905X42860

Gorn, G. J., Chattopadhyay, A., Yi, T., & Dahl, D. W. (1997). Effects of color as an executional cue in advertising: They're in the shade. *Management Science, 43,* 1387–1400. doi:10.1287/mnsc.43.10.1387

Graesser, A. C., Chipman, P., Haynes, B. C., & Olney, A. (2005). AutoTutor: An intelligent tutoring system with mixed-initiative dialogue. *IEEE Transactions in Education, 48,* 612–618. doi:10.1109/TE.2005.856149

Harp, S. F., & Mayer, R. E. (1997). The role of interest in learning from scientific text and illustrations: On the distinction between emotional interest and cognitive interest. *Journal of Educational Psychology, 89,* 92–102. doi:10.1037/0022-0663.89.1.92

Harp, S. F., & Mayer, R. E. (1998). How seductive details do their damage: A theory of cognitive interest in science learning. *Journal of Educational Psychology, 90,* 414–434. doi:10.1037/0022-0663.90.3.414

Hongpaisanwiwat, C., & Lewis, M. (2003). Attentional effect of animated character. In M. Rauterberg, M. Menozzi, & J. Wesson (Eds.), *Proceedings of INTERACT'03* (pp. 423–430). Amsterdam, the Netherlands: IOS Press.

Isen, A. M., & Baron, R. A. (1991). Positive affect as a factor in organizational behavior. *Research in Organizational Behavior, 13,* 1–53.

Isen, A. M., & Daubman, K. A. (1984). The influence of affect on categorization. *Journal of Personality and Social Psychology, 47,* 1206–1217. doi:10.1037/0022-3514.47.6.1206

Isen, A. M., Daubman, K. A., & Nowicki, G. P. (1987). Positive affect facilitates creative problem solving. *Journal of Personality and Social Psychology, 52,* 1122–1131. doi:10.1037/0022-3514.52.6.1122

Isen, A. M., Johnson, M. M., Mertz, E., & Robinson, G. F. (1985). The influence of positive affect on the unusualness of word associations. *Journal of Personality and Social Psychology, 48,* 1413–1426. doi:10.1037/0022-3514.48.6.1413

Isen, A. M., & Patrick, R. (1983). The effect of positive feelings on risk-taking: When the chips are down. *Organizational Behavior & Human Performance, 31,* 194–202. doi:10.1016/0030-5073(83)90120-4

Isen, A. M., & Reeve, J. (2006). The influence of positive affect on intrinsic and extrinsic motivation: Facilitating enjoyment of play, responsible work behavior, and self-control. *Motivation and Emotion, 29,* 297–325. doi:10.1007/s11031-006-9019-8

Isen, A. M., Shalker, T. E., Clark, M., & Karp, L. (1978). Affect, accessibility of material in memory, and behavior: A cognitive loop? *Journal of Personality and Social Psychology, 36,* 1–12. doi:10.1037/0022-3514.36.1.1

Kalyuga, S. (2010). Schema acquisition and sources of cognitive load. In J. Plass, R. Moreno, & R. Brünken (Eds.), *Cognitive load theory* (pp. 48–64). New York, NY: Cambridge University Press.

Kalyuga, S., Chandler, P., & Sweller, J. (2000). Incorporating learner experience into the design of multimedia instruction. *Journal of Educational Psychology, 92,* 126–136. doi:10.1037/0022-0663.92.1.126

Keller, J. M. (1987). Development and use of the ARCS model of motivational design. *Journal of Instructional Development, 10,* 2–10. doi:10.1007/BF02905780

Konradt, U., Filip, R., & Hoffman, S. (2003). Flow experience and positive affect during hypermedia learning. *British Journal of Educational Technology, 34,* 309–327. doi:10.1111/1467-8535.00329

Lazarus, R. S. (1991). *Emotion and adaptation.* New York, NY: Oxford University Press.

Lidwell, W., Holden, K., & Butler, J. (2003). *Universal principles of design.* Gloucester, MA: Rockport.

Linnenbrink, E. A., & Pintrich, P. R. (2002a). Achievement goal theory and affect: An asymmetrical bidirectional model. *Educational Psychologist, 37,* 69–78. doi:10.1207/S15326985EP3702_2

Linnenbrink, E. A., & Pintrich, P. R. (2002b). The role of motivational beliefs in conceptual change. In M. Limon & L. Mason (Eds.), *Reconsidering conceptual change: Issues in theory and practice* (pp. 115–135). Dordrecht, the Netherlands: Kluwer Academic. doi:10.1007/0-306-47637-1_6

Lorenz, K., & Generale, S. (1950). Ganzheit und Teil in der tierischen und menschilichen Germeinschaft [Wholeness and part in animal and human community]. *Part and Parcel in Animal and Human Societies, 3,* 9.

Mayer, R. E. (2001). *Multimedia learning.* New York, NY: Cambridge University Press.

Mayer, R. E. (2005). *Cognitive theory of multimedia learning.* New York, NY: Cambridge University Press.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90,* 312–320. doi:10.1037/0022-0663.90.2.312

Moreno, R., & Mayer, R. E. (2000). A coherence effect in multimedia learning: The case for minimizing irrelevant sounds in the design of multimedia instructional messages. *Journal of Educational Psychology, 92,* 117–125. doi:10.1037/0022-0663.92.1.117

Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19,* 309–326. doi:10.1007/s10648-007-9047-2

Norman, D. (2004). *Emotional design.* New York, NY: Basic Books.

North, A., & Hargreaves, D. (1999). Music and driving game performance. *Scandinavian Journal of Psychology, 40,* 285–292. doi:10.1111/1467-9450.404128

Oaksford, M., Morris, F., Grainger, B., & Williams, J. M. G. (1996). Mood, reasoning, and central executive process. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 22,* 476–492. doi:10.1037/0278-7393.22.2.476

Oatley, K., & Johnson-Laird, P. N. (1987). Towards a cognitive theory of emotions. *Cognition & Emotion, 1,* 29–50. doi:10.1080/02699938708408362

Ortony, A., Glore, G. L., & Collins, A. (1988). *The cognitive structure of emotions.* Cambridge, England: Cambridge University Press. doi:10.1017/CBO9780511571299

Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive load approach. *Journal of Educational Psychology, 84,* 429–434. doi:10.1037/0022-0663.84.4.429

Paivio, A. (1986). *Mental representation: A dual coding approach.* Oxford, England: Oxford University Press.

Park, S. (2006). *The effects of seductive augmentation and agent role on learning interest, achievement, and attitude.* Doctoral dissertation, Florida State University.

Pekrun, R. (1992). The impact of emotions on learning and achievement: Towards a theory of cognitive/motivational mediators. *Applied Psychology, 41,* 359–376. doi:10.1111/j.1464-0597.1992.tb00712.x

Pekrun, R. (2000). A social-cognitive, control-value theory of achievement emotions. In J. Heckhausen (Ed.), *Motivational psychology of human development: Developing motivation and motivating development* (pp. 143–163). New York, NY: Elsevier Science. doi:10.1016/S0166-4115(00)80010-2

Pekrun, R. (2006). The control-value theory of achievement emotions: Assumptions, corollaries, and implications for educational research and practice. *Educational Psychology Review, 18,* 315–341. doi:10.1007/s10648-006-9029-9

Pekrun, R., Goetz, T., Titz, W., & Perry, R. P. (2002). Academic emotions in students' self-regulated learning and achievement: A program of qualitative and quantitative research. *Educational Psychologist, 37,* 91–106. doi:10.1207/S15326985EP3702_4

Pekrun, R., & Jerusalem, M. (1996). Leistungsbezogenes Denken und Fühlen: Eine Übersicht zur psychologischen Forschung [Performance-related thinking and feeling: An overview of psychological research]. In J. Möller & O. Köller (Hrsg.), *Emotionen, Kognitionen und Schulleistung* (pp. 3–22). Weinheim, Germany: Beltz/Psychologie Verlags Union.

Petty, R. E., Schumann, D. W., Richman, S. A., & Strathman, A. J. (1993). Positive mood and persuasion: Different roles for affect under high- and low-elaboration conditions. *Journal of Personality and Social Psychology, 64,* 5–20. doi:10.1037/0022-3514.64.1.5

Picard, R. (1997). Affective computing. Cambridge, MA: MIT Press.

Plass, J. L., Moreno, R., & Brünken, R. (Eds.). (2010). *Cognitive load theory.* New York, NY: Cambridge University Press.

Preacher, K. J., & Hayes, A. F. (2004). SPSS and SAS procedures for estimating indirect effects in simple mediation models. *Behavior Research Methods, Instruments & Computers, 36,* 717–731. doi:10.3758/BF03206553

Reeves, B., & Nass, C. (1996). *The media equation: How people treat computers, televisions, and new media like real people and places.* Cambridge, England: Cambridge University Press. doi:1996-98923-000

Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review, 110,* 145–172. doi:10.1037/0033-295X.110.1.145

Seibert, P. S., & Ellis, H. C. (1991a). A convenient self-referencing mood-induction procedure. *Bulletin of the Psychonomic Society, 29,* 121–124. doi:1991-20464-001

Seibert, P. S., & Ellis, H. C. (1991b). Irrelevant thoughts, emotional mood states, and cognitive task performance. *Memory & Cognition, 19,* 507–513. doi:10.3758/BF03199574

Sobel, M. E. (1982). Asymptotic confidence intervals for indirect effects in structural equation models. In S. Leinhart (Ed.), *Sociological methodology,* pp. 290–312. San Francisco, CA: Jossey-Bass. doi:10.2307/270723

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12,* 257–285. doi:10.1207/s15516709cog1202_4

Szabo, M., & Kanuka, H. (1998). Effects of violating screen design principles of balance, unity, and focus on recall learning, study time, and completion rates. *Journal of Educational Multimedia and Hypermedia, 8,* 23–42.

Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics.* Boston, MA: Pearson.

Thompson, E., Palacios, A., & Varela, F. J. (1992). Ways of coloring: Comparative color vision as a case study for cognitive science. *Behavioral and Brain Sciences, 15,* 1–74. doi:10.1017/S0140525X00067248

Tractinsky, N., Katz, A. S., & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers, 13,* 127–145. doi:10.1016/S0953-5438(00)00031-X

Tucker, J. (1987). Psychology of color. *Target Marketing, 10,* 40–49.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54,* 1063–1070.

Weiss, H. M., & Nicholas, J. P. (1999). An examination of the joint effects of affective experiences and job beliefs on job satisfaction and variations in affective experiences over time. *Organizational Behavior and Human Decision Processes, 78,* 1–24. doi:10.1006/obhd.1999.2824

Wolfson, S., & Case, G. (2000). The effects of sound and color on responses to a computer game. *Interacting with Computers, 13,* 183–192. doi:10.1016/S0953-5438(00)00037-0

Yik, M. S. M., Russell, J. A., & Feldman Barrett, L. (1999). Structure of self-reported current affect: Integration and beyond. *Journal of Personality and Social Psychology, 77,* 600–619. doi:10.1037/0022-3514.77.3.600

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