Neuroscience-Informed Design of Learning Materials: Examining the Impact of Emotion, Interest, and Attention on Learning

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Abstract: The impact of emotional design on learning, particularly related to emotional valence, is a topic of interest in the domain of online and distance learning. This study, situated in the South African private higher education context, sought to explore how students learn and why certain learning materials better promote learning than others. The study used psychophysiological assessments, including eye-tracking, galvanic skin responses, and facial expressions, to explore the relationship between emotional arousal, interest, and attention in online learning. Nineteen students aged 18 to 24 were shown 11 different variations of an online module's first page, each differing in design elements, for 9 seconds to gauge their initial reactions. Emotional responses were measured using the Self-Assessment Manikin (SAM), and qualitative discussions provided further insights into students' preferences. The findings produced valuable recommendations for instructional design that fosters interest and enhances the learning experience. By integrating neuroscience techniques and educational psychology principles, the study established a link between emotion, interest and attention as key factors influencing student engagement and memory retention. This finding is significant as it highlights the importance of designing learning materials that capture students' initial interest, providing valuable insights into the universal principles of effective learning design. It emphasises the importance of emotional design in learning materials and the need for a balance between emotional arousal that generates interest but avoiding cognitive overload. The study underscores the critical role of purposeful learning design in creating engaging and effective learning experiences for students.

Keywords: Neuroscience for learning, Higher education, Learning material design, Emotional interest

1. Introduction

Widening access to higher education is a critical issue in South Africa, where there is a national shortage of university places for qualifying matriculants (IOL, 2024). In response to this challenge, STADIO Higher Education, a large private higher education institution, has committed to expanding its reach with the goal of enrolling 56,000 students by 2026. This ambitious target includes offering 20% of its programmes through Blended Contact Learning (BCL) and 80% through Distance Learning (DL), thereby catering to a diverse student body across nine academic schools, including Administration and Management, Engineering and Architecture, Commerce, Education, Fashion, Humanities, Information Technology, Law, and Policing and Law Enforcement.

STADIO's approach to education places a strong emphasis on student-centeredness and independent learning, particularly for DL students who rely heavily on their learning materials. To support these students towards their academic success, the institution recognises the important role of well-designed learning materials that support their independent learning experiences. The aim of these learning materials is to create effective, accessible, and high-quality educational experiences that align with the institution's broader goals of widening access and supporting student success (STADIO, 2024). The learning materials are designed to be affordable, inclusive, and tailored to the diverse needs of STADIO's student population. The policy emphasises the importance of accessibility and inclusivity, ensuring that learning materials are suitable for various demographic groups and consider cognitive load and the National Qualifications Framework (NQF) levels.

The STADIO Materials Development Policy (2024) emphasises the need for materials to be relevant and current, incorporating local and culturally relevant examples while promoting global perspectives. Legal and ethical compliance, including adherence to intellectual property laws and the ethical use of AI, is also a key consideration in the development of these materials. The materials are expected to align with learning outcomes and curriculum objectives, utilising effective instructional design principles to enhance the learning experience.

It is within this context that the current study was conducted. The research aimed to provide psychophysiological insights to develop learning materials that are engaging and effective. More specifically, the study focused on exploring the underlying psychophysiological reactions of first-year students when exposed to different layouts of learning materials, with the overarching goal of improving the learning experience. The study examined their approach, avoidance, and valence reactions to the presented stimuli, providing further insights into potential study material layouts. The primary research questions addressed

were: What are the psychophysiological reactions to different layouts of study material, and how can these insights better guide the design of learning materials?

2. Literature Review

The literature identifies several neuroscience factors that significantly influence student engagement with learning materials. Cohen (2018) found that neural engagement, as measured by the inter-subject correlation of the electroencephalogram (EEG), is predictive of academic performance, particularly in educational video contexts. Similarly, Khedher, Jraidi, and Frasson (2019) demonstrated that EEG signals could effectively monitor mental engagement during learning activities, with higher engagement levels correlating with better academic performance. Kalogeras, Mejri, and Efthimiou (2022) emphasised the importance of narrative instruction in enhancing student engagement. Conversely, Howard-Jones (2010) warned against the dangers of neuromyths in education, noting that misconceptions about brain function can negatively impact teaching practices. Collectively, these findings underscore the importance of integrating neuroscience insights into the design of learning materials to optimise student engagement and learning outcomes. The review of the literature that follows, covers the concepts of emotion, interest, and attention, and concludes with the current gaps identified as a result.

2.1 Emotion

The Cognitive-Affective Theory of Learning with Media (CATLM), developed by Mayer (2014), emphasises the importance of integrating emotionally engaging elements into the design of learning materials to enhance cognitive engagement and learning outcomes. According to this theory, emotional valence—the positive or negative emotions associated with a stimulus—plays a crucial role in learning. Positive emotions, such as joy and excitement, can enhance engagement, creating a conducive learning environment that improves retention and understanding of content (Hascher, 2010). Hascher (2010) further emphasises the connection between mood and student motivation, suggesting that emotionally engaging content is more likely to be processed and remembered.

Studying the link between emotion and memory, Bradley and Lang (1994) found that emotional experiences have two independent dimensions: valence, which depicts the extent of happiness or sadness, and arousal, related to the intensity of the experience. Emotional arousal, closely linked to emotional valence, influences attention, motivation, and information processing. O'Reagan (2003) challenges the traditional view that cognition is purely logical, arguing that cognition is intertwined with emotion. This perspective is supported by Plass et al. (2014), who highlight that the emotional design of multimedia learning materials can promote positive emotions in students, thereby enhancing comprehension and transfer.

A recent study by Ozcelik and Arslan-Ari (2023) on the relationship between emotional arousal and learning, revealed that interest acts as a mediator between arousal and learning. Their research found that emotional arousal can increase interest, which in turn enhances learning. They also discovered a direct effect of emotional arousal on learning, reinforcing the idea that emotion and cognition are deeply interconnected. From an evolutionary perspective, the remembrance of information surrounding emotional events is considered vital for survival (Hamann, 2001). For example, remembering the location of a water source or avoiding a predator's attack is crucial (Buchanan & Adolphs, 2002).

However, it is important to recognise that emotion does not always enhance memory. Meinhardt and Pekrun (2003) found that negative emotions could interfere with learning processes. Harp and Mayer (1997) also discovered that adding "seductive details"—emotionally interesting but irrelevant information—can detract from the recall and transfer of multimedia materials. Park, Flowerday, and Brünken (2015) suggest that such details may divert cognitive resources away from essential learning content, highlighting the complexity of emotional valence in educational settings. Therefore, while positive emotions can be beneficial, careful consideration must be given to the type and relevance of emotional content integrated into learning materials.

2.2 Interest

Interest, closely linked to curiosity, is essential for maintaining student engagement with learning materials Pintrich (2004). Research suggests that a student’s reaction to the visual appearance of text can significantly affect their interest in reading, which then influences their engagement with the material. Caine and Caine (1990) further emphasise that the human brain seeks novelty while requiring familiarity, suggesting that learning materials must balance these elements to sustain student interest.

2.3 Attention

Attention, defined as the cognitive process of selecting and focusing on specific information for processing, is another critical factor impacting learning. Dzulkifli and Mustafar (2013) describe attention as crucial for memory retention, noting that the degree of attention attached to certain stimuli increases the likelihood of that information being stored in memory. The eye-mind hypothesis supports this by suggesting that what is fixated upon is processed, highlighting the importance of strategically positioning key elements in learning materials to attract and maintain attention. While the importance of sustaining attention is recognised (Pintrich, 2004; Dzulkifli & Mustafar, 2013), there is a lack of longitudinal studies examining how sustained attention impacts long-term learning outcomes. This gap highlights the need for research into designing learning materials that maintain engagement over extended periods, particularly in self-paced online courses.

2.4 Summary

Despite the progress in understanding the impact of emotion, interest, and attention on learning, several gaps remain. While emotional arousal is recognised as a key factor influencing attention and cognitive engagement, most existing studies do not fully explore how emotional arousal specifically impacts learning in online or distance learning settings. The dynamics of emotional arousal in these contexts, where social cues are limited, remain underexplored. Although the role of visual design in capturing and maintaining student interest is acknowledged, there is a gap in understanding the specific visual design elements—such as colour, typography, and layout—that most effectively promote emotional engagement and learning (Mayer, 2014).

Finally, while there is a growing understanding of the importance of emotion, interest, and attention in learning, further research is needed, particularly in the context of online and distance learning. The findings of this paper are relevant for instructional design and materials development, especially in learning settings where social engagement is limited. Integrating these neuroscience-informed insights into the design of learning materials could significantly enhance student engagement and improve learning.

3. Methodology

In this study, an interpretivist approach was employed to understand participants' subjective experiences and perspectives to uncover underlying meanings and insights, acknowledging that knowledge is socially constructed and shaped by individual and cultural contexts (Schwartz-Shea & Yanow, 2012). Additionally, an experimental design was implemented alongside the interpretivist framework, allowing specific stimuli to be presented in a controlled environment. This combination of approaches enabled a systematic exploration of causal relationships within observed behaviours, facilitating an understanding of both subjective insights and specific reactions to controlled stimuli (Joubert & Bothma, 2019).

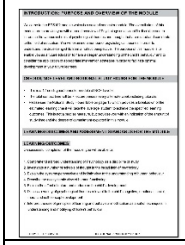
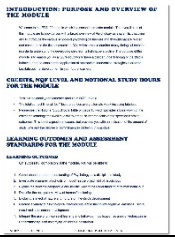
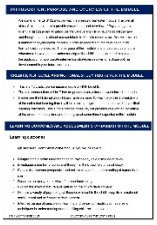
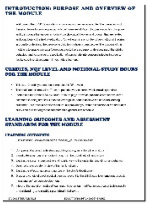
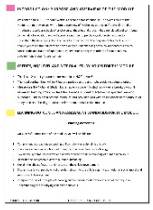
3.1 Sample

Participants were purposefully and conveniently selected from the first-year cohort on a single campus. The sample comprised 19 students, of whom 13 were aged between 18 and 20 years (68%), four were aged between 21 and 24 years (21%), and two were aged between 25 and 28 years (11%). The gender distribution included 15 female participants (79%) and four male participants (21%). Considering the experimental nature of this study, which does not require large sample sizes, this sample was deemed adequate to ensure reliable and valid data for analysis and reporting purposes.

3.2 Research Instruments

The study involved exposing participants to the introductory page of the study guide of an education module, presented in 11 different formats. Each page featured minor variations in font, colour, white spaces, and headings (see Table 1).

Table 1: Summary of the findings

		
Version 1	**Version 2**	**Version 3**
-	Grey shading behind headings removed	Headings: 14px and red. Content 12px and black
Original version	Same as original version but made very plain. Blue font	Original page content still fits on one page. Font remains blue
		
Version 4	**Version 5**	**Version 6**
Headings: 14px and red. Content 12px and black	Area below headings coloured blue with heading font in white	Same as version 5 but with addition of a graphic
Addition of colour and white space. Same font throughout as original.	Original page content still fits on one page	Page content less than original and with more white space – less text
		
Version 7	**Version 8**	**Version 9**
Heading font size increased	Heading font size increased	Same as version 3. Content font colour changed to black. Content indented 18 points
Colour added. Graphic added. Not all original content fits on page	Original page content still fits on one page. Blue font	Same as version 3 but content font colour changed to black. Increase in white space
		
Version 10	**Version 11**	
Same as version 4 but addition of thin red block line around page	Same as version 7. Font changed to Calibri. Same sizes as original but addition of coloured blocks next to headings and indented text. Sub-heading centred	
Addition of colour and white space	Colour added	

Students were exposed to each page in a random order for a duration of nine seconds to capture their initial reactions—specifically, their approach/avoidance responses—while preventing any in-depth reading of the content.

Two main research instruments were employed, the Self-Assessment Manikin (SAM), followed by student interviews. By combining unconscious physiological responses with conscious qualitative feedback, the study aimed to identify the visual elements that most effectively captured students' initial interest and attention, setting the stage for deeper cognitive engagement with the content.

3.2.1 Self-Assessment Manikin (SAM)

The Self-Assessment Manikin (SAM), developed by Bradley and Lang (1994), was used to capture the students' immediate emotional responses to each slide. SAM is a non-verbal tool that uses three pictorial scales—valence, arousal, and dominance—to represent different dimensions of emotional experience.

The following Psychophysiological measures were recorded during this exposure, as follows:

- **Heat map**: Eye-Tracking was captured to reveal attention by tracking where and for how long students looked at different parts of the slide. This measure indicated students' attention.
- **Pupillometry**: Pupil Dilation measured interest by determining how much students' pupils dilated while viewing the slide.
- **Galvanic Skin Response (GSR)**: Peaks in the GSR indicated arousal which was then linked to specific moments of eye movement to understand the relationship between what students saw and how emotionally engaged they were.
- **Human Facial Expression**: These were captured to determine the overall emotional valence response (positive, negative, or neutral) as students interacted with each slide.
- **Self-Assessment Manikin (SAM)**: Following the recording of psychophysiological measures, participants completed a Self-Assessment Manikin (SAM) attitude scale.

The data collection process commenced with initial exposures to a positive, a negative, and a neutral image to obtain benchmark readings, followed by the 11 different versions of a single learning materials page (see Figure 1).

3.2.2 Interview discussion

To complement the psychophysiological data, each student was briefly interviewed to share their impressions and feelings about each slide. This qualitative feedback provided deeper insights into the subjective experiences of the participants, which were then used to triangulate the findings from the psychophysiological assessments. In this way, it was possible to form an understanding of how different design elements influenced student engagement.

3.3 Data Analysis

Guided by the literature, the study was organised thematically around three key areas: emotion, interest, and attention.

3.3.1 Emotion

Emotional arousal responses were gauged using two primary methods: Galvanic Skin Responses (GSR) and human facial expression analysis. GSR data, linked with eye-tracking data, indicated levels of arousal, showing how emotionally stimulating each slide was. Facial expression analysis provided additional insights into the emotional valence—whether students felt positive, neutral, or negative emotions—associated with each slide. These observations were triangulated through the student feedback data collected during the focus group discussion.

3.3.2 Interest

Interest was signalled by pupil dilation (pupillometry), captured using eye-tracking technology. The extent of pupil dilation indicated how engaged a student was with a particular slide, providing insight into which design elements were most effective at capturing interest. This data was supplemented by the student feedback collected during the focus group discussion.

3.3.3 Attention

Attention was measured by eye-tracking through the recording points of fixation and the sequence of eye movements across the slide (heat map). This allowed the researchers to determine whether certain design elements, such as bold headings or colour contrasts, effectively guided students' attention through the content. In addition, the student responses collected during the focus group interview were noted.

3.4 Ethics

The research ethics for this study were overseen by the Bureau of Market Research (BMR) on behalf of the research team. All participants were thoroughly informed about the purpose of the study, the confidential nature of their participation, their right to withdraw at any time, and what to expect from their involvement in the research. Participants were provided with a clear explanation of the research objectives, the expected duration of their participation, and the potential risks—although none were anticipated—and benefits of their involvement. They were assured that the research would not cause them any harm and were explicitly informed that they were free to withdraw from the study at any point. An invitation to ask any questions regarding the research was also extended to them. Informed consent forms were distributed and explained to each participant, detailing the research methodology as outlined in this chapter.

4. Findings and Discussion

The study found that students' initial reactions to the slides varied significantly, with some slides eliciting higher levels of sustained interest and emotional arousal than others. For example: Slide 3 (with a change in heading font) and Slide 8 (with larger font size) both led to a logical top-down reading process, facilitating coherent engagement and knowledge acquisition. Slides 6 and 7, which included graphics and more white space, generated strong emotional responses, though interest in the graphics themselves was limited.

The results underscored the importance of first impressions of learning materials, especially in online learning environments. Visual presentation, including the use of colour, font styles, and layout, plays a crucial role in capturing students' attention and maintaining their interest. Emotional arousal was linked to sustained attention, supporting the notion that well-designed learning materials can enhance cognitive engagement and memory retention.

4.1 Emotion

The role of emotional arousal in enhancing transfer learning, as evidenced by the SAM measurements and the higher transfer scores associated with high-arousal slides, aligns with the findings of Gong, Jia and Li (2017) and Knörzer, Brünken and Park (2016), who also reported that emotion improves transfer performance. However, our study contradicts the meta-analysis by Brom, Starkova, and D'Mello (2018) and Wong and Adesope (2021), who suggested that emotional design positively affects all learning outcomes, including retention. The lack of significant improvement in retention scores in our study suggests that while emotional arousal can enhance the application of knowledge, its impact on the recall of factual information may be more limited.

4.2 Interest

The study's findings on the role of visual design in capturing and sustaining interest align with existing literature on the importance of distinct and engaging visual elements in educational materials. For instance, Plass et al. (2014) highlighted the significance of aesthetic design in enhancing student engagement, a finding supported by the strong interest generated by Slides 3 and 8 in our study. The logical top-down reading pattern observed with these slides also reinforces the notion that well-organised and visually appealing content can facilitate more structured engagement, as noted by Schiefele and Krapp (1996).

In contrast, the lack of sustained interest in Slides 1 and 2, which had more plain designs, contradicts the findings of Um et al. (2012), who suggested that even minimal aesthetic enhancements could positively affect student engagement. This discrepancy may be due to the specific context of our study, where students were exposed to highly similar content across slides, potentially diminishing the impact of minor design changes.

4.3 Attention

The eye-tracking data showing initial focus on the centre of the page and the effectiveness of bold and distinct headings in directing attention is consistent with the findings of Mayer and Estrella (2014), who emphasised the importance of visually salient features in guiding student focus. The relatively short gaze fixation on

graphics in Slides 6 and 7, despite their initial attraction, supports the conclusions of Park, Flowerday and Brünken (2015) that, while images can capture attention, their contribution to deeper cognitive processing may be limited unless they are directly relevant to the learning content.

5. Conclusion

This study confirms the vital role that neuroscience-informed design plays in creating engaging and effective learning materials. By focusing on the emotional aspects of valence and arousal in relation to the aesthetics of these materials, the research provides valuable insights into how the visual presentation of content can positively influence student engagement. The findings emphasise that a balanced approach to emotional arousal—one that captures interest without causing cognitive overload—is essential for fostering learning environments where emotional elements enhance both attention and curiosity. This balance is necessary to support better learning outcomes, particularly in contexts where maintaining student engagement is more challenging, such as distance and online learning.

One of the unique contributions of this study is the identification of a clear link between attention and curiosity, demonstrating that carefully managed emotional arousal can enhance student interest and cognitive engagement. This insight is particularly relevant for the design of learning materials, where emotional design can play a key role in maintaining engagement. Additionally, the research highlights the impact of specific design elements—such as font style, colour, and the inclusion of graphics—on emotional and cognitive engagement, offering practical guidance for developing more effective learning materials.

Furthermore, this study contributes to the growing body of research on the impact of neuroscience-informed design on learning by providing empirical evidence that emotional arousal, mediated by interest, enhances transfer learning but not necessarily retention. The findings support Cognitive-Affective Theory of Learning with Media (CATLM) (Mayer, 2014), highlighting the importance of integrating emotionally engaging elements into the design of learning materials to improve cognitive engagement and learning outcomes.

Finally, this research contributes to the broader goal of widening access to higher education in South Africa by informing the development of effective learning material design principles that are inclusive and responsive to the diverse needs of students.

Despite its contributions, the study acknowledges several limitations. The relatively small sample size and short exposure times may not fully capture the long-term effects of emotional design on learning outcomes. Additionally, the uniformity of content across different slides may have limited the ability to detect more subtle differences in how various emotional and aesthetic elements impact learning.

Future research should focus on exploring the long-term effects of emotional arousal on different types of learning outcomes, including both retention and transfer. It would also be beneficial to examine how emotional design influences learning in more diverse and complex environments, such as real-world tasks or collaborative learning scenarios. Further studies should investigate the interaction between different emotional and cognitive factors, such as how emotional valence interacts with cognitive load, to provide a more comprehensive understanding of how best to optimise student engagement and learning.

References

Bradley, M.M. and Lang, P.J. (1994) Measuring emotion: the self-assessment manikin and the semantic differential. Journal of Behavior Therapy and Experimental Psychiatry, 25(1), pp.49-59.

Brom, C., Starkova, T. and D'Mello, S.K. (2018) How effective is emotional design? A meta-analysis on facial anthropomorphisms and pleasant colors during multimedia learning. Educational Research Review, 25, pp.100-119.

Buchanan, T. and Adolphs, R. (2002) The role of the human amygdala in emotional modulation of long-term declarative memory. In: S. Moore and M. Oaksford, eds. Emotional Cognition: From Brain to Behavior. John Benjamins, pp.9–34. https://doi.org/10.1075/aicr.44.02buc

Caine, R.N. and Caine, G. (1990) Understanding a brain-based approach to learning and teaching. Educational Leadership, 48(2), pp.66-70.

Cohen, S.S. (2018). The Inter-Subject Correlation of EEG in Response to Naturalistic Stimuli. City University of New York.

Dzulkifli, M.A. and Mustafar, M.F. (2013) The influence of colour on memory performance: A review. The Malaysian Journal of Medical Sciences: MJMS, 20(2), p.3.

Gong, M., Jia, K. and Li, S. (2017) Perceptual competition promotes suppression of reward salience in behavioral selection and neural representation. Journal of Neuroscience, 37(26), pp.6242-6252.

Hamann, S. (2001) Cognitive and neural mechanisms of emotional memory. Trends in Cognitive Sciences, 5(9), pp.394-400.

Harp, S.F. and Mayer, R.E. (1997) The role of interest in learning from scientific text and illustrations: On the distinction between emotional interest and cognitive interest. Journal of Educational Psychology, 89(1), p.92.

Hascher, T. (2010) Learning and emotion: Perspectives for theory and research. European Educational Research Journal, 9(1), pp.13-28.

Howard-Jones, P. (2010) Introducing Neuroeducational Research: Neuroscience, Education and the Brain from Contexts to Practice. Taylor & Francis.

IOL (2024) Students are jostling for places. [online] Available at: https://www.iol.co.za/mercury/news/students-are-jostling-for-places-386d85d6-bdc4-48cd-b0e5-a35153c9c942 [Accessed 15 Jun. 2024].

Joubert, J.P.R. and Bothma, C. (2019) Using Neuroscience to Improve Teaching and Learning Materials. Study commissioned by STADIO Holdings. Pretoria: Bureau of Market Research (Pty) Ltd. Report No. CR149.

Kalogeras, S., Mejri, S. and Efthimiou, F. (2022) The neuroscience of student engagement: Case studies in narrative pedagogies in mathematics, science, and technology. International Journal of Online Pedagogy and Course Design (IJOPCD), 12(1), pp.1-19.

Khedher, A.B., Jraidi, I. and Frasson, C. (2019) Tracking students' mental engagement using EEG signals during an interaction with a virtual learning environment. Journal of Intelligent Learning Systems and Applications, 11(01), pp.1-14.

Knörzer, L., Brünken, R. and Park, B. (2016) Facilitators or suppressors: Effects of experimentally induced emotions on multimedia learning. Learning and Instruction, 44, pp.97–107. https://doi.org/10.1016/j.learninstruc.2016.04.002

Mayer, R.E. (2014) The Cambridge Handbook of Multimedia Learning. 2nd ed. Cambridge: Cambridge University Press.

Mayer, R. E., & Estrella, G. (2014) *Benefits of emotional design in multimedia instruction.* Learning and Instruction, 33, 12–18.

Meinhardt, J. and Pekrun, R. (2003) Attentional resource allocation to emotional events: An ERP study. Cognition and Emotion, 17(3), pp.477-500.

O'Reagan, K. (2003) Emotion and e-learning. Journal of Asynchronous Learning Networks, 7(3), pp.78-92.

Ozcelik, E. and Arslan-Ari, I. (2023) Enhancing multimedia learning by emotional arousal. The Journal of Experimental Education, 92(2), pp.247–261. https://doi.org/10.1080/00220973.2023.2182263

Park, B., Flowerday, T. and Brünken, R. (2015) Cognitive and affective effects of seductive details in multimedia learning. Computers in Human Behavior, 44, pp.267-278.

Pintrich, P.R. (2004) A conceptual framework for assessing motivation and self-regulated learning in college students. Educational Psychology Review, 16, pp.385-407.

Plass, J.L., Heidig, S., Hayward, E.O., Homer, B.D. and Um, E. (2014) Emotional design in multimedia learning: Effects of shape and color on affect and learning. Learning and Instruction, 29, pp.128-140.

Schiefele, U. and Krapp, A. (1996) Topic interest and free recall of expository text. Learning and Individual Differences, 8(2), pp.141-160.

Schwartz-Shea, P., & Yanow, D. (2012) *Interpretive Research Design: Concepts and Processes.* Routledge.

STADIO (2024) Materials Development Policy.

Um, E., Plass, J.L., Hayward, E.O. and Homer, B.D. (2012) Emotional design in multimedia learning. Journal of Educational Psychology, 104(2), pp.485–498. https://doi.org/10.1037/a0026609

Wong, R.M. and Adesope, O.O. (2021) Meta-analysis of emotional designs in multimedia learning: A replication and extension study. Educational Psychology Review, 33(2), pp.357-385.