

Emotional design in multimedia learning: Effects of shape and color on affect and learning



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ABSTRACT

We examine design factors that may evoke positive emotions in learners and investigate the effects of these positive emotions on learning. Recent research showed that **the emotional design of multimedia learning material can induce positive emotions in learners that in turn facilitate comprehension and transfer**. We sought to replicate these results with a different population and different mood induction procedure and examine individual emotions, and to decompose the effects of the design elements of *color* and *shape*. Study 1 showed that well-designed materials induced positive emotions and facilitated comprehension, though transfer performance was not affected by emotional design. Study 2 found that round face-like shapes both alone and in conjunction **with warm color** induced positive emotions. Warm colors alone, however, did not affect learners' emotions. Comprehension was facilitated by warm colors and round face-like shapes, independently as well as together. Transfer was facilitated by round face-like shapes when used with neutral colors.

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1. Introduction

How can the design of multimedia learning materials be used to foster positive emotions, and will such positive emotions facilitate learning? In particular, how do the colors and shapes used in multimedia learning environments impact affect and learning? These questions are of importance because we know that learners experience a broad variety of emotions in academic settings that are related to academic achievement (Pekrun, Goetz, Titz, & Perry, 2002), yet we are only beginning to understand which specific emotions are being experienced by learners, how these emotions affect key predictors of learning, such as students' metacognition or interest, and how students' emotions develop and are fostered through the learning environment (Pekrun, 2005). In this paper we are interested in *emotional design*, a term we use to describe visual design elements in multimedia learning environments that affect learners' emotions and foster learning (Um, Plass, Hayward, & Homer, 2011). The main goal of this study is to investigate whether an aesthetically appealing design of a multimedia learning material can induce positive emotions in learners, and whether positive emotions can affect cognitive outcomes (such as experienced cognitive load and learning outcomes), as well as affective outcomes (such as motivation, user satisfaction,

perceived task difficulty, and perception about learning achievement). We are also interested whether design elements such as *color* and *shape* in a multimedia learning material individually induce positive emotions in learners, and how they affect cognitive as well as affective outcomes.

By addressing the role of emotion in the design of multimedia learning materials, educational psychologists can develop a more robust scientific theoretical foundation for learning with multimedia and provide better guidance to the designers of such environments. We begin this paper by briefly summarizing relevant issues of emotion and learning in general before we turn to specific studies that investigated emotion in the context of multimedia learning and present the theoretical foundation for this research, the Cognitive-Affective Theory of Learning with Media (Moreno, 2007).

2. Emotion and learning

Emotions are a result of an individual's judgment about the world and appraisal of interactions with and in the world (Desmet, 2002; Frijda, 1993; Oatley & Johnson-Laird, 1987; Ortony, Glore, & Collins, 1988). Emotions can be described along two dimensions that affect performance, valence (positive–negative) and activation (activating–deactivating) (Pekrun, 1992; Russell, 2003). For example, *happy* and *hopeful* are positive emotions that are activating, and *satisfied* and *calm* are positive emotions that are deactivating (Pekrun et al., 2002).

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In the context of learning, researchers have been interested in negative as well as positive emotions directly related to instruction, learning, and achievement (Goetz, Pekrun, Hall, & Haag, 2006; Pekrun et al., 2002). In the control-value theory, Pekrun and colleagues (Pekrun, 2000; Pekrun et al., 2002) describe how academic emotions are a function of students' perceived control of academic encounters and of their academic values related to these encounters.

Research on negative academic emotions has focused mainly on test anxiety (Pekrun, 2005), and only in some cases on learning. A typical example of the latter is the finding that learners who experience negative emotions take longer reaching mastery levels and perform worse on transfer tasks than learners who experience positive emotions (Brand, Reimer, & Opwis, 2007). Learners' metacognitive experiences during learning, such as *feeling of difficulty* and *feeling of confidence* are related to positive and negative emotions (Efklides & Petkaki, 2005), and positive emotions result in a higher readiness of learners to invest mental effort in the learning task (Efklides, Kourkoulou, Mitsiou, & Ziliaskopoulou, 2006). Indeed, if learners who are in a state of engagement and flow face obstacles in their learning they may experience frustration and, if they are not able to restore their flow state, eventually boredom and reduced learning (D'Mello & Graesser, 2012). However, negative emotions such as confusion, resulting from contradictions experienced during learning, can also result in deeper learning (D'Mello, Lehman, Pekrun, & Graesser, 2013).

In the present study we were interested in the effect of positive emotions on learning. Positive emotions have mostly been implicated in their contribution to foster learning, although some researchers argue that positive emotions can distract from learning. Research on memory has shown that positive emotions improve recall and serve as retrieval cues for long-term memory (Isen, Daubman, & Nowicki, 1987; Isen, Shalker, Clark, & Karp, 1978). Studies of cognitive processing have found that positive emotions support information and communication processing, negotiation, decision-making, creative problem solving, and sorting performance (Erez & Isen, 2002; Konradt, Filip, & Hoffman, 2003). However, there is indication that in some cases, positive emotions can suppress cognitive processes such as deductive reasoning (Oaksford, Morris, Grainger, & Williams, 1996).

Much of the existing research on the impact of emotion on cognition was completed in laboratory settings. In classroom settings, more complex patterns of emotions and learning emerge. For example, self-reported arousal has been linked to students' regulation of their effort in solving math problems, and self-reported valence linked to cognitive regulation processes, but overall the reported emotions were unrelated to learning outcomes (Linnenbrink & Pintrich, 2002a). Similar results have been found with other academic subjects, such as college-level physics (Linnenbrink & Pintrich, 2002b).

One of the most compelling differences between the classroom-based research and a majority of the lab-based experimental research in this field is the way in which the emotions under investigation are induced. In laboratory research, emotions are typically induced via mood-induction tasks (e.g., watching cartoons, receiving sweets or small gifts) that are given before the learning- or performance task. In contrast, classroom-based studies typically investigate emotions induced by the design of the learning environment (Linnenbrink & Pintrich, 2002b), which means learners' emotions are impacted throughout the learning task. We therefore hypothesize that these emotions are sustained better throughout the learning process than those induced by procedures given before the learning- or performance task (Um et al., 2011). This is of particular interest in the context of multimedia learning, i.e., for learning involving pictures, videos and text in computer-based environments, because we believe that the design of these

environments, similar to the design of any other learning environment, impacts learners' emotions. However, little theory-based, empirically validated guidance exists for such *emotional design*, i.e., for how specific visual design elements in multimedia learning environments, such as the color and shape of the represented information, impact learners' emotions and foster learning. We are also interested in how the different mood induction procedures might differently affect specific positive emotions.

2.1. Emotion and multimedia learning

One theory that may provide guidance for the use of *emotional design* is Moreno's *Cognitive Affective Theory of Learning with Media* (CATLM), which expands Mayer's (2005) *Cognitive Theory of Multimedia Learning* (CTML) by incorporating motivational and meta-cognitive factors as mediators of multimedia learning (Moreno, 2007; Moreno & Mayer, 2007). Mayer's CTML describes how during multimedia learning, learners select relevant visual and verbal materials from what is presented, build visual and verbal internal representations of this information, and then connect the visual and verbal representations with one another and with prior knowledge (Mayer, 2005). These cognitive processes take place under the constraints of a limited working memory that can only hold a small number of chunks of information at a time (Baddeley, 1986; Cowan, 2001). The demand on working memory is determined by the difficulty of the material, the demands of the learning task, and the amount of mental effort invested by the learner, i.e., the depth of processing the material (Plass, Moreno, & Brünken, 2010; Sweller, Ayres, & Kalyuga, 2011). The goal of multimedia designers is to reduce the demands of the learning task that are non-essential to the learning process (e.g., the kind of problem and related instruction a learner is given), and to increase the amount of invested mental effort in processing a given learning material (Brünken, Plass, & Moreno, 2010).

Moreno makes two important additions to CTML. One, based on work summarized by Pintrich (2003), suggests that these processes of selecting, organizing, and integrating are mediated by motivational factors that impact cognitive engagement. The second, based on work summarized by McGuinness (1990), suggests that learning is mediated by metacognitive factors that regulate cognitive processing and affect (Moreno & Mayer, 2007).

Although the impact of both motivation and metacognition on learning has been studied for some time, it is a significant advance of the field to have a theory of multimedia learning that incorporates non-cognitive mediators of learning. Research on multimedia learning so far has mainly focused on cognitive factors, especially on optimizing the amount of cognitive load induced by the design of the learning environment (e.g., Mayer, 2009; Plass et al., 2010; Sweller et al., 2011). In fact, the introduction of appealing design elements that may induce positive emotions in learners and facilitate their intrinsic motivation has been met with much criticism in the multimedia learning literature. Appealing but interesting elements are often described as unnecessary for learning, and it is assumed that they add demand for processing of non-essential information and therefore harm learning. This view has been expressed as *seductive details* effect (Garner, Brown, Sanders, & Menke, 1992; Garner, Gillingham, & White, 1989; Harp & Mayer, 1997, 1998; Lehman, Schraw, McCrudden, & Hartley, 2007; Lenzner, 2009; Mayer, Heiser, & Lonn, 2001), and as *coherence principle* (Mayer, 2005, 2009). Both lines of research suggest removing verbal and visual information that is compelling but deemed irrelevant for learning.

The CATLM theory posits two functions of the visual design of multimedia materials. The first is a cognitive function, related to supporting the cognitive processing of the material. The second is an affective function, related to influencing the learners' attitudes and motivation (Moreno, 2007). Based on research results

summarized above that show how positive emotions support cognitive processing and metacognition, and on findings from studies on the impact of aesthetics in design (Tractinsky, Katz, & Ikar, 2000), our work seeks to provide empirical support for the affective function of the visual design of multimedia learning materials by studying the relation of visual design, emotion, and learning.

We have begun to investigate one of the key assumptions of CATLM by showing that the visual design of multimedia learning environments is able to induce positive emotions in learners that in turn facilitated comprehension and transfer performance (Um et al., 2011). The design of that study used a combination of two visual design elements, color and shape, to manipulate the emotional impact of the materials without adding new information. Research on color has shown an increase in pleasure and excitement due to saturated and warm colors (Berlyne, 1970; Tucker, 1987), and has found that they can elicit greater feelings of arousal than cold colors (Bellizzi & Hite, 1992; Wolfson & Case, 2000). However, the strongest effects have been found between warm, light colors (e.g., yellow, orange) and dark or achromatic colors (e.g., gray) (Boyatzis & Varghese, 1994; Hemphill, 1996; Kaya & Epps, 2004). Research on shape has shown that features that are round and baby-like (large eyes, small noses, short chins) can induce positive emotion (Alley, 1981; Berry & McArthur, 1985; Lorenz, 1950). Similarly, anthropomorphic computer interfaces have been found to better attract users' attention and to better engage them in active tasks than non-anthropomorphic interfaces (Dehn & Van Mulken, 2000).

The positive emotional design variant of the materials in the Um et al. (2011) study therefore used saturated warm hues and round face-like shapes in order to induce positive emotions. The control condition was a neutral design, using achromatic (gray-scale) displays and square shapes that did not resemble human faces. We chose a neutral design rather than a negative emotional design as control for several reasons. First, only color has a clear opposite inducing negative emotions (bright versus dark hues), whereas shape does not. Research on the effect of color on learning and performance has consistently shown that compared to gray scale or black and white, color alone does not provide learning benefits other than those related to affect (cf. Pett & Wilson, 1996) unless it is used for color coding or cueing (Plass, Homer, & Hayward, 2009). Second, the goal of this research was not to study negative emotions since personality systems interaction theory suggests that positive and negative emotions are accompanied by qualitatively different models of information processing (Bolte, Goschke, & Kuhl, 2003; Kuhn, 2000) and have a different biological basis (Ashby, Isen, & Turken, 1999), which would make a meaningful interpretation of findings difficult. Finally, the present study aims to extend previous research that also employed materials using achromatic displays for the neutral (control) design (Szabo & Kanuka, 1998; Um et al., 2011).

Results of our previous study were that learners using the positive emotional design had more positive emotions and higher comprehension and transfer test scores. Learners using the positive emotional design also perceived these materials as less difficult and invested more mental effort in processing them than learners receiving the neutral design, and they reported higher motivation, satisfaction, and perception toward the learning materials.

3. Study 1

3.1. Research questions and hypotheses

In this paper we will present two follow-up studies to our initial work. Our first study sought to replicate the Um et al. (2011) results with a different population and different mood induction procedure, and examined individual emotions of learners by asking:

Hypothesis 1. Does an aesthetically appealing design of a multimedia learning material induce positive emotions in learners? Based on the previous research reported above we hypothesize that the positive emotional design induces more positive emotions than neutral design, and that emotions induced by the design of the learning materials are sustained better throughout the learning process than emotions induced by a mood induction procedure.

Hypothesis 2. How do positive emotions affect cognitive outcomes such as experienced cognitive load and learning outcomes (comprehension and transfer)? Based on the previous research reported above we hypothesize that positive emotions result in higher comprehension test scores, transfer test scores, and invested mental effort, and lower perceived task difficulty than neutral emotions.

Hypothesis 3. How do positive emotions affect affective outcomes such as motivation, user satisfaction, perceived task difficulty, and perception about learning achievement? Based on the previous research reported above we hypothesize that positive emotions result in higher motivation, higher user satisfaction, and a more positive perception about learning achievement than neutral emotions.

3.2. Method

3.2.1. Participants and design

Participants were 121 Education graduate students recruited from a German university. There were 20 male and 101 female participants, and all of them were over 18 years old ($M = 21.98$, $SD = 2.13$). Participants were randomly assigned to one of four conditions, created by two design factors with two levels each. These factors were the *external* induction of positive emotions by means of a video-based mood induction procedure (positive (PE) or neutral (NE) emotions), and the *internal* induction of positive



Fig. 1. Screen shots of multimedia learning materials from study 1: neutral emotional design (ND), left, and positive emotional design (PD), right. Translation from German: "How does Immunization Work?" (For color figures please refer to the online version of the paper.)

emotions by means of the emotional design of the learning materials (positive (PD) or neutral (ND) design). The learning materials are shown in Fig. 1 and are described in detail in the materials and apparatus section below. 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). The external induction of positive emotions served as additional control that provided a baseline and allowed us to relate our findings to those in previous experimental research using external mood inductions.

3.2.2. Materials and apparatus

3.2.2.1. Emotion induction procedure. For the external mood induction we employed two 2-min videos to induce either positive or neutral emotions. Videos were selected because a meta-analysis of different mood induction procedures had identified this method as most effective for mood induction (Westermann, Spies, Stahl, & Hesse, 1996). For the neutral mood induction, participants viewed a 2:13-min segment of *Chillout* (<http://tinyurl.com/388buwc>), a video depicting flying birds and underwater marine life with a soothing sound track. For the positive mood induction, learners viewed the trailer of the movie *Ice Age 3—Dawn of the Dinosaurs* (<http://tinyurl.com/8rsd3p>), a 2:13-min segment where a saber-toothed squirrel named Scrat meets a girl and struggles to decide between romance and his beloved acorn. These two videos were pretested with a small sample of 10 participants from the same population, and we found that they were able to induce the intended neutral and positive emotional states.

3.2.2.2. Design of learning material. A multimedia learning environment on immunization designed for Um et al. (2011) served as learning material. It incorporated text, pictures, and animations accompanied by narration. The learning content was presented in six chapters with a total duration of 7 min. The material was self-paced and allowed learners to start, stop and replay short sequences. There were two different versions of emotional design to manipulate affect. The *neutral emotional design* (NE) was developed in gray-scale and with neutral 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 (Fig. 1).

3.2.2.3. Measures. The measures used in this study were the same as those used by Um et al. (2011). The *Positive Affect Scale* (PAS) from the *Positive and Negative Affect Schedule* (PANAS; Watson, Clark, & Tellegen, 1988) was used to measure participants' positive affect. The PAS is an established measure of positive affect that has been successfully used in previous research (e.g., Crawford & Henry, 2004; Riva et al., 2007; Um et al., 2011). In completing the PAS, respondents indicate the degree to which they experience seven different feelings related to positive affect (interested, excited, enthusiastic, 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 seven responses, resulting in a range from 5 to 35 points. 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 7-item self-report checklist in which learners indicated their level of knowledge of the topic of immunization (e.g., "I can explain what antibodies are."). In

addition to the 7-item self-report checklist, the prior knowledge test also included one item for learners to rate their prior knowledge in the subject matter: "Please place a check mark indicating your knowledge of immunization" with response options "novice" (1), "beginner" (2), "intermediate" (3), "advanced" (4), "expert" (5). The total score for prior knowledge was computed by adding the responses to the 7 questions to the response to this self-report item (value 0–5). The total score for each participant was obtained by adding points from all items, resulting in a range from 0 to 12 points. Self-reports of prior knowledge are sometimes used in studies such as the present when prior knowledge is expected to be generally low, and where short treatment durations increase the risk of priming effects from pre-test knowledge measures (e.g., Harp & Mayer, 1998; Mayer et al., 2001).

Comprehension and *transfer* tests were administered to assess learning outcomes. The *comprehension* test measured learners' understanding of key concepts of the materials and was comprised of 16 multiple-choice questions, for which participants received one point for each correct answer (e.g., "Which cells are eating and scavenging the virus?"), resulting in a range of 0–16 points. The *transfer* test measured participants' ability to apply the concepts learned to solve problems and consisted of four questions (e.g., "Explain why a person who has already been infected with chicken pox does not need a 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, resulting in a range from 0 to 19.

The *cognitive load* experienced by learners was measured by asking participants to complete a 9-point Likert style Cognitive Load Subjective Experience Questionnaire targeting invested mental effort (Paas, 1992). Participants also completed a survey on their perceptions of task difficulty, which consisted of a 7-point Likert scale question (Kalyuga, Chandler, & Sweller, 2000). These scales have been successfully used in previous research, and we decided to include both in this study as there is support for the claim that they measure different constructs (DeLeeuw & Mayer, 2008).

Three additional measures included students' *satisfaction* with their *learning experience* of using the computer-based multimedia lesson was assessed using a 7-point Likert style question ("How much did you like the "immunization" learning material?"). In addition, one 7-point Likert style question was asked to measure users' *perception about their learning achievement* ("How well do you think you did in the preceding tests?"). Learners' *motivation* was measured using a self-report instrument consisting of an 8-item questionnaire with 7-point Likert style items developed by Isen and Reeve (2005) for measuring intrinsic motivation ("e.g., "The learning material is fun."). Participants were asked to rate how interesting and enjoyable they found the experience (1 = strongly disagree, 7 = strongly agree). One point was assigned for each item, and a mean score of the 8 items was calculated and used in the analysis (range: 1–7).

3.2.2.4. Procedure. The procedure was in its entirety administered through a computer system. Participants were tested in groups of 10–16 in a laboratory setting. Participants were randomly assigned to one of the four groups, and each session lasted for about 1 h.

Participants received an introduction to the computer-based procedures and were asked to follow the instructions on the screen. After spending 5 min completing the demographic questionnaires, the participants were presented either the positive or the neutral video in order to externally induce emotions. Participants then completed the positive affect schedule for the first time (PAS1). Next, the multimedia instruction with either neutral or positive design of the material was presented to the participants on the

computer. Participants were told that they would be tested on the content of the material after using the computer program and were instructed to study the learning material for 15 min. Participants were then given 25 min to complete the questionnaires of mental effort and perceived task difficulty, the PAS for the second time (PAS2), and self-report measure of intrinsic motivation, learning performance (comprehension and transfer tests), perception of achievement, and satisfaction with their learning experience.

3.3. Results

Table 1 shows the descriptive statistics for the independent and dependent variables involved in the analyses.

3.3.1. Manipulation check of mood induction

3.3.1.1. Evidence of positive mood induction. In order to test whether the mood induction was successful, we computed an independent samples *t*-test on the scores of the first PAS test by mood induction condition (neutral, positive). The analysis revealed that after the mood induction, the Positive Emotion (PEND and PEPD) groups ($M = 22.61$; $SD = 4.88$) rated their emotions significantly more positively than the Neutral Emotion (NEND and NEPD) groups ($M = 19.28$; $SD = 5.03$) at $t(119) = -3.69$, $p < .001$, Cohen's $d = .68$. These results suggest that the neutral versus positive emotional states were successfully induced before the learning session.

A comparison of the scores on the individual items of the first PAS for the group receiving neutral and the group receiving positive mood induction revealed that the cartoon affected the following emotions, excited (“freudig erregt”), NE: $M = 2.35$, $SD = 1.07$; PE: $M = 3.36$, $SD = 1.08$; $t(1,119) = -5.17$, $p < .001$; enthusiastic (“begeistert”), NE: $M = 2.55$, $SD = .99$; PE: $M = 3.16$, $SD = 1.07$; $t(1,119) = -3.26$, $p = .001$; determined (“entschlossen”), NE: $M = 2.55$, $SD = .99$; PE: $M = 2.93$, $SD = 1.05$; $t(1,119) = -2.06$, $p = .041$; and attentive (“aufmerksam”), NE: $M = 3.23$, $SD = .93$; PE: $M = 3.79$, $SD = .78$; $t(1,119) = -3.56$, $p = .001$. A comparison of the individual scores for these groups for the first and the second PAS showed that all of these differences disappeared, and scores for the positive mood group reverted back to PAS 1 levels of the neutral induction group (PE PAS2: excited, $M = 2.03$, $SD = .88$; enthusiastic, $M = 2.59$, $SD = .97$; inspired, $M = 2.89$, $SD = .98$; and attentive, $M = 3.56$, $SD = .85$). These results indicate that those individuals who received the positive mood induction cartoon initially had elevated feelings of excitement, enthusiasm, determination, and attentiveness, relative to those who did not view the cartoon; however, these elevations were not sustained over the course of the learning session.

3.3.1.2. Evidence of positive emotional design. In order to determine whether the emotional design was able to induce positive emotions we computed an analysis of variance with repeated measures

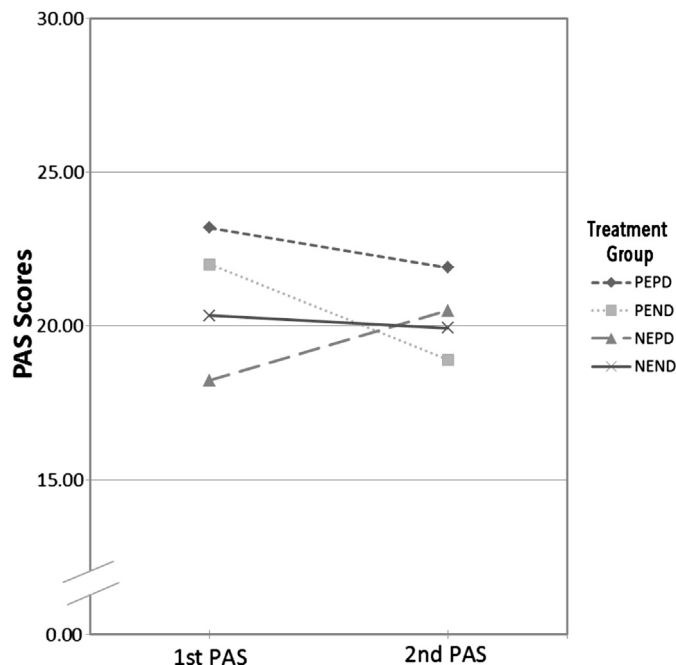


Fig. 2. Study 1 PAS scores by condition before learning (first PAS) and after the learning (second PAS). Note. NEND—neutral mood induction procedure and neutral emotional design of material; PEPD—positive mood induction procedure and positive emotional design of material; PEND—positive mood induction procedure and neutral emotional design of material; NEPD—neutral mood procedure and positive emotional design of material.

(RM-ANOVA) with condition as between-subjects factor and PAS scores on the first and second PAS tests as repeated measures variable. The analysis indicated a main effect for group, $F(3, 117) = 2.93$, $MSE = .79$, $p = .036$, $\eta_p^2 = .07$. This main effect was qualified by an interaction effect between the change in PAS scores and group, $F(3, 117) = 6.97$, $MSE = .22$, $p < .001$, $\eta_p^2 = .15$. A paired-sample *t*-test revealed that the PAS scores of two groups changed significantly over the course of the learning session (see Fig. 2). These two groups were PEND (Positive Emotions & Neutral Design group), $t(1, 29) = 5.15$, $p < .001$, Cohen's $d = 1.91$, for which positive emotions decreased significantly from PAS1 ($M = 22.00$, $SD = 5.83$) to the PAS2 ($M = 18.90$, $SD = 4.57$), and NEPD (Neutral Emotions & Positive Design group), $t(1, 29) = -2.36$, $p = .025$, Cohen's $d = .88$, for which positive emotions increased significantly from PAS1 ($M = 18.23$, $SD = 5.30$) to PAS2 ($M = 20.50$, $SD = 6.04$).

A comparison of the scores on the individual items of the second PAS for the groups receiving the neutral design and the group receiving the positive design revealed that the emotional design of the materials affected the following emotions, inspired (“angeregt”), ND: $M = 2.63$, $SD = 1.09$; PD: $M = 3.07$, $SD = 1.00$; $t(1,119) = -2.28$, $p = .025$; and interested (“interessiert”), ND: $M = 3.18$, $SE = .10$; PD:

Table 1

Study 1 means, standard deviation, and bivariate correlations between measures.

	M	SD	PAS1	PAS2	Comp	Transf	Mental effort	Perc. Diff.	Motiv.	Satis.	Percep.
Prior knowledge	4.00	1.95	.08	.11	.21*	.19*	-.05	-.26**	.06	.11	.32**
PAS1	20.96	5.21	—	.53**	-.03	-.01	.29**	.02	.33**	.29**	.19*
PAS2	20.32	5.08	—	—	.22*	.24**	.30**	-.02	.70**	.48**	.40**
Comprehension	11.17	3.08	—	—	—	.50**	-.03	-.29**	.27**	.10	.42**
Transfer	6.45	1.97	—	—	—	—	.08	-.09	.17	.11	.34**
Mental effort	4.42	1.05	—	—	—	—	—	.36**	.31**	.19*	.01
Perceived difficulty	3.07	1.26	—	—	—	—	—	—	-.13	-.15	-.26**
Motivation	32.94	8.59	—	—	—	—	—	—	—	.63**	.34**
Satisfaction	5.20	1.32	—	—	—	—	—	—	—	—	.36**
Perception	4.07	1.07	—	—	—	—	—	—	—	—	—

* $p < .05$, ** $p < .01$

$M = 3.61$, $SE = .10$; $F(1, 118) = 8.34$, $p = .005$ (corrected for PAS1 group differences), with enthusiastic (“begeistert”) approaching significance, ND: $M = 2.40$, $SD = 1.00$; PD: $M = 2.75$, $SD = 1.08$; $t(1, 119) = -1.88$, $p = .063$. In other words, individuals in the positive design group had elevated feelings of being inspired, interested, and enthusiastic that were sustained during learning.

These results indicate that positive emotions induced through the emotional design of the learning material helped maintain and increase the positive emotions during learning, confirming [Hypothesis 1](#). In contrast, positive emotions induced externally, before the learning task, tended to decrease during the learning when the emotional design was neutral. These findings lend support to the notion that positive emotions can be induced through the learning material by applying emotional design principles, which is consistent with findings by [Um et al. \(2011\)](#).

3.3.2. Learning outcomes

We first investigated differences in self-reported prior knowledge among the four conditions. [Table 2](#) shows means and standard deviations of the outcomes measures for the four condition groups.

A oneway ANOVA with prior knowledge as dependent measure and condition as factor did not reveal statistically significant differences, $F(1, 117) = 1.32$, $MSE = 3.76$, $p = .271$, suggesting that self-reported prior knowledge did not differ among groups. However, the results of the bivariate correlations reported in [Table 1](#) showed that higher prior knowledge scores were related to higher scores in comprehension and transfer tests for all learners independent of group.

Because of the moderate correlation between comprehension and transfer measures (see [Table 1](#)), we computed a 2×2 MANCOVA with Emotional Design (neutral, positive) and Mood Induction (neutral, positive) as between-subjects factors and comprehension and transfer scores as dependent measures. Prior knowledge was added to the model as covariate as it correlated with our learning outcomes and therefore accounted for some of the within-group variance. The multivariate tests revealed a significant main effect for Emotional Design, Wilks' Lambda = .91, $F(2, 115) = 5.39$, $p = .006$, $\eta_p^2 = .09$ and for prior knowledge, Wilks' Lambda = .92, $F(2, 115) = 4.91$, $p = .009$, $\eta_p^2 = .08$. The effect for Mood Induction did not reach statistical significance, Wilks' Lambda = .95, $F(2, 115) = 2.81$, $p = .065$. There was no interaction effect for the two factors, Wilks' Lambda = .99, $F(2, 115) = .53$, $p = .592$. Between-subject effects for each outcome measure are reported below.

3.3.2.1. Comprehension. In order to further investigate the effect of the two different manipulations of emotions on learners' comprehension of the multimedia materials, we inspected the between-subject effects reported by the MANCOVA for comprehension as dependent measure. The analysis revealed a significant main effect

Table 2

Study 1 mean scores and standard deviations for each group on comprehension, transfer, mental effort, perceived difficulty, satisfaction, perception, and motivation.

	NEND (controls)	PEPD	PEND	NEPD
Comprehension	10.47 (3.33)	11.39 (2.63)	10.43 (3.06)	12.40 (2.99)
Transfer	6.78 (2.01)	6.05 (1.94)	6.17 (1.99)	6.80 (1.93)
Mental effort	4.53 (.97)	4.42 (.92)	4.40 (1.25)	4.33 (1.06)
Difficulty	3.40 (1.33)	2.84 (.97)	3.27 (1.44)	2.77 (1.22)
Satisfaction	5.27 (1.34)	5.35 (.92)	4.97 (1.52)	5.20 (1.47)
Perception	3.93 (1.08)	3.87 (.96)	4.07 (1.11)	4.40 (1.10)
Motivation	31.50 (8.79)	34.93 (6.59)	31.23 (7.60)	34.03 (10.71)

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 procedure and positive emotional design of material.

for Emotional Design, $F(1, 116) = 8.41$, $MSE = 71.82$, $p = .004$, $\eta_p^2 = .07$ and for prior knowledge, $F(1, 116) = 8.11$, $MSE = 69.24$, $p = .005$, $\eta_p^2 = .07$. No main effect was found for Mood Induction ($F(1, 116) = 2.09$, $p = .151$), and there was no interaction effect for the two factors ($F(1, 116) = 1.01$, $p = .317$). Learners whose positive emotional state was induced internally, through the emotional design of the learning materials, performed better on the comprehension test than controls (neutral design, $M = 10.45$, $SD = 3.17$, positive design, $M = 11.89$, $SD = 2.83$; $d = .48$). External induction of positive emotions was not found to impact comprehension test performance (neutral induction, $M = 11.43$, $SD = 3.28$; positive induction, $M = 10.92$, $SD = 2.86$).

3.3.2.2. Transfer. To determine the effect of the two different manipulations of emotions on learners' transfer of the multimedia materials, we inspected the between-subject effects reported by the MANCOVA for transfer test as dependent measure. The analysis revealed a main effect for the external Mood Induction, $F(1, 116) = 5.54$, $MSE = 20.49$, $p = .020$, $\eta_p^2 = .05$, and for prior knowledge, $F(1, 116) = 6.48$, $MSE = 23.99$, $p = .012$, $\eta_p^2 = .05$. No other main or interaction effects were identified; see [Table 2](#) for descriptives.

In summary, the internal induction of positive emotions through emotional design of the materials increased comprehension, partially confirming [Hypothesis 2](#), but did not increase transfer. We also found that the external induction of positive emotions through a mood induction procedure enhanced transfer, but not comprehension. These findings are therefore partially consistent with those of [Um et al. \(2011\)](#), in that emotional design resulted in higher comprehension, but inconsistent in that such design did not promote transfer as well.

3.3.2.3. Cognitive load. Next we investigated the invested mental effort and perceived difficulty of the learning task as dependent outcome measures. For each of these measures, we computed a 2×2 ANOVA with Emotional Design (neutral, positive) and Mood Induction (neutral, positive) as between-subject factors. Since entering prior knowledge as covariate did not change the patterns of the results we report the analyses without this covariate. The ANOVA computed on *mental effort* scores as a dependent variable revealed no main effect or interaction effects.

The ANOVA run with *task difficulty* as a dependent variable revealed a significant main effect for Emotional Design, $F(1, 117) = 5.46$, $MSE = 8.52$, $p = .021$, $\eta_p^2 = .05$. Learners receiving the internal induction of positive emotions through Emotional Design rated the difficulty of the learning material as lower ($M = 2.80$, $SD = 1.09$) than learners in the neutral emotional design condition ($M = 3.33$, $SD = 1.37$; $d = .36$). There was no main effect for Mood Induction (neutral induction: $M = 3.08$, $SD = 1.31$; positive induction: $M = 3.05$, $SD = 1.23$), nor an interaction effect of the two factors.

In summary, positive emotions induced either before or during the multimedia learning task did not impact the amount of reported mental effort learners invested during learning. However, positive emotions induced during the learning task through emotional design reduced the perceived difficulty of the learning task, whereas induction of a positive mood through a video did not, again lending partial support for [Hypothesis 2](#). Again the findings of [Um et al. \(2011\)](#) were partially confirmed, in that emotional design did not promote increased mental effort, though this type of design evidently reduced perceived difficulty, as was the case in the previous study.

3.3.2.4. Learners' motivation, perception of learning achievement, and satisfaction with learning. Because of the moderate correlations among motivation, perception of achievement, and satisfaction, we ran 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. Since entering prior knowledge as covariate did not change the patterns of the results we report the analyses without this covariate. The analysis revealed no main effects for Mood Induction (Wilks' Lambda = .99, $F(3, 115) = .49$, $p = .689$) or Emotional Design (Wilks' Lambda = .96, $F(3, 115) = 1.52$, $p = .212$), nor a significant effect of the interaction term (Wilks' Lambda = .95, $F(3, 115) = 1.93$, $p = .129$).

Since research is only beginning to investigate the effect of emotional design on these domains, and since this is an exploratory study of insufficiently understood phenomena, we inspected between-subject effects as a guide for future research, as suggested by Tabachnick and Fidell (2007). No main or interaction effects were identified for *satisfaction* or *perception of learning achievement* scores; however, for the *motivation* scores there was a significant main effect for Emotional Design, $F(1, 117) = 4.02$, $MSE = 293.98$, $p = .047$, $\eta_p^2 = .03$. Learners whose positive emotional state was induced internally through the design of the learning materials reported higher motivation than controls (neutral design, $M = 31.37$, $SD = 8.15$; positive design, $M = 34.49$, $SD = 8.80$; $d = .37$). This result suggests that inducing positive emotions through design increased intrinsic motivation during learning, lending partial support to Hypothesis 3 and cohering with findings from Um et al. (2011), but did not affect satisfaction or perception of learning achievement.

3.4. Discussion

The findings from Study 1 replicate several but not all of the findings of Um et al. (2011). Our results indicate that positive emotions can be induced through design (Hypothesis 1), and that emotional design facilitates cognitive processes and learning (Hypothesis 2). Specifically, we found that by employing a positive emotional design, using a combination of the visual design elements of color and shape, a positive emotional state can be induced that is sustained throughout the learning task. Furthermore, learners who studied materials that were designed to induce positive emotions performed better on comprehension outcomes than those who learned from a neutral design. However, we did not find support for the effect of positive emotional design on measures of knowledge transfer. Positive emotions induced through design reduced perceived task difficulty and increased levels of learning motivation (Hypothesis 3), but did not affect satisfaction or perception of learning achievement.

We also found indication that emotional design induces different kinds of emotions compared to using a cartoon as mood induction procedure. The differences in the patterns of learning outcomes from emotional design versus mood induction suggest that although both mood induction methods were successful, showing a medium to large effect on positive emotions for the cartoon (Cohen's $d = .68$), and a large effect for the emotional design (Cohen's $d = .88$), they work in different ways. Our data showed that the mood induction via cartoon increased the emotions *excited*, *enthusiastic*, *determined*, and *attentive*, whereas the emotional design increased *inspired* and *interested*. The only emotion that both methods affected was *enthusiastic*, but the effect for emotional design on this emotion did not reach statistical significance. These findings are reflected in the reduced task difficulty and increased level of motivation experienced by learners who received the positive design.

Interpreting this from a CATLM perspective, the emotions experienced by learners receiving the cartoon, namely *excited*, *enthusiastic*, *determined*, and *attentive*, appear to have impacted their ability to construct a mental model that allowed them to apply their knowledge to new situations, but did not focus them on the specific details required to perform well on the comprehension test.

The learners receiving the positive emotional design, on the other hand, experienced higher valence of emotions such as *inspired* and *interested*, and their perception of the task difficulty decreased, and motivation increased. These learners focused on the details of the information presented and were able to produce them on the comprehension test, but they were not able to develop deep mental models that resulted in higher transfer performance. These results also show that our comprehension and transfer tests were able to discriminate different types of knowledge. The comprehension test asked for specific definitions of terms, whereas the transfer test asked learners to apply their knowledge to answer questions related to the big ideas, not to specific details. Our results suggest that emotions resulting from different mood induction methods may impact comprehension and transfer differently.

After at least partially replicating findings from Um et al. (2011) with a new population, we next asked whether the effect of our positive emotional design that was comprised of multiple effects can be decomposed; i.e., we ask which individual design elements may induce positive emotions. Specifically, we were interested in the unique contributions of color and shape as emotional design elements in impacting emotions, learning outcomes and affective outcomes.

4. Study 2

4.1. Research questions and hypotheses

After establishing to what extent the effects we found for American undergraduate students were also found for German graduate students, Study 2 aimed to decompose the effects of the design elements *color* and *shape* by examining them in separate designs. In particular, we asked:

Hypothesis 4. Do the design elements *color* and *shape* in a multimedia learning material individually induce positive emotions in learners? Based on the previous research reported above we hypothesize that the warm colors induce more positive emotions than neutral colors, and that round face-like shapes induce more positive emotions than neutral shapes.

Hypothesis 5. How do the design elements *color* and *shape* individually affect cognitive outcomes such as invested mental effort, perceived task difficulty, and learning outcomes (comprehension and transfer)? Based on previous research we hypothesize that warm colors result in higher comprehension test scores, transfer test scores, and invested mental effort, and lower perceived task difficulty than neutral colors, and, likewise, that round, face-like shapes result in higher comprehension test scores, transfer test scores, and invested mental effort, and lower perceived task difficulty than neutral shapes.

Hypothesis 6. How do the design elements *color* and *shape* individually affect affective outcomes such as motivation, user satisfaction, and perception about learning achievement? Based on previous research we hypothesize that warm colors result in higher motivation, higher user satisfaction, and a more positive perception about learning achievement than neutral colors, and that round face-like shapes result in higher motivation, higher user satisfaction, and a more positive perception about learning achievement than neutral shapes.

4.2. Method

4.2.1. Participants and design

Participants were 103 students recruited from a German university. There were 11 male and 92 female participants, and all of them were

over 18 years old ($M = 21.83$, $SD = 2.26$). Participants were randomly assigned to one of four conditions created by two design factors with two levels each: *color* (warm or neutral), and *shape* (round face-like or neutral). All groups received the neutral external mood induction procedure (NE) to allow for comparisons with results from Study 1. The control group (NEND group) received in addition to the neutral mood induction procedure (NE) the material with neutral design (ND: neutral color and neutral shape). The NEPD group received the material with positive emotional design (PD: warm colors and round face-like shapes). The NERO group received the material with round face-like shapes (RO), but neutral colors. The NECO group received the material with warm colors (CO), but neutral shapes.

4.2.2. Materials and apparatus

4.2.2.1. Emotion induction procedure. The emotion induction procedure was the same as the neutral mood induction procedure in Study 1.

4.2.2.2. Design of learning material. The same multimedia learning environment on immunization as used in Study 1 served as the learning material. To manipulate affect, there were four different versions of emotional design. The *neutral emotional design* (NE) was developed in achromatic color (gray-scale) and with neutral shapes, as in Study 1. 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, as in Study 1. The *round shape* design featured round face-like shapes, paired with neutral colors. The *warm color* design featured bright warm hues, paired with neutral shapes (Fig. 3).

4.2.3. Measures and procedure

The measures and procedure used in this study were identical to those used in Study 1.

4.3. Results

4.3.1. Initial analyses

We first conducted bivariate correlational analyses between the scores of independent and dependent variables to assess the need for a multivariate statistical approach, (see Table 3). These preliminary analyses revealed a moderate association ($r = .34$, $p < .001$) between the learning outcomes, comprehension and transfer as well as moderate to large associations between motivation, satisfaction, and perception of learning, which ranged from $r = .28$ ($p = .004$) to $.78$ ($p < .001$), suggesting that multivariate analyses of the effect of positive emotions on learning and attitudes about learning are appropriate (Tabachnick & Fidell, 2007). We found an increase in the magnitude of correlations evident between the comprehension scores and the PAS before ($r = .02$, $p = .827$) and after ($r = .26$, $p = .009$) the learning materials and emotional manipulation. This increase in association suggests that there may be a relationship between changes in affect in the learning environment and comprehension. This same pattern was not evident in transfer scores.

4.4. Manipulation check of mood induction

4.4.1. Evidence of neutral mood

As all groups received the neutral mood induction procedure, we did not expect them to differ with regard to baseline emotions. A oneway ANOVA confirmed that there were no differences in the initial emotional state between the four experimental groups, $F(3, 103) = 2.12$, $p = .103$. All four groups therefore showed the same baseline emotions, at values indicating a neutral state of emotion.

4.4.2. Evidence of positive emotional design

An analysis of variance with repeated measures (RM-ANOVA) with condition as between-subjects factor and scores on the first

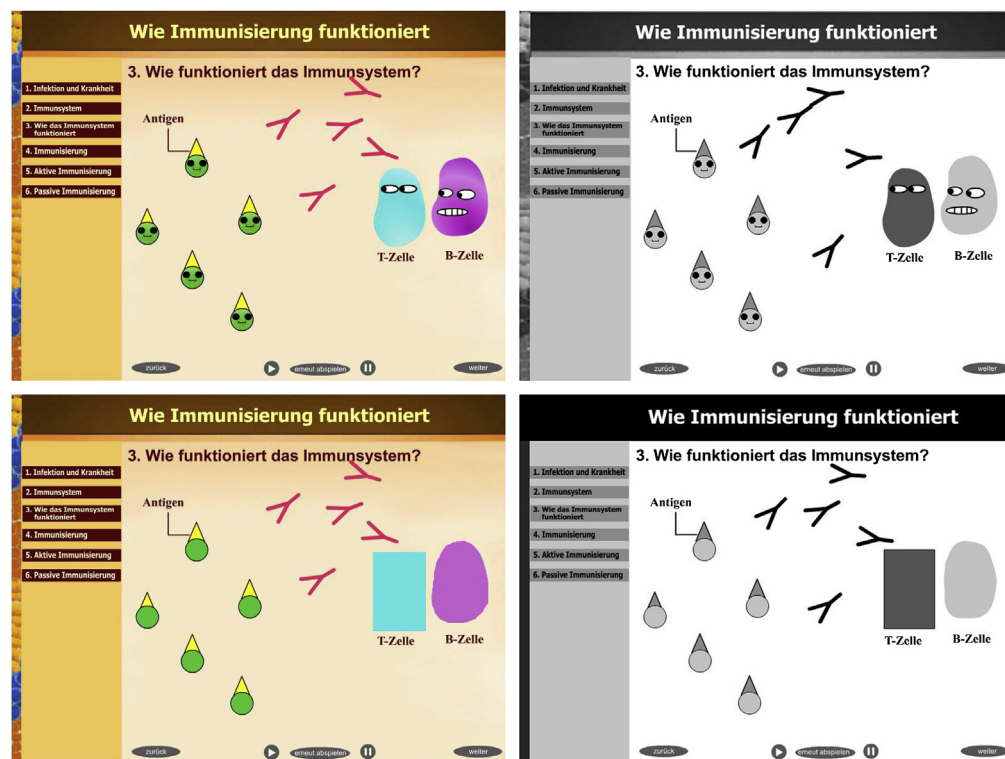


Fig. 3. Screen shots of multimedia learning materials from study 2. Translation from German: “How does Immunization Work?” (For color figures please refer to the online version of the paper.)

Table 3

Study 2 means, standard deviation, and bivariate correlations between measures.

	M	SD	PAS1	PAS2	Comp	Transf	Mental effort	Perc. diff.	Motiv.	Satis.	Percep.
Prior knowledge	4.25	1.89	.22*	.19	.17	.25*	.05	-.21*	.10	.04	.39**
PAS1	25.83	6.44	—	.50**	.02	.10	.24*	-.06	.30**	.31**	.23*
PAS2	26.91	7.04	—	—	.26**	.17	.36**	-.08	.74**	.54**	.50**
Comprehension	12.27	3.40	—	—	—	.34**	.07	-.20*	.28*	.06	.37**
Transfer	7.49	2.15	—	—	—	—	.11	-.16	.17	.10	.33**
Mental effort	4.25	1.15	—	—	—	—	—	.22*	.45**	.45**	.14
Perceived difficulty	2.94	1.23	—	—	—	—	—	—	-.09	-.05	-.24*
Motivation	32.55	9.65	—	—	—	—	—	—	—	.76**	.39**
Satisfaction	5.18	1.38	—	—	—	—	—	—	—	—	.28**
Perception	4.10	1.10	—	—	—	—	—	—	—	—	—

* $p < .05$, ** $p < .01$

and second PAS measure as repeated measures indicated no main effects for change in PAS scores or group. However, there was an interaction effect between the change in PAS scores and group, $F(3, 99) = 2.97$, $MSE = .22$, $p = .036$, $\eta_p^2 = .08$. Paired-sample t -tests revealed that the PAS scores of one group changed significantly over the course of the learning session (see Fig. 4): for the NEPD (Neutral Emotions & Positive Design) group, $t(1, 24) = -2.98$, $p = .006$, Cohen's $d = -1.22$, positive emotions increased significantly from PAS1 ($M = 24.04$, $SD = 6.37$) to PAS2 ($M = 28.04$, $SD = 8.02$). There was also a marginally significant change in PAS scores for the NERO group, $t(1, 25) = -2.04$, $p = .052$, Cohen's $d = -.81$, such that positive emotions increased from PAS1 ($M = 24.57$, $SD = 6.45$) to PAS2 ($M = 26.35$, $SD = 6.95$).

These results indicate that the positive emotional design of the learning material (i.e., warm colors and round face-like shapes), increased positive emotions during learning for those learners, lending additional support to Hypothesis 1 from Study 1, and cohering with the findings from both Study 1 as well as those of Um et al. (2011). There is also some support for Hypothesis 4, that round face-like shapes alone can induce positive emotions, though the same was not evident for warm colors alone.

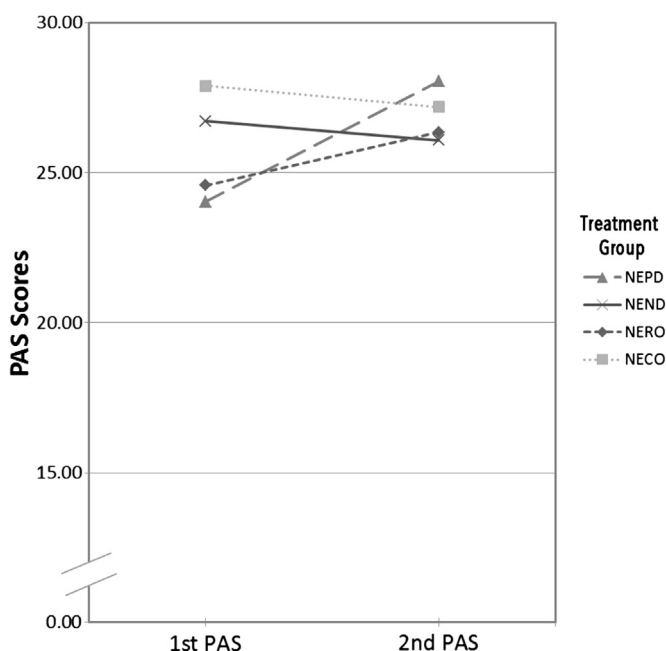


Fig. 4. Study 2 PAS scores by condition before learning (first PAS) and after the learning (second PAS). NEND—neutral mood induction procedure and neutral emotional design of material; NEPD—neutral mood procedure and positive emotional design of material, including round shapes and warm colors; NERO—neutral mood procedure and round face-like shapes; NECO—neutral mood procedure and warm colors.

4.5. Learning outcomes

The following analyses were conducted to investigate how the internal induction of positive emotions, through design that included either warm colors, round face-like shapes, or both, would affect learning outcomes compared to a neutral design. Table 4 shows means and standard deviations for all dependent variables.

Differences in self-reported prior knowledge among the four conditions were first explored. A oneway ANOVA with prior knowledge as dependent measure and condition as factor did not reveal statistically significant differences, $F(1, 99) = 1.58$, $MSE = 3.52$, $p = .199$, suggesting that self-reported prior knowledge did not differ among groups.

Because of the moderate correlation between comprehension and transfer scores, we computed a 2×2 MANCOVA with shape (neutral shape; round face-like shape) and color (neutral colors; warm colors) as between-subjects factors and comprehension and transfer scores as dependent measures. Prior knowledge was added as covariate to the model as it correlated with one of our learning outcomes and therefore accounted for some of the within-group variance. The multivariate tests revealed significant main effects for Color, Wilks' Lambda = .94, $F(2, 97) = 3.17$, $p = .046$, $\eta_p^2 = .06$, and for prior knowledge, Wilks' Lambda = .93, $F(2, 97) = 3.55$, $p = .032$, $\eta_p^2 = .07$, and a significant interaction effect for Shape and Color, Wilks' Lambda = .94, $F(2, 97) = 3.20$, $p = .045$, $\eta_p^2 = .06$. There was no main effect for Shape on learning outcomes overall, Wilks' Lambda = .96, $F(2, 97) = 2.13$, $p = .125$. Between-subject effects for each outcome measure are reported below.

4.5.1. Comprehension

In order to further investigate the effect of the two different manipulations of emotions on learners' comprehension of the multimedia materials, we inspected the between-subject effects reported by the MANCOVA for comprehension test as dependent measure. The analysis revealed a marginally significant main effect for Shape, $F(1, 98) = 3.75$, $MSE = 40.38$, $p = .056$, $\eta_p^2 = .037$, and significant main effects for Color, $F(1, 98) = 4.43$, $MSE = 47.73$, $p = .038$, $\eta_p^2 = .044$, and prior knowledge, $F(1, 98) = 4.50$, $MSE = 48.49$, $p = .036$, $\eta_p^2 = .04$. There was no interaction effect for Shape and Color ($F(1, 98) = .171$, $p = .680$). Post hoc comparisons showed that learners receiving warm colors had a higher score on the comprehension test ($M = 12.96$, $SE = .46$) than those receiving neutral colors ($M = 11.59$, $SE = .46$; Cohen's $d = .43$), and learners receiving round face-like shapes had higher scores on the comprehension test ($M = 12.90$, $SE = .46$) than learners receiving neutral shapes ($M = 11.65$, $SE = .46$; Cohen's $d = .39$). These results confirm Hypothesis 5 that both color and shape can independently affect comprehension.

4.5.2. Transfer

In order to further investigate the effect of the two different manipulations of emotions on learners' transfer of the multimedia

Table 4

Study 2 mean scores and standard deviations for each group on comprehension, transfer, mental effort, perceived difficulty, satisfaction, perception, and motivation.

	NEND (controls)	NEPD	NERO	NECO
Comprehension	11.08 (3.57)	13.48 (2.65)	12.19 (3.19)	12.33 (3.80)
Transfer	6.86 (1.97)	7.00 (1.69)	8.40 (2.53)	7.63 (2.06)
Mental effort	4.40 (.96)	4.32 (.99)	4.16 (1.34)	4.11 (1.28)
Difficulty	3.12 (1.20)	2.84 (1.25)	3.00 (1.22)	2.81 (1.30)
Satisfaction	5.36 (1.11)	5.24 (1.45)	4.84 (1.75)	5.26 (1.16)
Perception	4.04 (1.10)	4.32 (1.14)	4.08 (1.11)	3.96 (1.09)
Motivation	31.28 (9.40)	34.16 (11.10)	31.61 (9.06)	33.15 (9.23)

Note. NEND—neutral mood induction procedure and neutral emotional design of material; NEPD—neutral mood procedure and positive emotional design of material, including round shapes and warm colors; NERO—neutral mood procedure and round shapes; NECO—neutral mood procedure and warm colors.

materials, we inspected the between-subject effects reported by the MANCOVA for transfer test as dependent measure. The analysis revealed a significant interaction effect for Color and Shape, $F(1, 97) = 8.08$, $MSE = 35.03$, $p = .005$, $\eta_p^2 = .08$, and a main effect for prior knowledge, $F(1, 98) = 5.08$, $MSE = 21.32$, $p = .028$, $\eta_p^2 = .05$. No other main effects were identified.

This interaction effect was first decomposed by computing post hoc comparisons with Color held constant. When neutral colors were used in the design, there was a significant effect of Shape, $F(1, 49) = 5.87$, $MSE = 30.38$, $p = .019$, $\eta_p^2 = .11$, such that participants' transfer scores increased by nearly 2 points (NEND: $M = 6.86$, $SD = 1.97$; NERO: $M = 8.40$, $SD = 2.53$). When warm colors were used, there was no effect of Shape, $F(1, 50) = 1.41$, $MSE = 5.04$, $p = .241$. Next, the interaction was decomposed by holding the level of Shape constant. When neutral shapes were used, the effect of Color was not significant, $F(1, 50) = 1.89$, $MSE = 7.69$, $p = .175$. However, when round shapes were used, the effect of Color was significant, $F(1, 49) = 5.32$, $MSE = 24.89$, $p = .025$, $\eta_p^2 = .10$, such that participants' transfer scores decreased when warm colors were employed in addition to round shapes in the design (NERO: $M = 8.40$, $SD = 2.53$; NEPD: $M = 7.01$, $SD = 1.69$). In summary, these findings suggest that, in terms of performance on the transfer measure, the use of round face-like shapes has a unique positive effect on learning, further confirming Hypothesis 5. However, color did not have the same effect, and, in fact, was found to have a negative effect on transfer when combined with Shape.

4.5.3. Cognitive load

Cognitive load, as measured by invested mental effort and perceived difficulty of the learning task, was next explored as a dependent variable. See Table 4 for the means and standard deviations of these variables for the four conditions. For each of these measures, we computed a 2×2 ANOVA with Shape (neutral shape, round face-like) and Color (neutral color, warm hues) as between-subject factors. The ANOVAs computed on *mental effort* and *task difficulty* scores as dependent variables revealed no main or interaction effects. In summary, the factors of Color and Shape in the multimedia learning task did not uniquely impact the amount of reported mental effort learners invested or the perceived difficulty during learning, failing to lend support to Hypothesis 5.

4.5.4. Learners' motivation, perception of learning achievement, and satisfaction with learning

Table 4 shows means and standard deviations of scores for motivation, learners' perception of their learning experience, and learners' satisfaction for the four conditions. The moderate to strong correlations between motivation, perception of achievement, and satisfaction, indicate the need for a multivariate analysis of variance to determine the effect of the two different manipulations on learning outcomes. We computed a 2×2 MANOVA with

Shape (neutral shape, round face-like) and Color (neutral color, warm hues) as between-subjects factors and motivation, perception of achievement, and satisfaction as dependent measures. The analysis revealed no main effects for Shape, Color, or the interaction term. Inspection of between-subject effects revealed no main or interaction effects for *satisfaction*, *perception of learning achievement*, or *motivation* scores, which means Hypothesis 6 was not supported by our data.

4.6. Discussion

In Study 2, our results paint a more complex picture of how specific elements of design can be employed to induce positive emotions. The main effects for each element alone on comprehension were significant, although we could only confirm for shape, but not for color, that this design factor was able to induce positive emotions (Hypothesis 4) that had a statistically significant effect on enhancing comprehension. Results of learning outcome measures in Study 2 replicated findings from Um et al. (2011) and Study 1 in showing that emotional design that employed both round shape and warm color resulted in increased comprehension, as did color and shape individually (Hypothesis 5). However, an unexpected pattern was found for knowledge transfer: round shapes with face-like features uniquely contributed to learning. In fact, shape was most effective in facilitating transfer learning when used with neutral colors, but did not facilitate transfer when combined with color. Shape and color were not found to uniquely contribute to cognitive load or measures of satisfaction, motivation, or perception of learning (Hypothesis 6). Thus, findings from Study 2 provide further insight into the complexities of how the emotional design features of color and shape interact to impact learning.

5. General discussion

The purpose of this research was to replicate and extend research on the emotional design of multimedia materials and the efficacy of emotional design to facilitate learning. The Um et al. (2011) study found initial evidence supporting a facilitation hypothesis for emotional design: The positive emotional design variant was able to induce positive emotions in learners and resulted in higher comprehension performance and higher transfer performance. The authors also found that learners using the positive emotional design variant perceived these materials as less difficult, invested more mental effort in processing of the content, and reported higher levels of motivation, satisfaction, and perception toward the learning materials than learners receiving the neutral design variant. Study 1 was designed to provide a baseline for Study 2 and to verify whether findings by Um et al. (2011) could also be found with a different population and different mood induction procedure, and to determine which specific positive emotions were impacted by mood induction versus emotional design. Study 2 was designed to investigate the individual and joined contribution of color and shape as emotional design elements to facilitating comprehension and transfer in science learning. To that end, we designed two new variants of the multimedia materials that separately incorporated the emotional design modifications for color and for shape, as discussed above, and used the variant with neutral design as controls.

The present research was partially able to replicate these findings of Um et al. (2011) with a sample from a different population. Across both studies, the positive emotional design variant of the multimedia learning materials did induce positive emotion in learners; further, this design-induced positive emotional state was sustained throughout the learning task. Results of Study 2 clarify this finding, demonstrating, as a large effect, that round shapes

with face-like features alone seemed to be able to induce positive emotions, though the effect of emotional design in inducing positive emotions was largest when both round shapes with face-like features and warm colors were combined.

Results from Study 1 also replicate findings that positive emotions induced through design reduced the perceived task difficulty and increased the levels of motivation reported by learners, but the mood induction procedure did not. Previous findings by Um et al. (2011) that positive emotions induced through design increase learner mental effort, satisfaction, or positive perception of learning were not replicated in Study 1. In Study 2, shape and color were not found to be individually affecting cognitive load or measures of satisfaction, motivation, or perception of learning.

The results of our research raise a number of interesting questions. First, the lack of an overall effect of emotional design on transfer found in Study 1 is inconsistent with previous research (Um et al., 2011). Study 2 results shed light on this finding, showing that shape alone, with a neutral design for color, resulted in increased levels of transfer compared to neutral design, color alone, and a combination of shape and color. One possible explanation of this result may be the predominantly female sample of German participants compared to the more balanced sample of male and female American participants in Um et al. (2011). Research has shown gender differences in brain responses to affective visuals (Bradley, Codispoti, Sabatinelli, & Lang, 2001; Sabatinelli, Flaisch, Bradley, Fitzsimmons, & Lang, 2004) and in color preferences (Ellis & Ficek, 2001), as well as cultural differences in affective meanings of color (Adams & Osgood, 1973; Ou et al., 2010) that could have hampered the construction of a deep mental model of the subject matter, which then resulted in lower transfer scores. However, the populations used in Um et al. (2011) and the present study are both drawn from Western countries, rather than from cultures with more established perceptual differences, and further research is needed to determine whether such differences can be linked to learning outcomes such as those observed in the present studies.

Another question is related to the causal chain of effects related to emotional design. Our theoretical approach for the present study, and the previous research we reviewed, suggest that the design affected emotion, and the experienced emotion (inspired and interested) resulted in changes in the other affective variables. However, one could imagine other interpretations of our findings, for example, that the emotional design resulted in a perception of the task as easy, which led to the positive emotions we observed. Future research should further investigate the causal effects related to emotion, affect, and learning.

One could also argue that the use of face-like shapes may have increased the concreteness of the corresponding images. Research has shown that concrete words are recalled better than abstract words (Paivio, 1986; Tse & Altarriba, 2010), and an argument could be made that face-like shapes made images more concrete, resulting in better recall. However, since the modifications made to the materials did not relate to the content, i.e., the concreteness wasn't related to the subject matter taught (T-cells are just as concrete or abstract with or without face-like features), it seems less likely that the concreteness effect may have impacted our findings.

In sum, the results of both studies indicate that the presentation of well-designed learning material induces positive emotions and facilitates comprehension, but they raise a number of questions that should be addressed in future research. A facilitating effect on transfer as reported by Um et al. (2011) was not replicated in the first study; however, the second study indicated that transfer effects relate to specific design features. In particular, our analyses suggested that using round face-like shapes with neutral colors was

most effective in promoting transfer of knowledge. Given the inconsistency of this result across Um et al. (2011) and our present studies, the relationship between transfer learning and emotional design needs to be investigated further.

As is the case for all empirical studies, the design used in the present research imposes certain limitations on the generalizability of our findings. Among the limiting variables are the population used for this research, which was a mostly female sample of students at a German university, and the subject matter used, which focused on science learning. Further studies need to investigate whether our findings can be applied to other, more diverse populations and subject matter areas. In addition, the self-report measure used to assess prior knowledge is not able to provide the same insights as a test of prior knowledge, which limits the claim of group equivalency on this variable after randomization. Although the measures used to assess the amount of mental effort invested, and the task difficulty perceived by the learner, have been used successfully in previous research, they have been criticized for their psychometric shortcomings (Brünken, Plass, & Leutner, 2003). The PAS measure of positive emotions has been successfully used in the literature (e.g., Um et al., 2011; Riva et al., 2007), but may have been susceptible to response bias where participants knew they were supposed to be positively aroused by the cartoon. With regard to research on academic emotions, even though literature recommends examination of specific affects rather than simply global positive affect (Pekrun, 2005; D'Mello & Graesser, 2012), our study focused to a large extent on positive emotions rather than specific emotions because we wanted to first investigate a general effect of emotional design on learning. However, we were able to show that mood induction using a cartoon affected different emotions than emotional design, and follow-up studies should investigate how each of these emotions may differently impact learning. For such follow-up research it would also be desirable to use a continuous measure of emotion such as the biometric measures used in D'Mello and Graesser (2012) rather than the PAS used in the present study.

The research presented in this paper offers important practical as well as theoretical implications. On a practical level, findings from the current studies confirm that positive emotional feelings play an important role in multimedia learning and should therefore be taken into account when designing multimedia learning materials. Our study found that designers aiming to enhance learners' comprehension of the material can use warm colors (such as yellow and orange) rather than cold colors (such as gray) and round face-like shapes rather than square, non-face like shapes in their designs. However, more research is needed to examine the impact of emotional design on knowledge transfer, and to determine how specific positive emotions can be induced through emotional design, especially taking into account learner variables such as gender, cultural context, and prior knowledge. It also needs to be investigated whether other design elements, such as sound, that have been shown to impact comprehension and transfer (Macken, Mosdell, & Jones, 1999; Moreno & Mayer, 2000) induce emotions in learners that are related to these learning outcomes.

On the theoretical level, this research adds to the body of research emphasizing the importance of considering affective factors of learning with media. In particular, the results of our studies contribute to the *Cognitive Affective Theory of Learning with Media* (CATLM), proposed by Moreno and Mayer (2007), which incorporates motivational and metacognitive factors as mediators of multimedia learning. In support of one of the assumptions of CATLM, our results show that emotion is an important aspect of learning from multimedia materials that needs to be considered in addition to cognitive factors in order to understand the complex

process of knowledge construction in these environments. In particular, CATLM posits two functions for the visual design of multimedia learning materials, a cognitive function, related to supporting the cognitive processing of the material, and an affective function, related to influencing the learners' attitudes and motivation (Moreno, 2007). The results of our study provide empirical support for the affective function by showing that emotional design induced emotions that impact learning, and by beginning to determine the impact of specific emotional design elements, namely shape and color, on learning. It is of significance, albeit not yet fully understood, that both shape and color result in enhanced comprehension, whereas only shape affects transfer, and only when combined with neutral colors. Our research has also begun to investigate the role of specific positive emotions in complex learning processes, showing that mood induction through a cartoon induces different emotions than emotional design. Future studies should extend the Cognitive Affective Theory of Learning with Media by further extending the affective function of design, investigating how specific emotional design elements can induce specific emotions for learners from different cultural contexts and different gender.

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References

- Adams, F. M., & Osgood, C. E. (1973). A cross-cultural study of the affective meanings of color. *Journal of Cross-Cultural Psychology*, 4(2), 135–156. <http://dx.doi.org/10.1177/002202217300400201>.
- Alley, T. R. (1981). Head shape and the perception of cuteness. *Developmental Psychology*, 17, 650–654. <http://dx.doi.org/10.1037/0012-1649.17.5.650>.
- Ashby, F. G., Isen, A. M., & Turken, A. U. (1999). A neuropsychological theory of positive affect and its influence on cognition. *Psychological Review*, 106(3), 529–550. <http://dx.doi.org/10.1037/0033-295X.106.3.529>.
- Baddeley, A. D. (1986). *Working memory*. Oxford, UK: Oxford University Press.
- Bellizzi, R., & Hite, E. (1992). Environmental color, consumer feelings, and purchase likelihood. *Psychology and Marketing*, 9(5), 347–363. <http://dx.doi.org/10.1002/mar.422090502>.
- Berlyne, D. E. (1970). Novelty, complexity, and hedonic value. *Perception and Psychology*, 8, 279–286. <http://dx.doi.org/10.3758/BF03212593>.
- Berry, D. S., & McArthur, L. (1985). Some components and consequences of a babyface. *Journal of Personality and Social Psychology*, 48, 312–323. <http://dx.doi.org/10.1037/0022-3514.48.2.312>.
- Bolte, A., Goschke, T., & Kuhl, J. (2003). Emotion and Intuition: effects of positive and negative mood on implicit judgments of semantic coherence. *Psychological Science*, 14(5), 416–421. <http://dx.doi.org/10.1111/1467-9280.01456>.
- Boyatzis, C. J., & Varghese, R. (1994). Children's emotional associations with colors. *Journal of Genetic Psychology*, 155(1), 77–85. <http://dx.doi.org/10.1080/00221325.1994.9914760>.
- Bradley, M. M., Codispoti, M., Sabatinelli, D., & Lang, P. J. (2001). Emotion and motivation II: sex differences in picture processing. *Emotion*, 1, 300–319. <http://dx.doi.org/10.1037/1528-3542.1.3.300>.
- Brand, S., Reimer, T., & Opwis, K. (2007). How do we learn in a negative mood? Effects of a negative mood on transfer and learning. *Learning and Instruction*, 17(1), 1–16. <http://dx.doi.org/10.1016/j.learninstruc.2006.11.002>.
- Brünken, R., Plass, J. L., & Leutner, D. (2003). Direct measurement of cognitive load in multimedia learning. *Educational Psychologist*, 38, 53–61. http://dx.doi.org/10.1207/S15326985EP3801_7.
- Current issues and open questions in cognitive load research. (2010). In Brünken, R., Plass, J. L., & Moreno, R. (Eds.), *Cognitive load theory* (pp. 253–272). New York: Cambridge University Press.
- Cowan, N. (2001). The magical number 4 in short-term memory: a reconsideration of mental storage capacity. *Behavioural and Brain Sciences*, 24, 87–114. <http://dx.doi.org/10.1037/a0026356>.
- 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(3), 245–265. <http://dx.doi.org/10.1348/0144665031752934>.
- 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. <http://dx.doi.org/10.1046/j.0266-4909.2001.00237.x>.
- DeLeeuw, K. E., & Mayer, R. E. (2008). A comparison of three measures of cognitive load: evidence for separable measures of intrinsic, extraneous, and germane load. *Journal of Educational Psychology*, 100(1), 223–234. <http://dx.doi.org/10.1037/0022-0663.100.1.223>.
- Desmet, P. (2002). *Designing emotions*. Doctoral dissertation, Delft University of Technology, Delft, The Netherlands.
- D'Mello, S., & Graesser, A. (2012). Dynamics of affective states during complex learning. *Learning and Instruction*, 22(2), 145–157. <http://dx.doi.org/10.1016/j.learninstruc.2011.10.001>.
- D'Mello, S., Lehman, B., Pekrun, R., & Graesser, A. (2013). Confusion can be beneficial for learning. *Learning and Instruction*, 29, 153–170. <http://dx.doi.org/10.1016/j.learninstruc.2012.05.003>.
- Efklides, A., Kourkoulou, A., Mitsiou, F., & Ziliaskopoulou, D. (2006). Effort regulation, effort perceptions, mood, and metacognitive experiences: what determines the estimate of effort expenditure? *Metacognition and Learning*, 1, 33–49. <http://dx.doi.org/10.1027/1015-5759.a000145>.
- Efklides, A., & Petkaki, C. (2005). Effects of mood on students' metacognitive experiences. *Learning and Instruction*, 15(5), 415–431. <http://dx.doi.org/10.1016/j.learninstruc.2005.07.010>.
- Ellis, L., & Fieck, C. (2001). Color preferences according to gender and sexual orientation. *Personality and Individual Differences*, 31(8), 1375–1379. [http://dx.doi.org/10.1016/S0191-8869\(00\)00231-2](http://dx.doi.org/10.1016/S0191-8869(00)00231-2).
- Erez, A., & Isen, A. M. (2002). The influence of positive affect on the components of expectancy motivation. *Journal of Applied Psychology*, 87(6), 1055–1067. <http://dx.doi.org/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*. New York: Guilford Press.
- Garner, R., Brown, R., Sanders, S., & Menke, D. (1992). "Seductive details" and learning from text. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 239–254). Hillsdale, NJ: Erlbaum.
- Garner, R., Gillingham, M. G., & White, C. S. (1989). Effect of "seductive details" on macroprocessing and microprocessing in adults and children. *Cognition and Instruction*, 6(1), 41–57. http://dx.doi.org/10.1207/s1532690xci0601_2.
- 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. <http://dx.doi.org/10.1348/000709905X42860>.
- 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(1), 92–102. <http://dx.doi.org/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. <http://dx.doi.org/10.1037/0022-0663.90.3.414>.
- Hemphill, M. (1996). A note on adults' color–emotion associations. *The Journal of Genetic Psychology: Research and Theory on Human Development*, 157(3), 275–280. <http://dx.doi.org/10.1080/00221325.1996.9914865>.
- Isen, A. M., Daubman, K. A., & Nowicki, G. P. (1987). Positive affect facilitates creative problem solving. *Journal of Personality and Social Psychology*, 56(6), 1122–1131. <http://dx.doi.org/10.1037/0022-3514.52.6.1122>.
- Isen, A. M., & Reeve, J. (2005). The influence of positive affect on intrinsic and extrinsic motivation: facilitating enjoyment of play, responsible work behavior, and self-control. *Motivation and Emotion*, 29(4), 297–325. <http://dx.doi.org/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), 1–12. <http://dx.doi.org/10.1037/0022-3514.36.1.1>.
- Kalyuga, S., Chandler, P., & Sweller, J. (2000). Incorporating learner experience into the design of multimedia instruction. *Journal of Educational Psychology*, 92, 126–136. <http://dx.doi.org/10.1037/0022-0663.92.1.126>.
- Kaya, N., & Epps, H. H. (2004). Relationship between color and emotion: a study of college students. *College Student Journal*, 38, 396–405.
- Konradt, U., Filip, R., & Hoffman, S. (2003). Flow experience and positive affect during hypermedia learning. *British Journal of Educational Technology*, 34(3), 309–327. <http://dx.doi.org/10.1111/1467-8535.00329>.
- Kuhn, D. (2000). Metacognitive development. *Current Directions in Psychological Science*, 9, 178–181. <http://dx.doi.org/10.1111/1467-8721.00088>.
- Lehman, S., Schraw, G., McCrudden, M. T., & Hartley, K. (2007). Processing and recall of seductive details in scientific text. *Contemporary Educational Psychology*, 32, 569–587. <http://dx.doi.org/10.1016/j.cedpsych.2006.07.002>.
- Lenzner, A. (2009). *Visuelle Wissenskommunikation: Effekte von Bildern beim Lernen. Kognitive, affektive und motivationale Effekte [Visual communication: Effects of images in learning. Cognitive, affective, and emotional effects]*. Hamburg: Verlag Dr. Kovac.
- Linnenbrink, E. A., & Pintrich, P. R. (2002a). Achievement goal theory and affect: an asymmetrical bidirectional model. *Educational Psychologist*, 37, 69–78. <http://dx.doi.org/10.1037/a0026042>.
- 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 Publishers.
- Lorenz, K. (1950). Ganzheit und Teil in der tierischen und menschlichen Gemeinschaft [Part and parcel in animal and human societies]. *Studium Generale*, 3(9). Reprinted in Martin, R. (Ed.). (1971). *Studies in animal and human behaviour* (Vol. 2, pp. 115–195). Cambridge, MA: Harvard University Press.
- Macken, W. J., Mosdell, N., & Jones, D. M. (1999). Explaining the irrelevant-sound effect: temporal distinctiveness or changing state? *Journal of Experimental*

- Psychology: Learning, Memory, and Cognition, 25(3), 810. <http://dx.doi.org/10.1037/0278-7393.25.3.810>.
- Mayer, R. E. (2005). *Cognitive theory of multimedia learning* (2nd ed.). New York: Cambridge University Press.
- Mayer, R. E. (2009). *Multimedia learning* (2nd ed.). New York: Cambridge University Press.
- Mayer, R. E., Heiser, H., & Lonn, S. (2001). Cognitive constraints on multimedia learning: when presenting more material results in less understanding. *Journal of Educational Psychology*, 93, 187–198. <http://dx.doi.org/10.1037/0022-0663.93.1.187>.
- McGuinness, C. (1990). Talking about thinking: the role of metacognition in teaching thinking. In K. Gilhooly, M. Deane, & G. Erdos (Eds.), *Lines of thinking*, Vol. 2, (pp. 310–312). San Diego: Academic.
- Moreno, R. (2007). Optimising learning from animations by minimising cognitive load: cognitive and affective consequences of signaling and segmentation methods. *Applied Cognitive Psychology*, 21, 765–781. <http://dx.doi.org/10.1002/acp.1348>.
- 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(1), 117. <http://dx.doi.org/10.1037/0022-0663.92.1.117>.
- Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review*, 19, 309–326. <http://dx.doi.org/10.1007/s10648-007-9047-2>.
- 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, 477–493.
- Oatley, K., & Johnson-Laird, P. N. (1987). Towards a cognitive theory of emotions. *Cognition and Emotion*, 1, 29–50. <http://dx.doi.org/10.1080/02699938708408362>.
- Ortony, A., Glore, G. L., & Collins, A. (1988). *The cognitive structure of emotions*. Cambridge: Cambridge University Press.
- Ou, L.-C., Ronnier Luo, M., Sun, P.-L., Hu, N.-C., Chen, H.-S., Guan, S.-S., et al. (2010). A cross-cultural comparison of colour emotion for two-colour combinations. *Color Research & Application*, 37(1), 23–43. <http://dx.doi.org/10.1002/col.20648>.
- 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. <http://dx.doi.org/10.1037/0022-0663.84.4.429>.
- Paivio, A. (1986). *Mental representations: A dual coding approach*. New York: Oxford University Press.
- Pekrun, R. (1992). The impact of emotions on learning and achievement: towards a theory of cognitive/motivational mediators. *Applied Psychology*, 41(4), 359–376. <http://dx.doi.org/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, US: Elsevier Science. [http://dx.doi.org/10.1016/S0166-4115\(00\)80010-2](http://dx.doi.org/10.1016/S0166-4115(00)80010-2).
- Pekrun, R. (2005). Progress and open problems in educational emotion research. *Learning and Instruction*, 15(5), 497–506. <http://dx.doi.org/10.1016/j.learninstruc.2005.07.014>.
- 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(2), 91–105. http://dx.doi.org/10.1207/S15326985EP3702_4.
- Pett, D., & Wilson, T. (1996). Color research and its application to the design of instructional materials. *Educational Technology Research and Development*, 44(3), 19–35.
- Pintrich, P. R. (2003). Motivation and classroom learning. In W. M. Reynolds, & G. E. Miller (Eds.), *Handbook of psychology: Educational psychology* (pp. 103–122). New York: Wiley. <http://dx.doi.org/10.1002/0471264385.wci0706>.
- Plass, J. L., Homer, B. D., & Hayward, E. O. (2009). Design factors for educationally effective animations and simulations. *Journal of Computing in Higher Education*, 21(1), 31–61. <http://dx.doi.org/10.1007/s12528-009-9011-x>.
- Plass, J. L., Moreno, R., & Brünken, R. (Eds.). (2010). *Cognitive load theory*. New York: Cambridge University Press.
- Riva, G., Mantovani, F., Capideville, C. S., Preziosa, A., Morganti, F., Villani, D., et al. (2007). Affective interactions using virtual reality: the link between presence and emotions. *CyberPsychology & Behavior*, 10(1), 45–56. <http://dx.doi.org/10.1089/cpb.2006.9993>.
- Russell, J. A. (2003). Core affect and the psychological construction of emotion. *Psychological Review*, 110(1), 145–172. <http://dx.doi.org/10.1037/0033-295X.110.1.145>.
- Sabatinelli, D., Flaisch, T., Bradley, M. M., Fitzsimmons, J. R., & Lang, P. J. (2004). Affective picture perception: gender differences in visual cortex? *NeuroReport*, 15(7), 1109–1112.
- Sweller, J., Ayres, P., & Kalyuga, S. (2011). *Cognitive load theory*. New York: Springer. <http://dx.doi.org/10.1007/978-1-4419-8126-4>.
- 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(1), 23–42.
- Tabachnick, B. G., & Fidell, L. S. (2007). *Using multivariate statistics*. Boston: Pearson.
- Tractinsky, N., Katz, A. S., & Ikar, D. (2000). What is beautiful is usable. *Interacting with Computers*, 13, 127–145. [http://dx.doi.org/10.1016/S0953-5438\(00\)00031-X](http://dx.doi.org/10.1016/S0953-5438(00)00031-X).
- Tse, C.-S., & Altarriba, J. (2010). The word concreteness effect occurs for positive, but not negative, emotion words in immediate serial recall. *British Journal of Psychology*, 100(1), 91–109. <http://dx.doi.org/10.1348/000712608X318617>.
- Tucker, J. (1987). Psychology of color. *Target Marketing*, 10(7), 40–49.
- Um, E., Plass, J. L., Hayward, E. O., & Homer, B. D. (2011). Emotional design in multimedia learning. *Journal of Educational Psychology*, 104(2), 485–498. <http://dx.doi.org/10.1037/a0026609>.
- 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(6), 1063–1070. <http://dx.doi.org/10.1037/0022-3514.54.6.1063>.
- Westermann, R., Spies, K., Stahl, G., & Hesse, F. W. (1996). Relative effectiveness and validity of mood induction procedures: a meta-analysis. *European Journal of Social Psychology*, 26(4), 557–580. doi:10.1002/(SICI)1099-0992(199607)26:4<557::AID-EJSP769>3.3.CO;2-W.
- Wolfson, S., & Case, G. (2000). The effects of sound and color on responses to a computer game. *Interacting with Computers*, 13, 183–192. [http://dx.doi.org/10.1016/S0953-5438\(00\)00037-0](http://dx.doi.org/10.1016/S0953-5438(00)00037-0).