Facilitators or suppressors: Effects of experimentally induced emotions on multimedia learning

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ABSTRACT

The present study investigated the influence of experimentally induced emotions (positive, neutral, negative) on learning with multimedia instruction with \( N = 75 \) university students. In order to provide sound explanations about how emotional state might impact learning, measures of motivation, cognitive load, and attentional processes (eye tracking) were integrated. Results showed that while emotions did not influence retention, emotions did influence outcomes of the comprehension and transfer test. Specifically, a facilitating effect of an induced negative emotional state on learning outcomes was observed, which could be attributed to a more focused and detailed information processing. In contrast, an induced positive emotional state had a suppressing effect on learning outcomes since learners were distracted from the learning materials by their emotions. Motivational measures were not influenced by learners’ different emotional states, but overall, controlled motivation increased and autonomous motivation decreased during learning. In sum, the learners’ emotional state should be considered in learning research as an important predictor for learning success.

1. Introduction

Do emotions suppress or facilitate successful learning? Even though there is a consensus that emotions do influence learning (e.g., Pekrun & Linnenbrink-Garcia, 2014), there are inconsistent findings on the direction of effects (e.g., Um, Plass, Hayward, & Homer, 2012). Thus, two contrasting hypotheses can be derived: The emotions-as-suppressor-of-learning hypothesis postulates that emotions may impair learning, while the emotions-as-facilitator-of-learning hypothesis assumes that emotions lead to better learning outcomes (Um et al., 2012). The validity of both hypotheses is supported by further theoretical considerations explaining how emotions influence cognitive processes and learning outcomes (e.g., Pekrun, 2006).

There is a lack of studies investigating the role of the learners’ emotional state and its impact on learning outcomes, particularly in multimedia research (Park, Plass, & Brünken, 2014). In the last decade, an expansion of theoretical assumptions in multimedia learning has initiated studies which also include affective measures (Moreno, 2006; Moreno & Mayer, 2007). A body of studies now exists on the influence of an emotionally appealing design on learning (Mayer & Estrella, 2014; Park, Knörzer, Plass, & Brünken, 2015; Plass, Heidig, Hayward, Homer, & Um, 2014; Um et al., 2012) and affective measures (Heidig, Müller, & Reichelt, 2015). While some multi-factorial studies have examined the effects of experimentally-induced positive emotions on learning (e.g., Park, Knörzer, et al., 2015), there has been no research to-date on the effects of experimentally-induced negative emotions on learning (Park, Flowerday, & Brünken, 2015).

In the present study, learners were exposed to a positive, neutral or negative emotion-induction procedure with the intent to investigate the impact of different emotional states on learning outcomes. Measures of motivation, cognitive load and attentional processes (eye tracking) were used in order to provide sound explanations about how emotional state might impact learning.

2. Theoretical framework

2.1. Emotions

The present study refers to the construct of emotion as a multi-faceted phenomenon through which affective, cognitive, physiological, motivational, and expressive processes combine into an emotional episode (Pekrun, 2006; Pekrun & Linnenbrink-Garcia, 2014).

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2014; Russell, 2003; Shuman & Scherer, 2014). Although some authors have distinguished between the concepts of affect, emotion, and mood in terms of their intensity and duration (e.g., Sokolowski, 2008) affect can be understood as a broader category subsuming emotion and mood (Shuman & Scherer, 2014). Following this assumption, the differentiation regarding intensity and duration classifies mood to be a more prolonged affective state of low intensity whereas an emotion is more intense and of rather short duration (Shuman & Scherer, 2014). The assumed short duration of emotions can lead to short-term changes of emotional state (e.g., during a learning phase; D’Mello & Graesser, 2012) whereas the overall mood state might stay the same (cf. Russell, 2003).

As proposed in Russell’s Circumplex Model of Affect emotions are arranged with respect to the two orthogonal dimensions activation, activating – deactivating, and valence, positive – negative, (Russell, 2003; see also; Pekrun, 2006). As an example, happiness is an activating and positive emotion and satisfaction is classified as deactivating and positive. For emotions with a negative valence, sadness is a deactivating whereas anger is an activating emotion. A further, modified version of Russell’s model differentiates between positive and negative activation (instead of activation and valence). The authors argue that these dimensions allow a better classification of emotions within empirically stable dimensions (Tellegen, Watson, & Clark, 1999; Watson, Clark, & Tellegen, 1988). However, in line with the theoretical assumptions of the primary model by Russell (2003), and for reasons of face validity, recently, the valence dimension was reinstituted in emotion assessment measures (Schallberger, 2005; see Fig. 1).

2.2. Multimedia learning

The Cognitive-Affective Theory of Learning with Media (CATLM) integrates cognitive and affective aspects of learning with respect to multimedia research (Moreno, 2006; Moreno & Mayer, 2007). Within CATLM, cognitive processes are initiated via verbal and non-verbal elements of a multimedia instruction. Learning content is selected, then organized and integrated with prior knowledge in order to build a coherent mental model. According to the assumptions of the CATLM, these cognitive processes take place within two independent information processing channels in working memory (Baddeley, 1986) where verbal and non-verbal information can be processed simultaneously and coded dually (Paivio, 1986). As working memory capacity has been shown to be limited active processing of the whole learning content is only possible when learning environments are designed in an optimal way to minimize extraneous challenges to working memory processes (Mayer, 2005). CATLM also states that three factors have an additional impact on multimedia learning: The affective mediation construct postulates that affective and motivational factors influence learning. The meta-cognitive mediation construct assumes that meta-cognitive and self-regulatory skills mediate learning by regulating cognitive and affective processes. The individual differences assumption indicates that learners’ prior knowledge, cognitive styles, abilities, and personality traits affect the efficiency of multimedia instructions (see Fig. 2).

2.3. Emotions and learning

Um er al. (2012) introduced the emotions-as-facilitator-of-learning and the emotions-as-suppressor-of-learning hypotheses highlighting that there are different underlying assumptions and inconsistent findings regarding the impact of emotions on learning. Many studies report beneficial effects of positive emotions and detrimental effects of negative emotions on cognitive processes (Isen, Daubmann, & Nowicki, 1987). However, results of studies incorporating valence-congruent effects are not consistent and sometimes neglect variables that may significantly influence the interplay of emotions and learning (e.g., Ellis, Thomas, & Rodríguez, 1984; Isen et al., 1987; Oaksford, Morris, Grainger, & Williams, 1996). Further, there are other studies reporting negative effects of positive emotional states (e.g., Seibert & Ellis, 1991) or positive effects of negative emotional states (e.g., Sinclair & Marks, 1992) on cognitive processes. Four different assumptions, that support either the facilitating or suppressing hypothesis, can be derived, which help explaining how emotions influence learning.

2.3.1. Extraneous load assumption

Contributing to the emotions-as-suppressor-of-learning hypothesis, this assumption postulates that both positive and negative emotions impair learning via consumption of working memory capacity compared to a neutral or balanced emotional state. Remembering the cognitive component of emotions, being in a positive or negative emotional state means that additional (emotional) cognitions are to be held in working memory beside a primary activity, e.g., learning. In terms of Cognitive Load Theory (Plass, Moreno, & Brünken, 2010; Sweller, Ayres, & Kalyuga, 2011), emotions impose extraneous cognitive load because they do not contribute to the generative learning processes associated with germane load. Studies supporting this assumption demonstrated a detrimental effect of experimentally induced positive and negative emotions on information processing (e.g., Ellis et al., 1984). In other research, emotions were found to hinder deductive reasoning processes (Oaksford et al. 1996).

2.3.2. Motivation assumption

The motivation assumption primarily contributes to the emotions-as-facilitator-of-learning hypothesis. It hypothesizes that emotions of positive or negative valence will foster motivation which will lead to better learning outcomes (Pekrun, 2006). For positive emotions, which are assumed to increase intrinsic motivation, this is a plausible construct. The assumption concerning negative emotions can be explained by the mood repair principle (Bless & Fiedler, 2006). The mood repair principle states that humans in negative emotional states seek to improve their affect, which can be regarded as an evolutionary motivational tendency.
Learning activities requiring cognitive engagement may help learners shift attention away from their negative emotional state because it diverts negative emotional thoughts (Fiedler, Nickel, Asbeck, & Pagel, 2003). Furthermore, it is suggested that learners who are experiencing a negative emotional state invest more effort in learning to improve their emotional state. The investment of effort, sometimes unconsciously, is exerted from the knowledge that past learning success evoked a positive emotional state. In this sense, negative emotions will increase extrinsic motivation. Empirical findings on this assumption indicate that positive emotions enhance intrinsic motivation. However, empirical studies thus far are inconsistent regarding negative emotions with some studies reporting an increase of extrinsic motivation (Pekrun et al., 2002), and others reporting a decrease in intrinsic motivation and the willingness to learn (Kim & Hodges, 2012; Turner, Thorpe, & Meyer, 1998).

2.3.3. Attention assumption

Focusing attention on learning materials is a prerequisite for information processing and successful learning. The attention assumption postulates that emotions influence a learner’s attention by altering the scope of attention or diverting attentional focus. Studies have found that positive emotions broaden the scope of attention (Frederickson & Branigan, 2005), whereas, negative emotions lead to a narrowed attentional focus (Frederickson, 2000; Kaspar & Koenig, 2012). This phenomenon has also been found in analyses of eye movement patterns (Kaspar et al., 2013). In addition, research indicates that positive and negative emotions distract from the learning material by inducing irrelevant thoughts (Seibert & Ellis, 1991), signifying that emotions interfere with optimal attentional focus on learning material and lead to lower learning outcomes.

2.3.4. Processing styles assumption

A study by Kuhl (2000) showed that processing styles differ with different emotional states. Positive emotions foster heuristic processing and lead to more holistic information processing (Bless & Fiedler, 2006). This coincides with more divergent and creative thinking (Isen et al., 1987). However, this processing style can also lead to more superficial information processing accompanied by considering less details (Bodenhausen, 1993). In contrast, negative emotions lead to a more convergent and analytic processing style accompanied by detailed information processing (Fiedler et al., 2003; Sinclair & Marks, 1992). The processing styles assumption speculates that the innate structure of learning materials or of the learning content or the learning task itself determine whether emotions suppress or facilitate successful information processing. In other words, being in a positive emotional state facilitates working on heuristic information, whereas being in a negative emotional state enhances processing of analytic information.

In summary, the four introduced assumptions provide a possible explanation for the inconsistent results in the literature regarding emotions and cognitive processes. These assumptions should be regarded as complementary rather than mutually exclusive: accepting one assumption does not mean rejecting others. Hence, all assumptions contribute in the end to a comprehensive explanation of findings. It should be noted that there might not be one assumption holding for all emotional states but that different assumptions account for different discrete emotions. In addition, inconsistent findings from the literature may be attributed to variability in the specific learning measures employed by each study. To account for this possibility, in the present study several measures were used to assess different levels of learning outcomes (i.e. retention, comprehension, and transfer) and subjective dimensions of learning (e.g., perceived task difficulty). Additional variables were also included to be consistent with previous research examining the four theoretically derived assumptions.

2.4. Research questions and hypotheses

The aim of the present study was to investigate the impact of the learners’ emotional state on multimedia learning outcomes. Learners were exposed to a positive, neutral or negative emotion.
induction procedure before working with multimedia instruction. Since previous empirical results and the derived theoretical hypotheses are inconsistent, no direction of effects was predicted in the following four hypotheses.

**Hypothesis 1.** The three experimental groups will differ regarding their learning outcomes with respect to their performance in retention, comprehension and transfer tasks. According to the emotions—as-facilitator and the emotions—as-suppressor of learning hypotheses (see above), the respective direction of effects of induced positive or negative emotions cannot be specified in the hypothesis.

**Hypothesis 2.** In line with the motivation assumption, the emotion induction will alter learners’ extrinsic and intrinsic motivation, and the three experimental groups are predicted to show different patterns of motivational shifts during learning pursuant to the direction of induced emotions’ effects on learning outcomes.

**Hypothesis 3.** In line with the attention assumption and the processing styles assumption, the three experimental groups are predicted to have differing eye movement patterns pursuant to the direction of induced emotions’ effects on learning outcomes, which reflect the focus of learners’ attention and cognitive activity.

**Hypothesis 4.** In line with the extraneous load assumption, the three experimental groups are predicted to differ in subjective dimensions on cognitive load, perceived task difficulty, and learning outcomes.

### 3. Method

#### 3.1. Participants and experimental design

The study was carried out in a one-factorial experimental design utilizing three experimental groups that received either a positive (POS), neutral (NEU) or negative (NEG) emotion induction before learning. Seventy-five university students enrolled at a university in Germany (69.33% female, age: \( M = 24.01 \) years, \( SD = 3.44 \)) participated voluntarily in the experiment either for course credits or payment. All participants were randomly assigned to one of the three experimental groups.

#### 3.2. Materials

**Emotion Induction.** The emotion induction procedure (see Lench, Flores, & Bench, 2011 for an overview) was designed to induce distinctive emotional states within the model of emotions distinguishing the valence and activation dimension (Pekrun, 2006). Hence, the positive emotion induction referred to happiness as a positive activating emotion whereas the negative emotion induction induced sadness as a negative deactivating emotion. The neutral emotion induction can be seen as a mellowing or neutralizing induction regarding prevailing emotional states (Chastain, Seibert, & Ferraro, 1995). The emotion induction procedure was carried out using a combination of music and autobiographic recall (Eich, Ng, Macaulay, Percy, & Grebnev, 2007). In the groups with the positive or negative emotion induction participants were told to recall a happy or sad event in their lives as vividly as possible, as if they were reliving the situation (c.f. Ellsworth & Smith, 1988; Jefferies, Smiley, & Eich, 2008). Then, while listening to the music, the participants were instructed to recall as many details as possible about their chosen event and to take notes about it. The musical pieces used to induce emotion were selected from lists of music that had already been successfully applied in emotion induction procedures (Gerrards-Hesse, Spies, & Hesse, 1994; Jefferies et al., 2008), and on the basis of their musical parameters, were connected to certain emotional responses (Vaestflaell, 2002). As positive musical piece, Mozart’s Divertimento No. 136 was used to induce the positive emotion. Sibelius’ Swan of Tuonela was used for the negative emotion induction. The group in the neutral condition did not listen to music, because emotionally neutral music is essentially impossible to find (Wood, Saltzberg, & Goldsamt, 1990). Participants in the neutral condition were asked to remember and describe a common Wednesday morning (Kühnbänder, Lichtenfeld, & Pekrun, 2011). All induction procedures had a comparable length of about 7:30 min in duration and were successfully pretested.

**Learning Material.** An established multimedia instruction about biology, specifically structure and function of the ATP synthase, served as learning material (e.g., Park, Flowerday, et al., 2015; see Fig. 3). With the learning program, students get to know the structure of the ATP-synthase molecule and learn about the process of ATP synthesis. The learning program contained eleven screens with text and a corresponding static picture respectively, which were presented on an eye tracking computer screen. These text-picture combinations on each screen present the relevant content to be learned. A pre-set, paced learning time was applied for each screen; the whole learning phase had a duration of 10:40 min.

#### 3.3. Measures

**Emotion Questionnaire.** The participants’ emotional state was assessed applying the PANAVA short scales (Schallberger, 2005) with the three scales positive activation (PA), negative activation (NA) and valence (VA). The PA and NA scales comprised four bipolar items respectively (PA: Cronbach’s \( \alpha = 0.73, 0.87 \); NA: Cronbach’s \( \alpha = 0.75, 0.75 \)). The VA scale originally contained two bipolar items. Due to reliability concerns a third item (“happy – sad”) was added to the scale (VA: Cronbach’s \( \alpha = 0.75, 0.92 \)). The items had to be rated on 7-point Likert scales.

**Learning Outcomes.** As dependent measures, learning performance tests were administered. The differentiation between different levels of required cognitive processing was considered by using the three subscales retention, comprehension, and transfer. All items met satisfactory item parameters with a difficulty index \( 0.20 < \pi_i < 0.80 \) as well as a discrimination index \( r_i(e_i) > 0.20 \). The retention test (Cronbach’s \( \alpha = 0.70 \); max. 8.5 points) included 6 questions of different formats (2 multiple-choice, 2 drag-and-drop, 2 open-format items) asking for declarative knowledge (“Please identify corresponding verbal and pictorial elements.”). The comprehension test (Cronbach’s \( \alpha = 0.80 \); max. 13.5 points) comprised 9 questions (3 multiple-choice, 2 drag-and-drop, 4 open-format items; “What is the function of the F0 portion? – transport of protons into the matrix; transport of protons into the inter-membrane space; the generation of proton-motive force; the formation of the proton gradient”) and the transfer test (Cronbach’s \( \alpha = 0.74 \); max. 8 points) consisted of 7 open-format questions (“Which cells do feature the largest number of mitochondria? Please, justify your answer.”). Answers of the open-format questions were rated by two independent raters (ICC(2,2) = 0.93) who resolved differences in scores by discussion.

**Motivation.** The Situational Motivation Scale (SIMS; Gillet, Vallerand, Lafreniere, & Bureau, 2013; Guay, Vallerand, & Blanchard, 2000) served as motivation questionnaire. Analogous to the study by Gillet et al. (2013), two different motivation indicators were computed. First, autonomous motivation was assessed using 8 items (Cronbach’s \( \alpha = 0.83, 0.88 \)) asking for the extent to which an activity is done out of own volition and choice (Deci & Ryan, 2000). Second, controlled motivation (8 items; Cronbach’s \( \alpha = 0.68, 0.83 \)) refers to the extent to which people pursue an activity due to feelings of pressure (Deci & Ryan, 2000). All items were assessed on
7-point Likert scales.

Eye tracking. As a process measure, during learning eye movements were recorded with a remote eye tracking system (Tobii Eyetracker TX300) which is integrated in a 23 inch TFT (1929 × 1080 pixel) monitor operating with a sample rate of 300 Hz. For analyses, only participants with less than 25% of missing data were considered. Therefore, 10 participants had to be excluded from the sample for analysis of the eye tracking variables. Participants’ eye movements were analyzed with regard to predefined Area Of Interest (AOI) containing the relevant information of the learning program (see Fig. 3). Accounting for the eye-mind hypothesis telling that information is simultaneously processed when it is fixated (Just & Carpenter, 1976; Rayner, 1998), analyses of the eye tracking data included two indicators for perception processes associated with cognitive processing. First, the percentage of recorded fixation time on relevant information was analyzed as an overall measure for paying attention to the learning material. Second, the absolute number of fixations on the relevant learning content was considered as a measure for the learners’ cognitive activity during learning (Cohen & Hegarty, 2010; De Koning, Tabbers, Rikers, & Paas, 2010).

Additional Dependent Measures. To measure cognitive load, participants completed a subjective rating scale on invested mental effort (“How much mental effort did you invest in studying the previous material?”; Paas, 1992). Participants also completed an item on their perception of task difficulty (“How easy or difficult was the material to understand?”; Kalyuga, Chandler, & Sweller, 2000). Even though these scales have been successfully used in previous research, it has to be considered that they are still under discussion (Brünken, Seufert, & Paas, 2010). Specifically, only construct validity can be claimed for the present one-item scales as indicators for cognitive load. For further studies it is highly recommended to use objective methods allowing a continuous cognitive load measurement (Park & Brünken, 2015). Since the present study applies eye tracking as an objective process measure delivering interesting insight into cognitive activity, the used items should be seen as add-on information to support coherent interpretation. An additional item asked for the participants’ subjective learning outcomes (“How well do you think you did in the preceding tests?”). These three items were assessed on 7-point Likert scales.

Control Variables. As control measure, the Corsi Block-Tapping Task (Kessels, Van Zandvoort, Postma, Kapelle, & De Haan, 2000) was administered to assess learners’ working memory capacity. Participants had to remember a sequence of numbers related to touched cubes on a board and then, repeat the sequence in backward direction (Kessels, Van Den Berg, Ruis, & Brands, 2008). This task requires processes that are associated with the visuo-spatial part of working memory, which is relevant for working successfully with a multimedia instruction where textual and pictorial information has to be mentally integrated. In addition, prior knowledge was assessed using a prior knowledge test before learning with 5 items in open or multiple-choice format (Cronbach’s α = 0.76). Emotion regulation strategies were assessed using a German version of the Emotion Regulation Questionnaire (ERQ; Abler & Kessler, 2009; Gross & John, 2003). The questionnaire included two common dimensions of emotion regulation strategies: Regarding reappraisal (6 items, Cronbach’s α = 0.73), participants had to rate to what extent they try to change their thoughts in order to regulate their positive/negative emotions (c.f. Lazarus & Alfert, 1964). The four items concerning suppression (Cronbach’s α = 0.82) asked to what extent the participants express their feelings. The items of the questionnaire were rated on 7-point Likert scales.

3.4. Procedure

Participants were individually tested in a laboratory setting for about 90 min. First, baseline measures of emotion, and motivation were assessed. Next, the working memory test was administered, after which participants completed the prior knowledge test. Then, participants received the positive, neutral or negative emotion induction and answered the emotion questionnaire as a
manipulation check of success of the emotion induction. An eye tracker calibration was conducted before the learning program was presented. During learning, after slide 4/11 of the learning program, participants answered the items regarding mental effort and perceived task difficulty. Immediately after learning, participants completed the motivation questionnaire for a second time. Finally, the retention, comprehension and transfer test were administered (without time restriction) and participants rated their subjective learning outcome.

4. Results

We applied $\alpha = 0.05$ as level of significance for all global tests of significance. For all contrast tests (all two-tailed) between the three experimental groups Bonferroni-Holm corrections were applied in order to control for $\alpha$-error inflation. Means and standard deviations of all variables regarding values in the three experimental groups are displayed in Table 1.

One-factorial ANOVAs with the control and baseline measures as respective dependent variables detected no significant between-group differences (working memory capacity: $F(2,72) = 1.12$, n.s.; prior knowledge, $F < 1$; emotion regulation strategies: suppression, $F(2,72) = 2.24$, n.s.; reappraisal, $F(2,72) = 2.60$, n.s.; autonomous and controlled motivation, $F_s < 1$). Therefore, internal validity concerning these potentially relevant variables is secured.

4.1. Manipulation check

In the emotions’ baseline, there were no significant differences between the three experimental groups as revealed by subsequent one-factorial ANOVAs with positive activation, negative activation, and valence values (PA: $F < 1$; NA: $F(2,72) = 1.39$, n.s.; VA: $F < 1$). Moreover, the three experimental groups differed significantly from each other regarding their emotional states after the emotion induction (see Fig. 4). Specifically, there was a large effect in PA for the between-subject factor, $F(2,72) = 16.61$, $p = 0.001$, $\eta^2 = 0.42$, telling that the group with the positive emotion induction showed highest ratings on this scale in contrast to the other groups (POS−NEU: $\Delta M = 0.68$, $p = 0.018$; POS−NEG: $\Delta M = 1.61$, $p = 0.002$). On the NA scale, the significant difference, $F(2,72) = 15.07$, $p = 0.001$, indicated that ratings in the group with the negative emotion induction were higher than in the other two groups, respectively (NEG−NEU: $\Delta M = 0.82$, $p = 0.004$; NEG−POS: $\Delta M = 1.45$, $p = 0.002$). On the valence scale the three groups differed significantly from each other in the assumed directions, $F(2,72) = 58.23$, $p = 0.001$, $\eta^2 = 0.62$. The group with the positive emotion induction reported highest valence values whereas the group with the negative emotion induction reported lowest (POS−NEU: $\Delta M = 0.80$, $p = 0.006$; NEU−NEG: $\Delta M = 2.12$, $p = 0.002$; POS−NEG: $\Delta M = 2.92$, $p = 0.002$). Hence, the experimental manipulation was successful which imposes a premise for later interpretation of the results.

4.2. Learning outcomes

A MANOVA was computed using group as between-subject factor (Fig. 5) for the three dependent learning outcome variables (retention, comprehension, and transfer). There was a multivariate effect for the group indicating that the groups differed significantly in learning outcomes, $\Lambda = 0.82, F(6,138) = 2.39, p = 0.031$, $\eta^2 = 0.09$. The attached univariate analyses revealed that the groups showed no significant difference in retention, $F(2,72) = 2.20$, n.s., but in comprehension, $F(2,72) = 3.76, p = 0.028$, $\eta^2 = 0.10$, and in transfer, $F(2,72) = 6.42, p = 0.003$, $\eta^2 = 0.15$. Contrast tests between the three groups concerning comprehension outcomes confirmed that the group with the negative emotion induction showed a significantly higher performance than the group with the positive emotion induction (POS−NEG: $\Delta M = 2.50$, $p = 0.009$; POS−NEU: $\Delta M = 1.61$, n.s.; NEG−NEU: $\Delta M = 0.89$, n.s.). In addition, learners in a positive emotional state showed significantly lower transfer outcomes than learners in the groups with the neutral and negative emotion induction (POS−NEG: $\Delta M = 1.87$,

Table 1

<table>
<thead>
<tr>
<th></th>
<th>POS n = 25</th>
<th>NEU n = 25</th>
<th>NEG n = 25</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M (SD)</td>
<td>M (SD)</td>
<td>M (SD)</td>
</tr>
<tr>
<td>Prior knowledge [max − 5]</td>
<td>1.08 (1.54)</td>
<td>1.62 (1.67)</td>
<td>1.56 (1.64)</td>
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<td>Working memory capacity</td>
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<td>8.33 (2.12)</td>
<td>9.20 (2.10)</td>
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<tr>
<td>Reappraisal [max − 7]</td>
<td>4.52 (0.96)</td>
<td>5.05 (1.03)</td>
<td>4.61 (0.72)</td>
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<td>Suppression [max − 7]</td>
<td>3.07 (1.27)</td>
<td>3.78 (1.42)</td>
<td>3.42 (0.95)</td>
</tr>
<tr>
<td>PA t1 [max − 7]</td>
<td>4.66 (0.90)</td>
<td>4.77 (0.86)</td>
<td>4.62 (0.94)</td>
</tr>
<tr>
<td>PA t2 [max − 7]</td>
<td>5.27 (0.86)</td>
<td>4.59 (1.18)</td>
<td>3.66 (0.91)</td>
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<td>NA t1 [max − 7]</td>
<td>2.49 (1.13)</td>
<td>3.00 (0.98)</td>
<td>2.43 (0.92)</td>
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<td>2.77 (0.99)</td>
<td>3.59 (0.81)</td>
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<td>VA t1 [max − 7]</td>
<td>5.60 (0.80)</td>
<td>5.60 (0.96)</td>
<td>5.69 (0.62)</td>
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<td>VA t2 [max − 7]</td>
<td>5.97 (0.88)</td>
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<td>3.05 (1.01)</td>
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<td>Retention [max − 8.5]</td>
<td>4.90 (2.44)</td>
<td>5.94 (2.64)</td>
<td>6.22 (2.09)</td>
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<tr>
<td>Comprehension [max − 13.5]</td>
<td>5.08 (3.60)</td>
<td>6.69 (3.71)</td>
<td>7.58 (2.75)</td>
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<td>Transfer [max − 8]</td>
<td>1.19 (1.23)</td>
<td>2.31 (1.89)</td>
<td>3.06 (2.22)</td>
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<td>4.37 (1.16)</td>
<td>4.57 (1.08)</td>
<td>4.36 (0.77)</td>
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<td>Autonomous motivation t2 [max − 7]</td>
<td>4.32 (1.29)</td>
<td>4.57 (1.04)</td>
<td>3.95 (0.94)</td>
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<tr>
<td>Controlled motivation t1 [max − 7]</td>
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<td>2.42 (0.93)</td>
<td>2.40 (1.07)</td>
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<td>Controlled motivation t2 [max − 7]</td>
<td>2.71 (1.05)</td>
<td>2.55 (1.02)</td>
<td>2.61 (1.21)</td>
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<tr>
<td>Percentage relevant fixations [decimals]</td>
<td>0.89 (0.07)$^{ab}$</td>
<td>0.89 (0.13)$^{bc}$</td>
<td>0.94 (0.03)$^{bc}$</td>
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<tr>
<td>Number of fixations</td>
<td>1142.57 (384.63)$^a$</td>
<td>1274.63 (236.71)$^b$</td>
<td>1274.63 (236.71)$^b$</td>
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<td>Cognitive load [max − 7]</td>
<td>4.88 (1.15)</td>
<td>4.42 (1.56)</td>
<td>4.44 (1.08)</td>
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<td>Task difficulty [max − 7]</td>
<td>4.88 (1.05)</td>
<td>3.96 (1.57)</td>
<td>4.12 (1.30)</td>
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<td>Subj. learning performance [max − 7]</td>
<td>2.52 (1.42)</td>
<td>2.68 (1.55)</td>
<td>3.04 (1.14)</td>
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</tbody>
</table>

PA = Positive Activation; NA = Negative Activation; VA = Valence; t1 = first measurement point (baseline); t2 = second measurement point.

$^a$ n = 20 due to missing data.

$^b$ n = 21 due to missing data.

$^c$ n = 24 due to missing data.
\( p = 0.001, \text{POS} - \text{NEU}: \Delta M = 1.13, p = 0.022; \text{NEG} - \text{NEU}: \Delta M = 0.75, \text{n.s.} \). Therefore, the hypothesis that emotions influence learning was supported concerning comprehension and transfer outcomes: A positive emotional state suppressed successful learning processes whereas a negative emotional state facilitated learning.

### 4.3. Motivation

In order to detect motivational shifts during learning, a RM-ANOVA with group as between-subject factor, and autonomous motivation values as repeated measure was computed (see Fig. 6). There was an effect of the measurement point, \( F(1,72) = 6.71, p = 0.012, \eta^2 = 0.09 \), indicating that autonomous motivation changed significantly during learning. There were neither an effect of the group factor nor an interaction of both factors, \( F_s < 1 \). Further analyses revealed that in the groups with the neutral and positive emotion induction, there were no significant changes during learning (POS: \( t(24) = 0.34, \text{n.s.} \); NEU: \( t(24) = 1.33, \text{n.s.} \)). The overall effect originated from a significant decrease of autonomous motivation in the group with the negative emotion induction, \( t(24) = 3.17, p = 0.004 \).

Another RM-ANOVA with controlled motivation values of two measurement points as dependent variables revealed no group
differences and no interaction between group and measurement point, $F_s < 1$. However, there was again an overall effect of the measurement point, $F(2,72) = 3.66$, $p = 0.043$, $\eta^2 = 0.06$. Nevertheless, the increase in controlled motivation was not significant for any of the three groups (POS: $t(24) = 1.56$, n.s.; NEU: $t(24) = 0.90$, n.s.; NEG: $t(24) = 1.24$, n.s.). Thus, controlled motivation only increased in general over all three groups.

4.4. Eye tracking

Significant group differences in the percentage of recorded fixation time were revealed by an ANOVA, $F(2,62) = 6.01$, $p = 0.004$, $\eta^2 = 0.16$. Contrast tests indicated that the group with the positive emotion induction spent significantly less time to fixate the relevant information in contrast to the group with the negative emotion induction, $\Delta M = 0.05$, $p = 0.006$. Other group differences were not significant (POS–NEU: $\Delta M = 0.05$, $p = 0.069$, n.s.; NEG–NEU: $\Delta M < 0.01$, n.s.). Hence, learners in a positive emotional state paid less attention to the relevant information.

An ANOVA revealed significant group differences in number of fixations, $F(2,62) = 5.49$, $p = 0.006$, $\eta^2 = 0.15$. The group with the positive emotion induction showed a significantly smaller number of fixations than the group with the neutral, $\Delta M = 147.72$, $p = 0.015$, and the negative emotion induction, $\Delta M = 279.78$, $p = 0.002$, whereas these two groups did not differ significantly from each other, $\Delta M = 132.06$, n.s.

4.5. Additional dependent variables

One-factorial ANOVAs using group as between-subject factor were conducted on the respective subjective rating scales. Group differences in cognitive load ratings were not significant, $F(2,72) = 1.047$, n.s., which was confirmed by contrast tests between all groups (POS–NEG: $\Delta M = 0.44$, n.s.; POS–NEU: $\Delta M = 0.45$, n.s.; NEG–NEU: $\Delta M = 0.02$, n.s.). Nevertheless, there was a significant group difference in perceived task difficulty, $F(2,72) = 3.445$, $p = 0.037$, $\eta^2 = 0.087$. The group with the positive emotion induction rated the task to be significantly more difficult than the group with the neutral emotion induction, $\Delta M = 0.92$, $p = 0.016$, whereas all other contrasts were not significant (POS–NEG: $\Delta M = 0.76$, $p = 0.046$, n.s.; NEG–NEU: $\Delta M = 0.16$, n.s.). Ratings on subjective learning outcomes did not differ between the three groups, $F < 1$, n.s., which was again supported by non-significant contrast test results (POS–NEG: $\Delta M = 0.52$, n.s.; POS–NEU: $\Delta M = 0.16$, n.s.; NEG–NEU: $\Delta M = 0.36$, n.s.). Although, subjective ratings on cognitive load and the learners' subjective learning outcomes were not affected by the emotion induction, the task was perceived to be most difficult in the group with the positive emotion induction.

5. Discussion

The present study showed that experimentally induced emotions influenced learning with multimedia instruction: Induced negative emotions (associated with sadness) facilitated learning, whereas induced positive emotions (associated with happiness) suppressed learning processes.

The present study has theoretical implications for multimedia learning. Parts of the affective mediation assumption of the Cognitive-Affective Theory of Learning with Media (Moreno & Mayer, 2007) are supported by the study's results showing that different emotional states lead to differences regarding learning outcomes. As a consequence, future studies should consider the learners' emotional state as an important factor in addition to the pure cognitive perspective on knowledge acquisition. For practitioners, the study showed that educators should be aware of the learners' emotional state and its possible consequences for learning (e.g., detrimental effects of positive emotional states). This does not implicate having students in a negative emotional state prior to learning. Students' positive affect should rather be counterbalanced as it could probably distract from focusing on complex tasks (e.g., learning).

5.1. Induction of emotional states before learning

The participants in the sample were randomly assigned to the three experimental groups. Additionally, potential confounding variables such as prior knowledge, working memory capacity, and emotion regulation strategies did not differ between the three experimental groups. Further, there were no significant group differences in the baseline measures of motivation and emotion. This strengthens the argument for secure internal validity.

The reported emotions after the induction of different emotional states could be ordered on the line of the positive–negative valence continuum, which showed that the three experimental groups were clearly distinguishable. Additionally, the group having received the positive emotion induction reported higher positive activation values than the other groups. This indicates that the induced positive emotional state with high positive valence and high positive activation values can be associated with happiness, which is a positive activating emotion (Pekrun, 2006; Russell, 2003). The negatively induced group reported higher negative activation values than the other two groups. Since the induced negative emotion should be sadness, these results seem to contradict our manipulation check hypotheses. However, taking the adapted Circumplex Model of Affect (Schallberger, 2005; Watson et al., 1988) into account, the high negative activation values of the induced negative emotional state in the present study locates the emotion on the left half of the model (Fig. 1), which is associated with negative emotions or emotions of low valence. Hence, the negative emotion induction can be regarded as successful. However, it has to be noted that the group with the negative emotion induction scored moderately on the valence and activation scales with respect to absolute values instead of showing concrete characteristics of sadness (low values). This might hint at an answering tendency of the participants (e.g., social desirability) or at the fact that the negative emotion induction mellowed the rather positive emotional state of the participants at the beginning of the experiment resulting in a rather neutral emotional state before learning. This issue must be kept in mind for further interpretation of the results. However, the presence of clearly differentiated emotional states of positive and negative valence, which were intended to induce, has been demonstrated by analyses and, therefore, prerequisites for further analyses were set.

5.2. Effects of emotions on learning outcomes

In the present study, there is evidence for differential effects of diverse emotional states on multimedia learning. There was a facilitating effect of induced negative emotions (associated with sadness) and a suppressing effect of induced positive emotions (associated with happiness) on learning outcomes. Interestingly, the influence of positive emotions was more apparent even though the negative emotion induction had stronger impact on the learners' emotional state. Furthermore, emotions' effects on learning outcomes turned out to be larger for tasks in which deeper understanding was required. In essence, an induced positive emotional state especially constrained deeper understanding of the learning material, while a more negative emotional state, which has been induced, enhanced deeper levels of processing.
Admittedly, the suppressing effect of positive emotions contradicts previous findings in multimedia research which showed that positive emotions enhanced learning (Park, Flowerday, et al., 2015, Park, Knörzer, et al., 2015; Plass et al., 2014; Um et al., 2012). However, there are some differences between these studies which might explain the opposing results. First, these studies applied different emotion induction procedures: The studies by Um et al. (2012) and Park, Knörzer, et al. (2015) used the Velten method which is highly susceptible to demand characteristics (Buchwald, Strack, & Coyne, 1981). The study by Plass et al. (2014) used an emotion induction via films which is shown to be very effective (Lench et al., 2011). However, the film material presents a situational stimulus which is not directly related to the learners themselves. This aspect points to the fact that different emotion induction procedures address different components of emotions (Sokolowski, 2008). The induction of different components of emotions may, therefore lead to different effects on emotional processing and, as in the present study, different learning outcomes. Second, a different multimedia instruction has been used as learning material in the previous studies. Even though, in both materials, the topic is derived from biology, the program of the emotional design studies by Plass and colleagues is less difficult for the recruited participants (they also had a sample of university students). Their materials on immunization are appropriate for 6th graders at school, whereas, the learning content used in the present study on the ATP synthase is typically at the earliest learned in 9th grade. Third, the learning programs of the studies by Plass and colleagues and the present one differ regarding their modality: The program on immunization accounts for the modality effect (Park, Flowerday, et al., 2015) by presenting verbal parts of the learning content as narration. For reasons of collecting eye tracking data the present learning material was presented in visual-only modality. To what extent these three factors and other aspects (e.g., study sample specificities, motivational impact of learning material) had an influence on the direction of effects, will need to be investigated systematically in future studies (see below).

Further, the induced emotional states in this study differed both on their valence and activation levels since happiness is a positive-activating and sadness is a negative-deactivating emotion. Therefore, effects might originate from differences in the valence or activation dimension of the induced emotional states. However, the higher positive activation values of the group with the positive emotion induction did not lead to a higher cognitive activation during learning as shown by eye tracking variables (this group had the smallest number of fixations, i.e., lowest cognitive activity). On the one hand, this finding can be interpreted as being the valence dimension crucial for the emotions’ impact on learning. On the other hand, this result alludes to the Yerkes-Dodson law (Yerkes & Dodson, 1908) postulating that extremely high activation can lead to a lower performance in very difficult and complex tasks. The latter explanation also contributes to explaining the inconsistency of findings in multimedia research on the impact of positive emotions (see above). Nevertheless, the facilitating or suppressing impact of induced emotions in the present study was determined by the kind of emotional state. The differential effects suggest that for diverse emotions different variables connect emotions and learning processes, i.e., different assumptions (see 2.3) account for the respective effects. Hence, the postulated assumptions that were introduced must be discussed for the different induced emotions.

### 5.3. An induced positive emotional state as suppressor of learning

The emotions-as-suppressor-of-learning hypothesis counts for induced positive emotions (associated with happiness) in the present study. Hence, the extraneous load assumption and the attention assumption provide potential explanations of the results. First, in line with the extraneous load assumption, induced positive emotions might have taken up cognitive capacity so that deeper processing of the learning materials was not possible. This is in accordance with the fact that learning outcomes were especially influenced in more complex tasks. Positive emotions were induced by a self-referencing emotion induction procedure using autobiographic recall. Episodic memory contents were activated which is associated with a large cognitive component of the induced emotion (Sokolowski, 2008). Support for this argumentation should have been found in the reported cognitive load measures. In contrast, participants in this group did not report a higher cognitive load; however they did report a higher perceived task difficulty. Participants might have rated the learning material as more difficult, because less cognitive capacity was available for learning. Participants in this group had the least fixations on the relevant parts of the learning materials. In line with the eye–mind hypothesis (Just & Carpenter, 1976) this can be interpreted as lower cognitive activity during learning. In this light, learners in this group invested least effort in processing the relevant parts of the learning material, which they rated as difficult.

To some extent the difficulty rating can also be interpreted as having an attribution purpose. Since participants in positive emotional states seek to maintain their emotion (Bless & Fedler, 2006), they tend to attribute their failure to external, uncontrollable and variable causes (Weiner, 1985), i.e. task difficulty, in order to not endanger their positive emotional state. Contributing to this interpretation is the fact, that participants in this group also tended to rate their subjective learning outcomes as high as the other experimental groups. Essentially, participants in this condition were overestimating their performance as they were less critical toward their learning results. Therefore, subjective ratings in research on the impact of emotions have to be taken lightly, especially when single-item scales are used, as they might have been influenced by the emotions as well.

Second, the suppressing impact of induced positive emotions is aligned with the attention assumption, which states that emotions distract from learning. Participants might have experienced irrelevant thoughts (Seibert & Ellis, 1991) potentially focused on the positive event recalled in the emotion induction procedure. Of primary concern is that participants’ attention was not directed primarily on the learning materials, which was supported by eye movement analyses where learners spent less learning time focused on the relevant content than learners of other groups. Hence, learners in a positive emotional state had a broadened scope of attention (Kaspar & Koenig, 2012) and therefore, might have paid less attention to the learning material. In line with the processing styles assumption, less details of the learning content were processed as evidenced by the eye tracking data. Potentially, due to this decrease in processing, analytic and focused processing did not occur, and latter performance was impared especially in regards to the comprehension and transfer test. In summary, positive emotions suppressed learning processes as they presumably distracted learners from the relevant learning materials coinciding with less cognitive activity associated with the learning task.

### 5.4. An induced negative emotional state as facilitator of learning

In the present study, induced negative emotions supported the emotions-as-facilitator-of-learning hypothesis leading to better learning outcomes. As already outlined for positive emotions, there are different explanations possible in order to explain this effect.

First, according to motivation assumption, negative emotions may have enhanced participants’ extrinsic motivation. However, an increase in extrinsic motivation was not apparent in any of the
experimental groups, so the motivation assumption has to be rejected as potential explanation in the present study. Intrinsic motivation decreased in the group with the negative emotion induction, which is in line with findings by Kim and Hodges (2012). The shifts in motivation that were independent from group affiliation might be explainable when the learning program itself is considered. Since the only observable change among all groups was of materials during learning time, one might argue that the observed decrease in autonomous motivation on the one hand was due to the fact that the multimedia instruction was not designed in a way that enhanced motivation. On the other hand, it maybe was caused by the participants who received course credit or payment for their participation and were not studying for a personal goal. This aspect would also explain why an increase in controlled motivation was observed.

Second, in accordance with the attention assumption, participants’ induced negative emotions did lead to a narrowed focus of attention as observed in the eye tracking measures. Learners in the induced negative emotional state spent a larger percentage of their fixations on the relevant learning materials. This finding combined with the larger number of fixations also supports the processing styles assumption as more fixations coincide with more detailed processing with a higher cognitive activity. This detailed processing are in line with assumptions of perceived task difficulty and better learning outcomes. These findings lead to the conclusion that learners in the negative emotion group might have shown a higher cognitive activity in order to receive high learning outcomes, which help to improve their emotional state. However, this explanation is not supported by results on motivation measures.

Summarizing, induced negative emotions promoted more focused attention on the learning environment, a higher cognitive activity and more detailed information processing, which was related to better learning outcomes.

5.5. Limitations and future directions

Combining the interpretations, in the present study, the attention assumption as well as the processing styles assumptions explained the impact of induced emotions on learning outcomes most appropriately. However, additional dependent variables and further experimental variation as well as a mediation approach regarding these assumptions should be integrated for a replication of results. Replication studies using eye tracking should refer to sample sizes, which are large enough to compensate decimation due to low eye tracking quality. The extraneous load assumption and the motivation assumption did not explain the pattern of results in the present study, which might be due to the fact of inappropriate measurement. Since the present study only measured cognitive load with a single-item scale of subjective impression, further research on the extraneous load assumption is needed. Particularly objective measures of cognitive load or experimental settings with a systematic variation of extraneous load factors in a learning environment are required (Park & Brünken, 2015; Park, Flowerday, et al., 2015). For further examination of the motivation assumption, another learning material should be considered in future studies, which is designed in a more motivation enhancing way. Additionally, effects on emotional state and motivation due to learning program specificities should be investigated.

Future research should also focus on the independent variable again in order to investigate the role of the activation or valence dimension of emotions regarding their impact on learning. Further, even though short-term learning builds the focus of most multimedia studies, possible shifts in emotional states during learning should be assessed applying the experience sampling paradigm (D’Mello & Graesser, 2012). As it is true for most multimedia studies, ecological validity is a concern, as the study was carried out in a laboratory setting in order to control different aspects of the learning situation. Future studies in this field should be conducted in more realistic settings and should comprise participants for whom the learning content is of high relevance, which might also impact their emotional states and the emergence of certain academic emotions (c.f. Pekrun, 2006). Additionally, the sustainability of learning outcomes should be investigated and more prolonged learning settings should be considered in multimedia research. Including retrospective interviews as a supplemental qualitative perspective might be helpful for explaining results and how conscious people were of the experimental manipulation and its impact on dependent variables. The impact of learner characteristics like personality traits or cognitive styles should also be integrated in future studies. This also would be in line with assumptions of the theoretical framework CATLM (Moreno & Mayer, 2007) and its individual differences assumption. Further limitations of the study must consider that the induced emotional states may not be directly associated with the learning task. It may be prudent for future studies to focus on real academic emotions (Pekrun, 2006), which emerge from the learning activity itself with a multimedia instruction in realistic settings. In addition, research on emotional design where emotions are induced by altering pictorial design features of the environment further multimedia principles should be examined with regard to emotional impact (Domagk, Schwartz, & Plass, 2010; Park, Flowerday, et al., 2015, Park, Knörzer, et al., 2015).

The present study introduced and investigated a variety of assumptions regarding the influence of emotions on learning processes. It was shown that induced positive emotions suppressed successful learning processes and distracted learners’ attention. Conversely, induced negative emotions facilitated learning processes in the present study and led to higher cognitive activity during learning. Additionally, findings support the need to further integrate cognitive and affective processes in future studies by investigating interceding mechanisms explaining the impact of the learners’ emotional state on learning.

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References


