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EMOTIONS AND LEARNING FROM MULTIPLE REPRESENTATIONS AND PERSPECTIVES

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ABSTRACT

Using control-value theory as a conceptual framework, we review the literature on the role of emotions in learning from multiple inputs. We first provide a conceptual definition of emotion and an overview of the different types of emotions that play a role during learning, including achievement, epistemic, topic, and social emotions. Next, we discuss theoretical propositions about the origins and functions of these emotions. In the third section, we review empirical evidence on emotions during learning from multiple representations, both in terms of the sensory channels used and in terms of structures of multiple representations that guide learners' emotion-prompting appraisals. Most of this evidence has been gathered in studies on technology-enhanced multimedia learning, such as learning with intelligent tutoring systems, simulations, and games. Subsequently, we summarize recent findings on learning from multiple perspectives, such as contradictory perspectives provided in texts on controversial issues or refutation texts targeting conceptual change. Finally, we discuss directions for future research and implications for practice.

Key words: achievement emotion, epistemic emotion, appraisal, control-value theory, multimedia learning

Traditionally, research on emotions in education has focused on learners' anxiety, such as their test anxiety or math anxiety (Zeidner, 1998). However, learning is infused ~~with~~ a broad range of different emotions, including negative emotions other than anxiety, such as anger, frustration, confusion, shame, hopelessness, and boredom, as well as positive emotions like enjoyment of learning, hope for success, pride, and contentment. It seems likely that the occurrence and intensity of these various emotions can be even further enhanced when learning from multiple inputs. For example, the demands of such learning can prompt increased enjoyment in learners who enjoy the challenge, but undermine positive feelings and trigger frustration and confusion in those who lack the competencies needed to deal with complex materials (see also D'Mello, 2013).

Over the past 20 years, researchers have started to investigate the multiple emotions occurring during learning (for an overview, see Pekrun & Linnenbrink-Garcia, 2014a). While the bulk of these studies pertained to learning from single representations (such as text) and single perspectives (such as current scientific knowledge in a given discipline), researchers who focus on multimedia learning or learning about controversial topics have started to also investigate the emotions accompanying learning from multiple inputs. In this chapter, we review theory and evidence on these emotions.

We first provide a conceptual definition of emotion and an overview of the different types of emotions that play a role during learning. Next, we use Pekrun's (2006, 2018, Pekrun & Perry, 2014) control-value theory (CVT) as a conceptual framework to discuss propositions about the origins and functions of emotions during learning. In the third section, we review empirical evidence on emotions during learning from multiple representations. Much of this evidence has been gathered in studies on technology-enhanced multimedia learning, such as learning with intelligent tutoring systems, simulations, and games using different sensory channels and representational formats. Subsequently, we summarize recent findings on learning from multiple perspectives, such as contradictory perspectives presented in texts on controversial issues or refutation texts targeting conceptual change. In closing, we outline directions for future research and implications for practice.

CONCEPTS OF EMOTION

Emotion, Mood, and Affect

Emotions are multifaceted phenomena that consist of several interrelated component processes (Shuman & Scherer, 2014), including subjective feelings (affective component), cognitions (cognitive component), motivational tendencies (motivational component), physiological processes (physiological component), and expressive behavior (expressive component). For instance, a student experiencing anxiety when confronted with contradictory information may feel uneasy and nervous (affective), think about possible failure in resolving the contradictions (cognitive), want to avoid dealing with the material (motivational), have sweaty palms (physiological), and display an anxious facial expression (expressive component).

In comparison to emotions, *moods* are of lower intensity, have less-specific reference objects, and are typically of longer duration. Some authors define emotion and mood as categorically distinct phenomena – whenever you experience enjoyment, anger, or anxiety, this state falls into either the category of emotion or the category of mood (Rosenberg, 1998). Alternatively, since moods show similar qualitative differences as emotions (as in cheerful, angry, or anxious mood), they can also be regarded as low-intensity emotions (Pekrun, 2006).

Different emotions and moods are often compiled in more general concepts of *affect*. Two variants of this term are used in the research literature. In the educational literature, affect is often employed to denote a broad variety of non-cognitive constructs including emotion, but also self-concept, beliefs, motivation, etc. (see, e.g., McLeod & Adams, 1989). In contrast, in emotion research, affect refers to emotions and moods more specifically. In this research, the term is often used to refer to more global variables of positive versus negative emotions or moods, with *positive affect* including various positive emotions (e.g., enjoyment, pride, satisfaction) and *negative affect* various negative emotions (e.g., anger, anxiety, frustration).

Two important dimensions describing emotions, moods, and affect are *valence* and *activation* (Barrett & Russell, 1998). Valence denotes the degree of pleasantness, making it possible to distinguish positive (i.e., pleasant) states, such as enjoyment and happiness, from negative (i.e., unpleasant) states, such as anger, anxiety, or boredom. In terms of activation, physiologically activating states can be distinguished from deactivating states, such as activating excitement versus deactivating relaxation. By classifying affective states using these two dimensions, four broad categories of emotions can be distinguished, including *positive activating* emotions such as enjoyment, excitement, hope, and pride; *positive deactivating* emotions such relief, relaxation, and contentment; *negative activating* emotions like anger, anxiety, and shame; and *negative deactivating* emotions like hopelessness and boredom (see Table 22.1).

Table 22.1 Valence × Activation Taxonomy of Emotions

	Valence	
Activation	**Positive (pleasant)**	**Negative (unpleasant)**
Activating	Enjoyment Hope Pride Gratitude Surprise[a] Curiosity[b]	Anxiety Anger Frustration [c] Shame Envy Surprise[a] Confusion
Deactivating	Relief Contentment Relaxation	Disappointment Frustration[c] Boredom Sadness Hopelessness

Note. This classification is based on established taxonomies of achievement emotions and epistemic emotions (Pekrun & Stephens, 2012; Pekrun & Perry, 2014).

[a] Frustration can comprise elements of (activating) anger and (deactivating) disappointment.
[b] Valence may vary based on emotion-eliciting event (positive, negative).
[c] Curiosity is considered as unpleasant in some conceptions (see Loewenstein, 1994).

Emotions Related to Learning

Emotions differ according to the events and objects that trigger them. As such, emotions can also be grouped according to their *object focus* (Pekrun & Stephens, 2012). Regarding the influence of emotions on students' learning, object focus is critical because it determines if emotions pertain to the learning task at hand or not. In terms of object focus, the following broad groups of emotions and moods may be most important for learning from multiple inputs.

General and Specific Moods

By definition, moods may not be directly tied to a specific learning activity. Nevertheless, they have the potential to shape students' learning. For example, when you are in a joyful mood, you may be better disposed to creatively solve a complex task involving multiple perspectives than when you are in an anxious or angry mood.

Achievement Emotions

These are emotions that relate to achievement activities, such as studying and taking tests, and to the achievement outcomes of these activities (i.e., success and failure). Accordingly, two groups of achievement emotions are *activity emotions*, such as enjoyment, anger, frustration, or boredom during learning, and *outcome emotions*, such as hope and pride (related to success) or anxiety, hopelessness, and shame (related to failure). Many of the emotions experienced in academic settings can be classified as achievement emotions because they relate to activities and outcomes that are judged according to competence-based standards of quality.

Past research on achievement emotions predominantly focused on outcome emotions. Two important traditions of research on outcome emotions are test anxiety studies and studies on the links between perceived causes of success and failure and subsequent emotions, such as pride and shame (Weiner, 1985; Zeidner, 1998). Though outcome emotions are of critical importance for achievement strivings, emotions directly pertaining to the activities performed in achievement settings (i.e., activity emotions) are of equal relevance for learning.

Epistemic Emotions

The term "epistemic" is derived from ancient Greek and denotes thoughts and activities that aim to expand human knowledge. Thinking, however, is not just based on pure cognitive reasoning alone ("cold cognition"). Rather, it is closely tied to emotions such as surprise, curiosity, or confusion. Because they relate to the knowledge-generating qualities of cognitive tasks, these emotions have been called *epistemic emotions* (Brun, Doğuoğlu, & Kuenzle, 2008; Pekrun & Stephens, 2012). Epistemic emotions serve evolutionary-based purposes of acquiring knowledge about the world and the self. A prototypical situation for the arousal of emotions like surprise, curiosity, and confusion is contradictory information and cognitive incongruity, which imply that different pieces of information are not compatible and do not fit together.

A typical sequence of epistemic emotions induced by cognitive incongruity may involve (1) surprise; (2) curiosity and situational interest if the surprise is not dissolved; (3) anxiety in case of severe incongruity and information that deeply disturbs existing beliefs about the world, thus making clear that knowledge is not certain; (4) enjoyment and delight experienced when recombining information such that the problem gets solved; or (5) frustration when this seems impossible (Pekrun & Stephens, 2012). For example, a student who believes that climate change is due to natural causes but who is confronted with convincing information that a major part of climate change is human-made may be surprised and become curious about this information. Alternatively, the discrepancy between prior beliefs and current information may trigger confusion, and, if the incongruity continues, then this may be quite frustrating for the student. However, if the student is able to reconcile these different perspectives, she may be delighted by the solution she found. Importantly, epistemic confusion and frustration are not generated by the topic (such as climate change) itself; rather, they are driven by the cognitive conflict between existing beliefs and discrepant new information.

Topic Emotions

Emotions can be triggered by the contents covered by learning material. Examples are the empathetic emotions pertaining to a protagonist's fate when reading a novel, the emotions triggered by political events dealt with in political lessons, or the emotions related to topics in science class, such as the frustration experienced by American children when they were informed by their teachers that Pluto was reclassified as a dwarf planet (Broughton, Sinatra, & Nussbaum, 2013). In contrast to achievement and epistemic emotions, topic emotions do not directly pertain to learning and problem solving. However, they can influence students' engagement by affecting their interest and motivation in an academic domain (Ainley, 2007).

Social Emotions

Learning is situated in social contexts. Even when learning alone, students do not act in a social vacuum; rather, the goals, contents, and outcomes of learning are socially constructed. By implication, academic settings induce a multitude of emotions related to other persons. These emotions include both social achievement emotions (such as admiration, envy, contempt, or empathy related to the success and failure of others) and non-achievement emotions (such as love or hate in the relationships with classmates and teachers). Social emotions can directly influence students' engagement with academic tasks, especially when learning is situated in teacher–student or student–student interactions. They can also indirectly influence learning by motivating students to engage or disengage in task-related interactions with teachers and classmates.

ORIGINS AND FUNCTIONS OF EMOTIONS: CONTROL-VALUE THEORY

To discuss the origins and functions of emotions related to learning, we use Pekrun's (2006, 2018, Pekrun & Perry, 2014) control-value theory of achievement emotions as a conceptual framework. Propositions of CVT explain learners' appraisals that function as proximal antecedents of their emotions, the role of learning tasks and environments, and the effects of emotions on processes and outcomes of learning. The theory pertains to learners' emotions across types of learning tasks. As such, it can also be used to explain emotions during learning from multiple inputs.

Appraisals as Proximal Antecedents

Perceived Control and Value

CVT posits that appraisals of control over, and the value of achievement activities and their outcomes function as proximal antecedents of achievement emotions. Succinctly stated, the theory proposes that learners experience these emotions when feeling in control over, or out of control of, achievement activities and outcomes that are subjectively important. Perceived control comprises expectations to be able to successfully perform actions (i.e., self-efficacy expectations) and attain outcomes (outcome expectations) as well as attributions of success and failure to different causes. Perceived value pertains both to the intrinsic, interest-based value of achievement activities, and to their extrinsic value to attain success and avoid failure (achievement value), or to obtain further outcomes such as praise from parents or future career opportunities (utility value; see also Lombardi, Heddy, & Matewos, Chapter 20).

Prospective emotions related to future outcomes, such as hope for success and fear of failure, are thought to depend on expectations of these outcomes, combined with perceptions of their value. For example, a student who expects to succeed on an exam will experience hope and anticipatory enjoyment, provided that the exam is sufficiently important to be emotionally arousing. Conversely, a student who feels out of control will feel anxious. *Retrospective emotions* related to past achievement outcomes, such as pride and shame, are thought to depend on causal attributions of these outcomes, in line with Weiner's (1985) attributional theory of achievement emotions. Pride is thought to be triggered when success is attributed to internal causes such as ability or effort, and shame when failure is attributed to lack of ability or effort. *Activity emotions* such as enjoyment and boredom during learning are thought to be triggered by perceived competence to perform the activity and the perceived value of the activity. For example, students can enjoy learning if they feel competent to master the material and are interested in the contents. Boredom is experienced when learning lacks any incentive value, and when perceived competence is either too low relative to task demands (over-challenge) or too high (under-challenge). The extant empirical evidence supports these propositions (for reviews, see Pekrun & Perry, 2014; Putwain et al., 2018).

Cognitive Incongruity

For epistemic emotions such as surprise, curiosity, and confusion, appraisals of cognitive incongruity are relevant. Cognitive incongruity can be due to discrepancies between prior knowledge and current information, between current information and desired information, or between different pieces of current information (Pekrun & Stephens, 2012; see also Muis, Chevrier, & Singh, 2018). Discrepancies between prior expectancies and current information are thought to trigger surprise (Scherer, 2009). Gaps between current knowledge and desired knowledge give rise to curiosity (Loewenstein, 1994). Discrepancies between different pieces of currently available information prompt confusion, if not resolved quickly. As outlined below (section on emotions and learning from multiple perspectives), empirical findings support the importance of cognitive incongruity for the arousal of epistemic emotions during learning. For example, research by Muis et al. (2015~~a~~) has shown that contradictory texts on the causes of climate change (natural vs. man-made) and its effects (positive vs. negative) can increase learners' surprise and confusion.

Non-Cognitive Induction of Emotion

Learners' emotions need not always be mediated by appraisals. There are two alternative, non-cognitive routes to emotion arousal. First, appraisal-based emotion induction can routinize during repeated occurrence of the same emotional situation. For example, repeatedly feeling out of control and fearful before math exams can lead to the formation of an emotion schema that directly triggers fear upon the math teacher's announcement of the next exam, further deliberation not being necessary. Second, other persons or features of the learning material can directly transmit emotions through entrainment and emotional contagion (see also Loderer, Pekrun, & Plass, in press).

Entrainment is a process through which physical or biological systems become synchronized over time by way of interacting with each other (Trost, Labbé, & Grandjean, 2017). Entrainment drives changes in emotions by influencing physiological and motor-expressive components. Similarly, emotions can be "caught" directly from external stimuli by means of emotional contagion. Emotional contagion is held to be driven by observation and automatic imitation of others' emotionally expressive behaviors (e.g., facial expression; Hatfield, Cacioppo, & Rapson, 1994). Such contagion may also occur in learning environments that allow for learning from multiple representations, such as multimedia learning games programs in which video- or voice chat-supported social interactions with fellow learners (Admiraal, Huizenga, Akkerman, & ten Dam, 2011) or digital agents (Gratch & Marsella, 2005; Krämer, Kopp, Becker-Asano, & Sommer, 2013) constitute one among multiple available channels for providing content.

Learning Environments as Antecedents

Given the role of appraisals as proximal antecedents, CVT proposes that learning tasks and environments influence learners' emotions through their appraisals (except for non-cognitive emotion induction as outline above). As such, features of tasks and environments that influence learners' perceptions of control, value, and incongruity will also influence their emotions. Relevant factors include task demands and the cognitive quality of learning materials; scaffolding by teachers or virtual agents; support of learners' autonomy; incentives and goal structures in the environment; and social interaction. As all of these factors are important features of tasks and environments providing multiple representations, they will be discussed in the section on emotions and learning from multiple representations.

Functions for Learning and Performance

The cognitive-motivational model of emotion effects that is part of CVT (Pekrun, 2006, 2018) proposes that emotions impact learning outcomes through various cognitive and motivational mechanisms (for a similar view, see Plass & Kaplan, 2016). This idea is grounded in research showing that affective states influence cognitive processes such as allocation of attention, memory storage and retrieval, and problem solving as well as motivational tendencies and behavior (Barrett, Lewis, & Haviland-Jones, 2016). We consider four mechanisms that are particularly important for learning from multiple inputs.

Cognitive Resources

Resource allocation models of emotion (Ellis & Ashbrook, 1988; Meinhardt & Pekrun, 2003) and cognitive load theory (Sweller, 1994) suggest that emotions impose extraneous cognitive load, that is, that they require working memory resources, which are then not available to perform complex learning tasks. CVT proposes a more differentiated view that considers the object focus of emotions. Emotions with task-external referents such as worries about problems in the relationship with a friend disrupt attentional focus. In contrast, enjoyment or curiosity targeted at the learning activity may focus attention on task completion. Findings from multimedia learning studies support this view.

Multimedia studies indicate that task-extraneous positive emotions induced via autobiographical recall of emotional events can distract attention and impede learning (e.g., Knörzer, Brünken, & Park, 2016). In contrast, positive states elicited by the visual design of multimedia environments can reduce cognitive load (Plass, Heidig, Hayward, Homer, & Um, 2014; Um, Plass, Hayward, & Homer, 2012) and sustain focus on the task itself (Park, Knörzer, Plass, & Brünken, 2015). One explanation may be that certain characteristics of visual design trigger low-intensity positive moods that increase learners' motivation to stay focused (Park, Flowerday, & Brünken, 2015).

Motivation to Learn

Positive activating emotions (Table 22.1) are thought to promote students' motivation to learn (see also Miele, Nokes-Malach, & May, Chapter 21). Specifically, enjoyment and curiosity can fuel investment of effort in learning tasks. In contrast, *negative deactivating emotions* like boredom and hopelessness undermine motivation. Boredom especially may increase tendencies to engage in off-task thought such as daydreaming and mind wandering. *Positive deactivating* and *negative activating emotions* can have more variable motivational effects. Positive deactivating emotions such as relief over unexpected success can undermine immediate motivation to invest effort, but may support reengagement with the learning task in the long term. Negative activating emotions such as anxiety and shame can undermine intrinsic motivation to learn, but can induce extrinsic motivation to increase effort and avoid failure, which has been observed both in classroom (Turner & Schallert, 2001) and multimedia learning environments (Loderer, Pekrun, & Lester, 2018). Anger or envy in response to others' achievements may also motivate students to learn more and outperform peers.

Memory Processes and Learning Strategies

Emotions facilitate different modes of processing information (see also Follmer & Sperling, Chapter 18). Experimental mood research indicates that positive states promote top-down, relational, and flexible processing, whereas negative states lead to bottom-up, analytical, and more rigid thinking (Fiedler & Beier, 2014). One implication is that emotions impact encoding and retrieval of learning material. While positive emotions can enhance the integration of information from multiple inputs in memory, negative emotions can increase accuracy in processing of single units of information (Spachtholz, Kuhbandner, & Pekrun, 2014) but possibly hinder flexible integration of information.

Accordingly, *positive activating emotions* should promote the use of flexible and deep learning strategies such as elaboration, organization of material, or critical thinking. As such, these emotions should facilitate the integration of information from multiple inputs. In contrast, *negative activating emotions* such as anxiety are thought to facilitate use of more rigid strategies such as simple rehearsal, and confusion may also instantiate critical thinking as a means to reduce cognitive incongruity. *Deactivating emotions* can undermine any strategic efforts, yielding superficial processing. This may be particularly true for boredom and hopelessness. Evidence from studies with multimedia learning environments supports these propositions (Artino & Jones, 2012; Loderer et al., 2018; Plass et al., 2014; Sabourin & Lester, 2014; Um et al., 2012).

Self-regulation of Learning

Self-regulation requires flexibility to adapt thought and action to task demands and individual goals (see Denton, Muis, Munzar, & Etoubashi, Chapter 19). This is particularly important in learning from multiple representations and perspectives that puts learners in charge of managing different inputs. Given that positive activating emotions promote flexible strategy use, they likely facilitate self-regulation of learning. In contrast, negative emotions like anxiety or shame should lead to increased reliance on external guidance, and negative deactivating emotions reduce overall engagement in learning. In line with these propositions, enjoyment and curiosity have been found to relate positively, and boredom to relate negatively, to learners' self-regulation in both traditional as well as multimedia learning environments (Artino & Jones, 2012; Muis, Psaradellis, Lajoie, Di Leo, & Chevrier, 2015b; Pekrun, Goetz, Titz, & Perry, 2002).

Learning Outcomes

Due to the multifaceted influence of emotions on different learning mechanisms, their effects on overall learning outcomes are inevitably intricate. Net effects are a function of the interplay between tasks demands, interindividual learner attributes (e.g., working memory capacity; self-regulatory competencies), and the different cognitive and motivational processes set off by emotion. Positive activating emotions likely enhance learning under most conditions, including learning from multiple inputs. Supporting these assumptions, our meta-analysis revealed significant positive relations of enjoyment and curiosity with performance outcomes across diverse technology-based environments including multimedia environments (Loderer et al., 2018). In contrast, negative deactivating emotions like boredom impede learning (Tze, Daniels, & Klassen, 2016).

Achievement effects of positive deactivating and negative activating emotions are less straightforward. As noted, positive deactivating emotions may reduce task attention and strategic efforts but increase long-term motivation to learn. It remains unclear whether the interplay of these mechanisms facilitates or hinders overall achievement. Negative activating emotions generate task-irrelevant thinking and undermine intrinsic motivation to learn, but can increase extrinsic motivation and facilitate rehearsal of contents, which can be conducive to specific tasks that require rote memorization. However, the modal impact of these emotions on cognitive outcomes from learning with multiple inputs is likely to be negative (see also Goetz & Hall, 2013). In sum, CVT proposes that emotions are key drivers of learning. However, simply equating pleasant emotions with positive effects, and unpleasant emotions with negative effects does not account for the complex ways in which emotions can shape learning processes and outcomes.

Theoretical Corollaries: Reciprocal Causation

The propositions of CVT outlined above have a number of theoretical implications for the domain specificity of learning-related emotions, the role of individual antecedents, the regulation of these emotions, and their relative university across genders, contexts, and cultures (Pekrun, 2018). Of specific importance for the role of emotions in learning, CVT implies that emotions, their antecedents, and their outcomes are linked by reciprocal causation. Learning environments shape emotions through individual appraisals and emotional transmission, and these emotions, in turn, impact learning. In addition, emotions reciprocally influence learners' appraisals. For instance, enjoying learning can increase appraisals of the intrinsic value of learning. Moreover, learning activities and their outcomes reciprocally influence emotions and their antecedents (Pekrun, Lichtenfeld, Marsh, Murayama, & Goetz, 2017). Success and failure at learning are important informants of learners' control beliefs and the emotions they trigger.

In classroom contexts, learners' expressed emotions and achievements can shape the reactions of teachers or peers, including emotional responses (e.g., pity, anger) as well as instrumental behavior (e.g., design of appropriate learning tasks). Similarly, in collaborative multimedia environments, emotionally expressive virtual or human instructors may reciprocate learners' emotions. Affect-aware environments offer interventions designed to reduce maladaptive emotions and foster adaptive emotions based on continuous real-time analysis of learners' emotions (Calvo & D'Mello, 2012). Thus, learners' emotions may affect current representations provided in the environment which, in turn, shape their subsequent emotional trajectories.

EMOTIONS AND LEARNING FROM MULTIPLE REPRESENTATIONS

In this section, we summarize extant evidence on how features of multiple representations impact learners' emotions. We first review studies that focused on effects of combining multiple sensory features, which are often due to processes of entrainment and emotional contagion as discussed earlier. Subsequently, we discuss structural features of learning environments that are likely to influence learners' appraisals and the emotions that are contingent on these appraisals. Finally, we highlight that research has not yet systematically examined how multiplicity and connectedness of representations influence learners' emotions, the study by Schneider, Dyrna, Meier, Beege, & Rey (2018) being an exception. Throughout this section, we use the term "multimedia learning" to denote learning from instruction that uses input from different sensory channels, or input from one channel using different symbolic representations, such as words versus pictures (Stark, Malkmus, Stark, Brünken, & Park, 2018).

Sensory Features of Multimedia Learning Tasks

Visual Design

The basic "look" is one of the first characteristics learners process when they encounter a learning task or environment. Egenfeldt-Nielsen, Smith, & Tosca (2008) argue that visuals "add to the atmosphere, provide a sense of realism, and generally make the world seem alive." In a meta-analysis of emotions in multimedia and computer-based learning environments, learners' curiosity differed across aesthetic designs of learning environments (Loderer et al., 2018). While visual design seem to constitute a superficial quality, learners may disengage from a learning task if its overall look and feel are unappealing (McNamara, Jackson, & Graesser, 2010).

Basic emotion-relevant features of visual design include color and shape, both of which can affect mood. Um et al. (2012) found that infusing multimedia learning environments with bright and saturated warm colors (yellow, pink, and orange) increased learners' positive emotions and enhanced their comprehension as well as knowledge transfer, in comparison to an environment using grey coloring, a finding which has been replicated by Mayer & Estrella (2014). Children tend to associate bright colors with positive, and dark colors with negative emotions (Boyatzis & Varghese, 1994).

However, other findings suggest a more nuanced picture of the effects of bright colors. Specifically, the color red may signal danger or, in achievement contexts, failure (Elliot, Maier, Moller, Friedman, & Meinhardt, 2007), thus prompting negative emotions. In contrast, green colors can prompt positively connoted associations of hope, growth, and success (Lichtenfeld, Elliot, Maier, & Pekrun, 2012). In addition, there may be cultural and individual differences in color preference (Taylor, Clifford, & Franklin, 2013), such that it may be useful to allow for adapting color schemes of environments to personal tastes.

Elements of shape can also influence learners' emotions. Plass et al. (2014) showed that round face-like shapes in a multimedia learning environment induced positive emotions. This might be attributable to the fact that round shapes resemble human physical appearance and baby-like attributes signify innocence, safety, and honesty (baby-face bias; Plass & Kaplan, 2016). Shape and color may also aid in guiding attention to increase positive and reduce negative emotions by facilitating experiences of mastery and control over learning. This also applies to more complex visual effects such as learning from dynamic, multidimensional simulations of scientific phenomena (Plass, Homer, & Hayward, 2009).

In a similar vein, the visual appearance of virtual agents can impact learners' emotions. This can be done by way of adhering to general principles of aesthetics, but also by attending to the perceived similarity between learners and the agent (Domagk, 2010). Physical attractiveness as well as realistic, lifelike design and motion can foster positive emotional reactions to virtual characters (Shiban et al., 2015). Agents that resemble the learner in age, gender, and expertise (peer vs. expert agents) are rated as more likable and are evidently more effective in promoting positive emotions (Arroyo, Burleson, Tai, Muldner, & Woolf, 2013). Furthermore, enabling learners to design and personalize avatars (i.e., impersonations representing the learner in the computerized environment) can lead learners to identify more strongly with their virtual character (Turkay & Kinzer, 2014). Fidelity and realism in visual representation further impact the general intensity of learners' emotional involvement (Yee & Bailenson, 2007).

Musical Score

Some multimedia learning environments, such as game-based environments, use sound and music to enliven their narrative. Auditory stimuli can amplify learners' enjoyment by enriching sensory experience. In addition, music directly influences emotions through rhythmic entrainment or triggering associations to real-world events based on their emotional tone. Incorporating audible feedback into the environment may increase the perceived pleasantness of interacting with the learning tasks, irrespective of specific audio qualities (Nacke, Grimshaw, & Lindley, 2010). Husain, Thompson, and Schellenberg (2002) found that when confronting participants with different versions of a Mozart sonata, higher musical tempo increased perceived arousal, whereas mode (major vs. minor) impacted emotional valence. Moreover, self-reported enjoyment as well as achievement on a spatial abilities task were highest for the fast-major rendition, confirming that positive activating emotions are particularly beneficial for cognitive performance.

A closely related design feature is the vocal sound of characters in computerized learning tasks. As summarized by Baylor (2011), research indicates a human (as opposed to a computer-generated) voice can enhance social presence and lead to increased interest because it is perceived as more likable and engaging. Similarly, vocal sounds can be emotionally infectious. For example, an agent articulating excitement over a fun learning activity may lead learners to join in positive emotion.

Much like visual elements, acoustic qualities of learning environments can also influence their effectiveness in guiding attention to important content and emotional events within the environment (e.g., an approaching enemy; Collins, 2009). Explanations that need to be integrated with visual information (e.g., diagrams) enhance retention if presented in auditory instead of visual mode, especially when both sources of input contribute to understanding and thus are complementary (e.g., Fiorella, Vogel-Walcutt, & Schatz, 2012). Sound can further be used to provide performance feedback and to make learners aware of mistakes. Such sound feedback can either be used to downplay failure or to add a celebratory note to success to foster positive emotions.

Features of Multimedia Learning Tasks that Shape Learners' Appraisals

Beyond simple sensory features, learning tasks can be designed to influence learners' appraisals, such as their perceived control and value related to learning. Mediated by these appraisals, such design can also influence learners' emotions and resulting learning outcomes.

Task Demands and Clarity

Perceived control is enhanced when task demands match learner's competencies and when instruction is clearly structured and uses illustrative explanations. Furthermore, the match between task demands and competencies can also influence learners' valuing of learning. Demands that are either too high or too low may reduce the intrinsic value of tasks to the extent that boredom is aroused (Pekrun, 2006). Clarity and comprehension can be promoted by considering known constraints (e.g., limited working memory capacity) and reducing extraneous cognitive load (Plass, Homer, & Hayward, 2009). As comprehension leads to higher perceived control, enhancing clarity should be emotionally adaptive. To promote clarity in learning, instructional designers can attend to principles such as representing key information through iconic rather than symbolic information which requires more effortful processing (Plass, Homer, Milne, et al., 2009).

Scaffolding

Perceived control is also enhanced when others help learners through scaffolding. Cognitive scaffolding can entail modifying task difficulty, repeating content, providing additional explanations, using advance organizers to structure information and assist navigation in the learning environment, as well as the use of supportive and encouraging messages (Arroyo, Muldner, Burleson, & Woolf, 2014). Metacognitive scaffolding can be used to prompt effective problem-solving behaviors (e.g., providing hints), modify ineffective strategies (e.g., "Let's think again: What are the steps we have to carry out to solve this one?" Arroyo et al., 2014, p. 82), and promote goal setting as well as self-monitoring. The meta-analysis by Loderer et al. (2018) found that cognitive and metacognitive scaffolding resulted in higher levels of enjoyment.

However, the dosage of scaffolding may determine its impact on learners' perceptions of mastery. Frequent reminders or hints to change one's learning approach may gradually lead learners to rely on external sources of guidance rather than promote self-regulation, which can diminish perceived autonomy and control. As such, intelligent environments that continuously track learners' knowledge levels to adjust and potentially fade degrees of scaffolding, account for individual differences in prior knowledge and learning pace, and intervene only where necessary may be most effective (Janning, Schatten, & Schmidt-Thieme, 2016). In intelligent systems, this can be achieved by implementing algorithms that allow for learner-based problem selection, including open learner models (e.g., visualizations of a systems' learning analytics that reveal learning progress; Long & Aleven, 2017) or sending personalized cues (e.g., "That was too easy for you. Next time, go for a more challenging problem – it's much more exciting and it will help you increase your learning!"; Arroyo et al., 2014, p. 81). Such scaffolds can be used to prevent loss of control when students are overwhelmed by too much autonomy (e.g., due to poor planning).

Autonomy Support

Providing learners with a sense of autonomy over their learning can also enhance their perceived control and any emotions shaped by control. In an experimental study with German 10th graders, Stark et al. (2018) tested propositions of Pekrun's (2006, 2018) CVT. They manipulated learners' control over, and perceived value of, a multimedia science learning task and examined effects on learning-related emotions and learning outcomes. The computer-based task consisted of 11 screens that contained information about the structure and function of the ATP synthase molecule. Each screen contained text and a static picture. Positive and negative learning-related emotions were measured using combinations of the learning-related positive and negative emotion scales of the Achievement Emotions Questionnaire (AEQ; Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011). Learning outcomes were assessed with an achievement test.

Supporting CVT assumptions, the findings showed that control and value exerted synergistic, interactive effects on learners' positive learning-related emotions as well as their learning outcomes. As predicted, positive emotions and performance were highest when both control and value were high. Furthermore, positive emotions served as a mediator in the effects of control and value on performance, demonstrating the impact of learners' emotions on their achievement. These findings suggest that providing learners with autonomy by given them the choice between tasks, or between different strategies to perform a task, can support their positive emotions and learning.

Incentives and Goal Structures

Learning environments can provide incentives (i.e., reward and punishment) that enhance learners' perceptions of the value of learning, thus influencing their emotions. For example, in multimedia learning games, incentive systems can take on the form of progress bars, point score systems, badges, opportunities to change the environment (e.g., appearance of one's avatar), or systematic unlocking of game levels or virtual goods. Because they are typically contingent on learners' performance, they also comprise feedback about individuals' learning progress that influences their perceived control.

Incentives can vary in terms of their instrumental value. Rewards that entail access to additional fun activities or to new levels with new content can serve to build value through intrinsically valuable content. Such incentives may be particularly conducive to increasing enjoyment or curiosity (McNamara et al., 2010). Extrinsic incentives include rewards that enable learners, for instance, to exchange points for changing their avatar, or score tallying for comparisons with other learners through leaderboards. Such external compensation can enhance the value of learning. This can be a helpful tool for emotionally engaging learners who perceive the content as little intriguing, and to build interest value in the long run.

Incentives can also vary in their emphasis of certain goal orientations. Different standards for defining achievement can involve individualistic (mastery), cooperative, or competitive (normative) goal structures. These structures can be communicated through incentive structures (e.g., rewards for individual improvement vs. for outperforming others) and via feedback (e.g., referencing improvement in correct solutions vs. performance relative to others). Incentives and feedback reflecting mastery- or performance-approach goals can promote positive emotions (Pekrun, Cusack, Murayama, Elliot, & Thomas, 2014). Mastery standards and mastery-approach goals are held to be most emotionally adaptive, because they hone learners' focus in on the intrinsic values of learning activities. Nevertheless, normative standards and performance-approach orientations can provide enticing challenge and excite learners to engage with the learning task.

For example, Plass and colleagues (Biles & Plass, 2016) found that administering badges accentuating social comparison (e.g., "You figured out the straight angle rule faster than most players!") can yield better learning outcomes than mastery-related badges (e.g., "You have mastered the triangle rule!"). In the mastery condition, learners reporting high situational interest in the game contents outperformed those with low situational interest. Situational interest did not affect performance in the performance badge and no badge conditions. These findings point to interactions between goal-priming incentives and interest, but more research is needed to clarify these relations.

Mastery-oriented feedback can be combined with control-enhancing statements derived from attributional retraining (Perry, Chipperfield, Hladkyj, Pekrun, & Hamm, 2014). Arroyo et al. (2014) found that focusing feedback on the controllability of learning and the importance of effort (e.g., "Good job! See how taking your time to work through these questions can make you get the right answer?"; p. 81) can reduce frustration and anxiety. Such messages are designed to prompt adaptive control appraisals and thereby increase adaptive emotions. To reduce emotions like boredom, feedback can focus on appraisals of the utility value of learning contents (see Harackiewicz & Priniski, 2018).

Two additional emotionally relevant aspects pertain to learner choice and salience of rewards. Choice between different rewards can increase perceived autonomy and control over learning, but may result in learners becoming distracted by marginal elements of rewards such as modifying the visual layout of the multimedia environment (McNamara et al., 2010). With regard to salience, visually ornate or acoustically augmented extrinsic rewards can enhance their emotional pull, but may undermine intrinsic valuation of learning (Abramovich, Schunn, & Higashi, 2013). Specifically, frequently displaying badges during learning can overemphasize the value of achievement, which can be detrimental to learners who are struggling with the learning task and experience failure. For these students in particular, providing feedback and incentives based on individual learner progress rather than normative standards or raw achievement (see Arroyo et al., 2014, for examples) may be particularly helpful.

Social Interaction

Multimedia learning environments can comprise social interaction with fellow learners, teachers, or virtual agents. Social interaction can shape learner emotions in two ways. First, interaction partners may influence one another by way of emotional contagion and empathy. This makes it possible to regulate learners' emotions through modeling (e.g., enthusiastic expression such as "This task looks cool!"), parallel empathy (i.e., replicating the learners' state), and reactive empathy (i.e., displaying emotions that differ from the learners' state in order to alter it). The features of agent design described earlier may be important moderators of the effectiveness of such interventions. For instance, realistic agents might provide more convincing role models and thus more powerful interventions.

Second, social exchange may cater to students' needs for relatedness and thereby make the learning task more exciting for learners (Sheldon & Filak, 2008). However, frequent social interaction *per se* may not be sufficient for triggering positive emotions: The perceived quality, rather than quantity, of interaction is key (Heidig & Clarebout, 2011). Supportive and empathic interaction is likely most beneficial. For instance, polite "face-saving" measures such as displaying hints employing collectives (e.g., "How about *we* solve for x?") rather than directives (e.g., "You need to solve for x"; Lane, 2016, p. 51) can elicit more positive learner affect.

In addition, the cooperative or competitive structure of interaction can influence students' emotions by impacting their goals during learning. While both structures may increase situational interest and enjoyment relative to individual learning settings, cooperation seems to be most beneficial from an emotional point of view (Ke & Grabowski, 2007). Competition can induce performance-avoidance goals (Murayama & Elliot, 2012), which shift learners' attention toward potential failure and lack of control, thus increasing the probability of experiencing negative emotions. Moreover, in competitive settings, some learners are bound to experience failure and, as a consequence, negative emotions. As such, cooperative formats, perhaps infused with carefully designed competitive activities, might be most beneficial to learners' emotions.

Multiplicity and Connectedness of Representations

The studies summarized in this section demonstrate how features of multimedia learning tasks can influence learners' emotions and performance. However, research has yet to address the emotional impact of the multiplicity of representations itself. To this end, it would be necessary to compare the effects of single versus multiple representations, or the effects of different combinations of representations. Related studies are largely lacking. An exception is the study by Schneider et al. (2018). In three experiments, learning material was presented that consisted of text and pictures that were either strongly or weakly connected. The first two experiments included instructional texts about South Korea, the third experiment included a text about the human body. The pictures were either affectively positively or negatively charged, and text and pictures were either strongly or weakly connected. As expected, positive pictures led to positive self-reported changes in affect (measured with an adapted version of the Positive Affect Negative Affect Schedule, PANAS; Watson, Clark, & Tellegen, 1988), whereas negative pictures led to negative changes. In contrast, the degree of connectedness did not influence affect. Moreover, positively charged pictures led to better learning outcomes than negatively charged pictures. Additional analyses revealed that this effect was likely due to irrelevant thinking promoted by the negative pictures.

These findings confirm that the affective contents of learning materials can influence both learners' emotions and their learning outcomes. In contrast, the relations between different representations in terms of their connectedness may not exert a strong influence on emotions. Connectedness had positive effects on performance, similar to the effects of positive affective contents, but the effects of connectedness were not mediated by emotion. It is an open question if such emotional irrelevance of cognitive relations between representations also holds for other types of representations, other types of relations, and other types of learning materials. It also remains open to question if the findings would generalize to discrete emotions that may be more susceptible to effects of connectedness, such as confusion that could be prompted if representations are not well connected.

EMOTIONS AND LEARNING FROM MULTIPLE PERSPECTIVES

Multiple perspectives on learning contents can be complementary or contradictory. The nascent research on emotions prompted by multiple perspectives has focused on the latter case: Contradictory information that prompts epistemic emotions such as surprise, curiosity, confusion, frustration, or delight when the contradiction can be resolved. Specifically, surprise, curiosity, and confusion have attracted researchers' attention. These three emotions are epistemic by definition, because they are specifically generated by cognitive incongruity as outlined earlier.

Epistemic Emotions: Surprise, Curiosity, and Confusion

Surprise is triggered by unexpected or schema-discrepant events (e.g., Berlyne, 1960; Noordewier, Topolinski, & Van Dijk, 2016; Scherer, 2009). Surprise is likely to be the first emotional reaction to unexpected events. Surprise fixates individuals' gaze (i.e., visual attention) on the unexpected event (e.g., Horstmann & Herwig, 2015), elicits interest (Renninger & Hidi, 2016), facilitates curiosity and exploratory behavior (Berlyne, 1960; Litman, Hutchins, & Russon, 2005; Loewenstein, 1994), and promotes recall of the unexpected event (e.g., Parzuchowski & Szymkow-Sudziarska, 2008).

Curiosity has been labelled as a "drive to know" (Berlyne, 1954, p.187). Unexpected information or events that reveal gaps in one's knowledge arouse curiosity (Loewenstein, 1994). Curiosity is typically viewed as a gateway for meaningful learning in educational contexts (von Stumm, Hell, & Chamorro-Premuzic, 2011) and has been shown to promote exploration of new knowledge (Berlyne, 1954, 1960; Litman et al., 2005) and to enhance retention for new information (Gruber, Gelman, & Ranganath, 2014; Kang et al., 2009).

Confusion arises when learners are confronted with novel and complex information, or when new information is discrepant from previous knowledge and the resulting incongruity cannot be immediately resolved (Muis et al., 2018; Pekrun & Stephens, 2012). Confusion can stimulate task engagement (D'Mello & Graesser, 2012) because impasses (and the associated state of confusion) require active engagement and effortful cognitive processing in order to be overcome (Brown & VanLehn, 1980). For confusion to be productive, however, it is crucial that incongruity is ultimately resolved (D'Mello & Graesser, 2014). One way of achieving such resolution may be to explore or construct new knowledge (Berlyne, 1954, 1960).

Contradictory Perspectives and Epistemic Emotions during Learning

Learning from multiple, contradictory perspectives is a special case of processing contradictory information more generally. In contrast to effects of other types of contradictory information, such as unexpected events, the impact of contradictory learning materials on emotions has received scant attention. However, a few recent studies have focused on epistemic emotions prompted by contradictory learning contents.

Contradictory Perspectives in Social Interaction

Collaborative learning can involve having to deal with diverging opinions expressed by fellow learners or teachers. In two experiments, D'Mello, Lehman, Pekrun, and Graesser (2014) examined the effects of contradictory opinions on learners' confusion and performance. The learning material related to scientific reasoning knowledge, including topics such as construct validity, random assignment, or experimenter bias. In trialogues, learners interacted with a virtual tutor and a virtual peer who either agreed or disagreed with the learner, or among themselves, by providing correct or incorrect opinions. Confusion was measured via retrospective self-report or a more objective measure of learners' confusion visible in their responses to questions on the learning material. Specifically, frequency of incorrect answers after communication of contradictory perspectives was considered as an objective indicator of confusion.

The findings showed that contradictory opinions tended to increase learners' confusion, especially as assessed through the objective measure. The delayed retrospective self-report measure may not have been sufficiently sensitive to fully detect learners' momentary affective states. Confusion, in turn, influenced learners' performance as measured with immediate and delayed performance tests. Specifically, confusion had positive effects on performance when there were contradictory opinions, likely due to enhanced efforts to resolve the contradictions. As such, the findings suggest that confusion can be beneficial for learning from multiple perspectives.

Prior Beliefs and Learning from Contradictory Texts

Muis and her colleagues (Muis et al., 2015a) introduced an experimental paradigm that connects research on epistemic emotions with inquiry on conceptual change and learning from refutation texts. In this paradigm, two levels of contradictory perspectives are considered, and the impact of these multiple perspectives on epistemic emotions and resulting learning outcomes is explored. The first level involves multiple cognitive perspectives represented by contradictory texts on controversial issues, such as climate change, genetically modified foods, or vaccination of children. For example, in our original study (Muis et al., 2018), participants were provided with two scientific texts arguing that climate change is either man-made (Text 1) or due to natural causes (Text 2), and two texts arguing that climate change has either negative (Text 3) or positive consequences (Text 4). The second level involves multiple metacognitive perspectives in terms of the congruity, or lack of congruity, between participants' epistemic beliefs and the task of reading contradictory texts. Epistemic emotions were assessed using the *Epistemic Emotion Scales* (EES; Pekrun, Vogl, Muis, & Sinatra, 2017).

We hypothesized that contradictory texts prompt epistemic emotions, including surprise, curiosity, and confusion, and that these emotions, in turn, would influence students' learning strategies when reading the texts as well as their learning outcomes. Furthermore, we expected lack of congruity between epistemic beliefs and learning from contradictory materials to also influence epistemic emotions. Specifically, we expected non-constructivist beliefs (i.e., beliefs that scientific knowledge is simple, certain, and defined by authority) to enhance emotions such as surprise and confusion when reading contradictory texts.

The findings provided support for some of these propositions. As expected, reading contradictory texts increased participants' surprise and confusion. Furthermore, some of the epistemic beliefs also were predictors of epistemic emotions. For example, belief in the simplicity of scientific knowledge positively predicted confusion, anxiety, and boredom, and belief in the certainty of knowledge positively predicted anxiety and frustration. Epistemic emotions, in turn, predicted use of learning strategies, such as curiosity predicting elaboration, critical thinking, and metacognitive self-regulation. Finally, elaboration and critical thinking were positive predictors of achievement. Metacognitive self-regulation was negatively related to achievement, likely due to difficulties in understanding the material prompting efforts to regulate one's learning.

Using the same experimental paradigm, Trevors, Muis, Pekrun, Sinatra, & Muijselaar (2017) replicated the Muis et al. (2015a) study. Again, we found support for some of the proposed links. Reading the contradictory texts again increased surprise and confusion. The epistemic beliefs were predictors of emotions, such as a belief in justification of knowledge through inquiry positively predicting curiosity. Some of the emotions, in turn, predicted participants' increase in understanding. Specifically, curiosity tended to positively predict participants' understanding, whereas confusion was a negative predictor.

In related research on the role of self-beliefs for the effects of multiple perspectives on emotions and learning, Trevors, Muis, Pekrun, Sinatra, & Winne (2016) examined the "backfire effect" that can occur when attempting to change individuals' attitudes. This effect involves strengthening rather than changing attitudes through intervention, and can occur when individuals are emotionally invested in their attitudes. We asked participants to report about their diet self-concept and to read either an expository text on genetically modified foods that presented scientific information, or a refutation text that contained the same information but presented within a format that identifies misconceptions and refutes them. Participants who read the refutation text and believed in the importance of keeping a healthy diet reported more negative epistemic emotions than participants who cared less about diet, likely because the refutation text made contradictions between these beliefs and scientific information more salient. Negative emotions, in turn, negatively predicted attitude change after reading, and negatively predicted knowledge change after reading the refutation text specifically. Positive emotions did not predict change of knowledge or attitude.

Finally, Trevors, Kendeou and Butterfuss (2017) examined the role of emotions in learning from refutation texts. By directly addressing the misconception, refutation texts induce cognitive incongruity, thus presumably also prompting epistemic emo- tions. The texts addressed common misconceptions that were found to be frequent among undergraduate students, such as the belief that meteors that land on earth (meteorites) are hot; that chameleons change color to match their surroundings; or that reading in dim light ruins your eyes. Using a within-person experimental design, participants read both refutation texts and non-refutation texts dealing with these misconceptions. Emotions during reading the texts were assessed with a think-aloud protocol. As compared with non-refutation texts, reading refutation texts prompted surprise early during reading and enhanced learning. Furthermore, surprise positively predicted learning outcomes and mediated the effects of text condition on these outcomes.

Overall, the findings of these studies suggest that contradictory perspectives can prompt epistemic emotions. This seems to be true both for cognitive perspectives (contradictory texts, refutation texts) and metacognitive perspectives (prior beliefs vs. the nature of the current learning task). Surprise and curiosity were found to have positive effects on learning, whereas negative epistemic emotions can hinder learning from contradictory texts, especially so if these perspectives contradict individuals' prior self-beliefs.

Prior Beliefs and Learning After Unexpected Feedback

Most studies in this field, and in educational and psychological research more generally, have used between-person designs, with few exceptions like the study by Trevors et al. (2017) cited above. However, our theories typically pertain to within-person psychological functioning, such as theories of achievement and epistemic emotions as discussed earlier. Between-person approaches are not well suited to examine within-person functioning, because between- and within-person parameters (such as covariation between variables) can differ widely. By implication, it is imperative to supplement traditional between-person approaches with intra-individual analysis.

As such, and following calls to conduct within-person research (see Murayama et al., 2017), we used within-person analysis in a recent series of three experimental studies exploring the emotional effects of cognitive incongruity (Vogl, Pekrun, Murayama, & Loderer, 2019). Specifically, we investigated the effects of incongruity prompted by high-confidence errors during a trivia task. The task consisted of 20 questions that relate to common misconceptions, similar to the material used by Trevors et al. (2017) as cited earlier (e.g., "Popes cannot have children legitimately" – true or false?). High-confidence errors are incorrect answers that individuals had believed to be correct, thus involving a lack of congruity between prior confidence and current negative feedback. We examined the effects of such feedback on three epistemic emotions (surprise, curiosity, and confusion), two achievement emotions (pride and shame), and participants' exploration of the correct answer. Multi-level analysis was used to explore the effects of feedback (Level 1: questions within persons, Level 2: persons).

Between-person analysis of the relations between these variables did not yield a clear pattern of findings. In contrast, within-person results were strong and consistent across studies. As expected, feedback on the trivia task induced both epistemic and achievement emotions but under different circumstances. Specifically, correct answers (i.e., success) predicted pride, and incorrect answers (i.e., failure;) predicted shame. Incorrect answers also triggered the epistemic emotions surprise, curiosity, and confusion. However, for these emotions, the effects were speci- fied by an interaction with prior confidence in the accuracy of the answer. Surprise, curiosity, and confusion were induced by high-confidence errors; their intensity depended on participants' confidence in the answers that turned out to be incorrect, thus generating cognitive incongruity. The results also shed light on the dynamic interplay of multiple epistemic emotions suggesting that surprise may precede curiosity (Loewenstein, 1994) and confusion (D'Mello & Graesser, 2012).

In addition, surprise and curiosity related positively to subsequent motivation to explore as well as actual exploratory behavior. The findings suggest that cognitive incongruity promotes exploration, and that surprise and curiosity are mediators in this relationship. Confusion also was a positive predictor of exploration. However, the effects for confusion were relatively weak, maybe due to variable effects on motivation. As argued earlier, negative activating emotions like confusion can strengthen motivation in individuals who expect to successfully solve the problem, but undermine motivation and knowledge exploration when a solution seems unlikely.

DIRECTIONS FOR FUTURE RESEARCH AND IMPLICATIONS FOR PRACTICE

Directions for Research

The findings summarized in this chapter provide clear evidence that features of multiple inputs can influence learners' emotions, and that these emotions, in turn, can impact on performance. Specifically, various sensory features of multimedia learning were found to influence affective state, likely due to processes of emotional entrainment and contagion. Furthermore, features of multimedia learning that are likely to influence learners' appraisals, such as task demands, scaffolding, autonomy support, incentives, and social interaction, were also found to influence emotions. However, one caveat is that the extant studies typically examined single features of multiple inputs but did not investigate how they interact in influencing appraisals and emotions.

In addition, in a few recent studies on the impact of multiple perspectives on the same topic, it was found that contradictory perspectives can prompt epistemic emotions such as surprise, curiosity, and confusion. The extant evidence from these three lines of research also suggests that the emotions during learning that were prompted in these ways can influence processes and outcomes of learning.

However, so far the number of available studies is too small, and the evidence from these studies not sufficiently consistent to reach firm conclusions. As argued by D'Mello (2013, p. 1083), there is a lot of theory but "a dearth of data" in the field, "leaving many fundamental questions about how affective states arise, morph, decay, and impact learning outcomes largely unanswered … Systematic research focused on answering basic questions … is still in its infancy". As such, intensified efforts are needed to understand how emotions relate to learning from multiple inputs. As part of such efforts, research should be conducted along the following lines (see also Pekrun & Linnenbrink-Garcia, 2014b).

First, the theories that guide research on emotion and learning need to be further developed. The available theories need better integration, which may be feasible given that they are largely complementary rather than contradictory. For example, Scherer's (2009) component process model of emotion, models of effects of emotion on cognition (e.g., Fiedler & Beier, 2014), Moreno's (2006), and Plass and Kaplan's (2016) cognitive-affective models of multimedia learning, Muis et al.'s (2018) model of epistemic emotions, and Pekrun's CVT which was used to organize this chapter, share basic assumptions about the mechanisms that mediate effects of antecedents on emotions, and effects on emotions on outcomes. Theory-building in the field also needs to attend to recent progress in basic research on emotions, such as cognitive and neuroscientific evidence on the appraisal processes that guide emotion.

Second, many of the current findings need replication with sufficiently large and diversified samples before conclusions on generalizability can be reached. While some of the research cited in this chapter consisted of series of studies involving conceptual replications (e.g., D'Mello et al., 2014; Muis et al., 2015a, combined with Trevors et al., 2017), much of the research consisted of isolated, single studies with small, non-representative samples, thus leaving the field in a state of fragmentation overall. Use of small convenience samples and lack of statistical power is a general problem of studies especially in technology-based and multimedia learning, largely due to the costs for conducting this kind of research. Following the models developed in social psychology, organizing multi-lab studies may be a way to tackle this problem.

Third, most studies used between-person designs. Given that these designs are not well suited to investigate learning processes within individuals as argued earlier, future research should make increased use of within-person designs. This is complicated to achieve especially for controlled laboratory studies, given that sufficient a number of measurement occasions need to be available for each participant to render robust estimates for within-person effects. Using small tasks such as the trivia tasks in the research by Vogl et al. (2019) can solve this problem but comes at the cost of jeopardizing the authenticity of the learning tasks. Findings on trivia tasks may not be representative for learning with more complex materials.

Furthermore, with few exceptions, the available studies relied on self-report of emotions. Self-report is advantageous as it can represent a broad range of affective and cognitive facets of learners' emotions. For a nuanced picture of these emotions, self-report is indispensable. However, self-report is also known to have major disadvantages. Self-report is subject to response sets and memory biases, is limited to reports about consciously accessible emotion, and cannot capture dynamic processes of emotion in real-time (Pekrun & Bühner, 2014). As such, self-report needs to be complemented by other channels including physiological and behavioral measures.

On a related note, most of the available studies used one-shot assessments of emotion and did not assess the development of emotions over time during learning. Studies are needed that assess emotions in real-time throughout different phases of the learning process. In addition, studies are needed that examine the development of learning-related emotions over the lifespan. The extant studies focused on high-school and university students' emotions; studies should also investigate emotions during learning from multiple inputs in other age groups, using cohort-sequential and longitudinal designs. It would be especially important to analyze emotions and learning from multiple inputs in the pre-school and elementary school years. These years may be critically important for affective development, as competencies underlying cognitive appraisals (e.g., competencies to process causal expectancies and attributions) and an understanding of emotions develop at this age.

Finally, once the role of emotions in learning has been more firmly established, it will also be important to more fully explore the mechanisms that mediate effects. In this chapter, effects of multiple inputs have been theoretically explained by mechanisms of appraisals and emotional transmission, but these mediating mechanisms have rarely been directly investigated in research on learning from multiple inputs. In other words, studies have investigated effects of multiple inputs on emotions, but have failed to examine the processes that presumably cause these effects. Similarly, various motivational and cognitive mechanisms are held responsible for the effects of emotions on success in learning from multiple inputs, but these mechanisms typically have not been directly assessed either. For more fully explaining effects of emotions, it will be especially important to simultaneously consider different mechanisms that mediate learning, as it is necessary to understand the synergistic interplay of these mechanisms to more fully understand effects on learning outcomes.

Implications for Practice

Given the preliminary nature of the available evidence, caution should be exerted in deriving recommendations for instructional design and educational practice. Nevertheless, even if preliminary, it seems possible to infer a number of general guidelines. For example, in terms of sensory features of multimedia learning materials, it may often make sense to design features in a way that facilitates positive affect through emotional entrainment and contagion, as argued earlier. A range of related design principles can be derived, for example, from the literature on multimedia design as summarized in the section on sensory features (see also Clark, Tanner-Smith, & Killingsworth, 2016; D'Mello, Blanchard, Baker, Ocumpaugh, & Brawner, 2014; Dickey, 2015; Graesser, D'Mello, & Strain, 2014; Ke, 2016; Loderer et al., 2018; Plass, Homer, & Kinzer, 2015).

In terms of the representational structures, it is advisable to construct learning tasks and environments such that learners' perceptions of control and value are promoted. The summary provided in the section on emotion and multiple representations suggests that this can be achieved by calibrating task demands based on learners' competencies, thus preventing under- or over-challenge; by scaffolding learner's activities to facilitate the development of competencies and a related sense of control; by providing incentive structures that promote emotional engagement; by avoiding excessive use of competitive goal structures, as these structures can exacerbate failure-related emotions such as anxiety and hopelessness in those who cannot win the competition; and by providing interaction with peers, teachers, or virtual agents to fulfill needs for social relatedness.

Finally, the nascent literature on emotions in learning from multiple perspectives suggests that it can be fruitful to provide learners with contradictory information that can stimulate surprise, curiosity, and confusion. However, for these emotions to be conducive to learning, it seems necessary to also provide learners with the opportunity to resolve contradictions. Learners who are competent to self-regulate their leaning and integrate complex information may often be able to productively use confusing situations on their own. For others, guidance through scaffolding may be needed to let these emotions benefit learning.

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