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Emotional Design of PowerPoint Slides: Effect on Self-Perceptions of Mood, Cognitive Load and Memory Retention in Three Anatomy Lectures

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ABSTRACT

In contrast to previous research on emotional design, this study investigates its effectiveness in a university lecture setting. We examine the impact of the emotional design of PowerPoint slides on self-reported mood, cognitive load and memory retention among medical and dental students across three separate anatomy lectures at a Malaysian university. The control group (first-year medical students) viewed emotionally neutral slides, whereas the experiment group (first-year dental students) viewed emotionally positive slides. Self-report questionnaires were used to assess the participants' changes in mood (pre- vs post-lecture) and cognitive load (intrinsic, extraneous, and germane loads). Additionally, a memory retention test was conducted post-lecture. Participants' self-reported positive mood due to emotional design increased to a greater degree when compared to neutral slides. However, no significant differences were found among the three types of cognitive load. Interestingly, emotional design negatively impacted memory retention in one of the three lectures. These results are discussed within the context of the ongoing debate between the "emotion-as-facilitator" and "emotion-as-suppressor" models of learning. The implications of our efforts to generate external validity via a quasi-experimental, exploratory field study are discussed, specifically regarding the generalisability of the results, the presence of external factors and other limitations, and the pedagogy of anatomy.

Keywords: *Emotional design, Lecture slides, Memory retention, Mood, Cognitive load*

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INTRODUCTION

The role of effective learning of human anatomy among medical and dental students cannot be overemphasised. Given that conventional lectures remain the primary pedagogical method used in contemporary anatomy education (1), their effectiveness needs to be enhanced. Some medical educationists (2, 3) advocate for reforming conventional didactic lectures or incorporating student-centric pedagogy, such as problem-based learning (4) and small-group discussions (5, 6), into the curriculum. Others (7) advocate for a reformed method of lecture delivery based on cognitive theories of learning, such as cognitive load theory (CLT). This study explores the suitability of implementing emotional design (8) in medical and dental anatomy lectures. Emotional design, in the educational context, refers to the act of inducing positive emotions to foster cognitive, motivational and learning outcomes via visual manipulations of lesson materials. It has proved to be a simple yet effective intervention for improving cognitive and learning outcomes (8–11). To date, emotional design has only been investigated in computer-based learning environments (10, 11).

Theoretical Framework

The development of emotional design as a concept was guided by pre-existing cognitive theories of learning. CLT (12, 13) is one of the most influential of these theories. The goal of CLT-based instruction is to improve learning by optimising the transfer of information from working memory (WM) to long-term memory (LTM). Three types of cognitive load have been identified (14): intrinsic load (IL), or the amount of WM resources used in processing learned information; extraneous load (EL), referring to the burden placed on WM when processing superfluous elements in the material (i.e., elements that do not directly benefit learning); and germane load (GL), which is characterised as the redistribution of WM resources away from EL and towards IL and is directly responsible for the consolidation of learned information into LTM.

Since WM is limited in capacity (15), IL and EL should be minimised. This can effectively prevent "cognitive overload" – when learners' cognitive loads exceed their WM capacity (14). Conversely, GL should be facilitated to enhance the construction of "schemas" (stores of information acquired from WM during learning and organised in LTM) (14).

Empirical studies have indicated that learning difficult and visually intensive topics, such as anatomy, increase the tendency for cognitive overload (16, 17) due to their complexity, the large volume of learning material, and the need for visualising complex anatomical structures in 3D (18, 19). In CLT terms, learning anatomy may involve high levels of element interactivity, where WM struggles to integrate multiple elements of information (20).

CLT has played an influential role in the development of the cognitive theory of multimedia learning (CTML) (21), another theory for describing the management of cognitive input. However, attempting to understand learning solely from a cognitive perspective is inadequate. The influence of emotional factors on cognitive processes is becoming more evident (22). Cognitive or learning outcomes have been found to be dependent on specific mood states: self-esteem (23), anxiety (24, 25), shame (26), and depression (27–29). Even on a more long-term basis, several longitudinal studies (30, 31) have shown a link between intellectual performance and chronic emotional states (emotional well-being).

The cognitive-affective theory of learning with media (CATLM) (32) is one attempt to wed the emotional and cognitive aspects of learning into a unified theory. It expands on CTML by elucidating the role of emotions as cognitive modulators. CATLM is built on four fundamental assumptions, initially explicated in CTML (21): (a) distinct channels exist for processing verbal and non-verbal information, which operate independently; (b) learning is enhanced through dual coding, utilising both verbal and non-verbal elements; (c) WM has limited capacity, while LTM has virtually unlimited capacity; and (d) learners need to actively engage with information to construct meaning.

CATLM introduces three new assumptions: (e) the affective mediation assumption, which proposes that motivational factors influence learning by either increasing or decreasing cognitive engagement; (f) the metacognitive mediation assumption, which suggests that metacognitive factors regulate cognitive and affective processes during learning; and (g) the individual differences assumption, which states that learners' prior knowledge, cognitive styles, and abilities influence the effectiveness of learning methods and media.

Assumptions (d), (e), and (f) indicate that CATLM is agreeable with the hypothesis of emotion-as-facilitator of learning. Moreno stressed the importance of emotions in regulating learners' motivation, thus determining the allocation of WM resources to the learning task (32). This is similar to the argument made in Fredrickson's broaden-and-build theory (33), which argues that certain positive emotions can "broaden" WM capacity and have favourable effects on cognitive tasks.

In contrast, the hypothesis of emotion-as-suppressor of learning states that both positive and negative emotions may hinder cognitive processes. In CLT terms, emotions may be a source of EL (22). This theory is also consistent with Ellis and Ashbrook's resource allocation model, which describes how emotions experienced during learning lead to ruminative behaviour and task-irrelevant processing (34).

Emotional Design

Most commonly, emotional design features utilise warm colours (e.g., orange, yellow and light brown), rounded images, and facial anthropomorphisms incorporated into the images to stimulate positive emotions (10–11). These features constitute what has been described as emotional design principles (10). Emotional design features are differentiated from external mood-induction procedures by their application in the learning material itself (10). Additionally, emotional design principles do not introduce extra information to the learning material and have been selected based on previous empirical research demonstrating their effectiveness in elevating mood (8). In 2012, Um et al. demonstrated that the emotional design of a computer-based learning program increased the mental effort of participants (suggesting increased GL) and reduced perceived task difficulty (suggesting decreased IL) (8). This resulted in increased lesson comprehension and transfer. However, subsequent studies utilising a variety of emotional design features, learning topics and learning performance measures have yielded mixed results. One example is Liew et al., who found that emotional design via anthropomorphisms and warm colours decreased transfer performance among female participants but increased transfer performance among males (35). Both genders also experienced an increase in EL due to positive emotional design. Another example is Park et al., who found no effect of emotional design on lesson comprehension and transfer (36). The conflicting outcomes in emotional design research reflect the emotion-as-facilitator and emotion-as-suppressor of learning dichotomy.

Nonetheless, a meta-analysis by Wong and Adesope investigated 28 emotional design studies and found a positive meta-analytic effect of emotional design on a variety of outcomes: change in positive affect, retention, transfer, comprehension, intrinsic motivation, mental effort (GL), and reduced perceived difficulty (IL) (11). Their findings demonstrate support for emotion-as-facilitator of learning and the affective mediation assumption of CATLM, as they suggest that emotional factors improve learning by modulating cognitive engagement, cognitive load and WM capacity.

The Present Study

Our primary focus in this study is to address a key limitation of earlier research (e.g., 37, 38): inauthentic experimental conditions. Previous emotional design studies faced constraints, such as short treatment times and learning environments that did not align with the typical experience of learners. Emotional design researchers have frequently called for more research utilising "ecologically valid educational contexts" (e.g., 8, 11, 37, 39). To date, emotional design has not been explored within live lecture or classroom environments. Additionally, no studies have explored the effects of emotional design in anatomy for medical/dental education. Given that medical anatomy is a visually intensive, complex subject, emotional design could potentially ease learners' cognitive burden, resulting in better learning outcomes for medical, dental and other allied health students.

The present study explored the effects of the emotional design of PowerPoint slides in the "natural" context of an undergraduate anatomy lecture. This study aimed to determine whether the emotional design of lecture slides affects changes in self-reported mood; intrinsic, extraneous, and germane cognitive load; or memory retention immediately after the lecture. Based on previous research, it was hypothesised that participants viewing emotional design slides would report a greater increase in mood, decreased intrinsic and extraneous cognitive loads, increased GL, and better memory retention compared to control participants.

METHODS

Experimental Design, Participants and Lectures

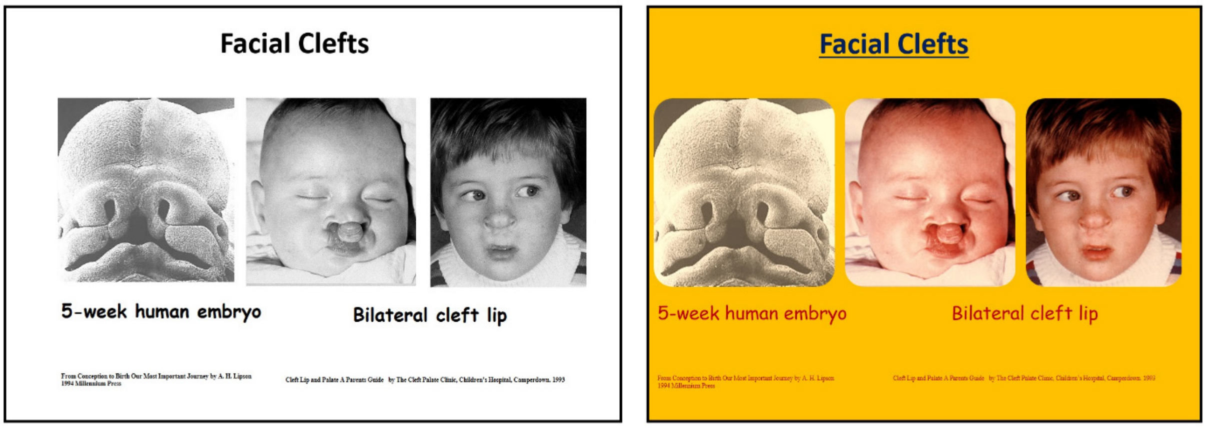
This study involved first-year undergraduate students from both medical and dental cohorts who were 18 years or older, were not colour-blind and were willing to give informed consent to participate in the study. A between-subjects quasi-experimental design was employed, randomly assigning dental students as the experiment group and medical students as the control group.

Both cohorts attended three specific lectures as part of their respective courses at Universiti Malaya. The topics of the lectures were as follows: Lecture 1 – Histology of the respiratory system, Lecture 2 – Anatomy of the neck and thyroid gland and Lecture 3 – Birth defects. These three lectures were selected due to their diversity in the main subdisciplines of anatomy (histology, gross anatomy and embryology, respectively). There were variations in sample sizes between the lectures: Lecture 1 (n = 120), Lecture 2 (n = 138), and Lecture 3 (n = 179). Each lecture was delivered by the same presenter (lecturer) to both groups. Lecturers were requested to maintain consistency in intonation, body language and emphasis across both sessions.

Intervention

After obtaining consent from the lecturers involved, their lecture slides were obtained and modified according to the principles of emotional design. Two different versions of each lecture's slides were created: one with a neutral emotional design (control) and the other with a positive emotional design (experiment). Consistent with previous research (8, 9, 37, 38), the following design elements were incorporated: experiment (positive emotional design) slides included bright, warm and highly saturated colours (e.g., orange, yellow) for the background and coloured images with rounded corners, and control (neutral) slides included a grey-scale colour scheme and images with sharp corners.

However, unlike most previous emotional design studies, facial anthropomorphism was not included as a design element. This was because of the heavy reliance of anatomy teaching on accurate diagrams. Negative learning outcomes might arise from “anthropomorphising” the diagrams used. Münchow et al. also excluded anthropomorphisms from their study for the same reason (38). Nonetheless, their emotionally designed slides successfully improved the participants’ moods. No other elements of the slides’ designs were changed, and the contents of both the control and experiment slides were identical. Figure 1 demonstrates the differences between the two versions.



(a) (b)

Figure 1: Comparison between (a) control and (b) experiment slides, taken from Lecture 3.

Instruments

“Prior engagement with anatomy” questionnaire

A “prior engagement with anatomy” questionnaire was administered as one measure of homogeneity between the groups. The participants were asked to respond to the following statements: (a) I have good knowledge of [topic of lecture]; (b) Biology was my favourite subject when I was in school; (c) I find myself on the internet looking up anatomy-related topics often; (d) I like to watch anatomy-related documentaries/YouTube videos in my spare time.

The statements were rated using a five-point Likert scale ranging from “strongly disagree” to “strongly agree”. The sum of the ratings for all items was calculated and assigned as the participants’ prior engagement score. Similar self-reports of prior engagement have been used in previous emotional design studies (37, 38). A self-report of prior engagement was used rather than a pre-test on the lecture contents to avoid a “priming effect”, wherein pre-testing improves memory retention, a phenomenon that has been previously documented (40, 41).

Positive affect scale (PAS)

For a mood measurement, participants were asked to complete the Positive Affect Scale (PAS) from the Positive and Negative Affect Schedule (42) – once before (PAS_before) and once after the lecture (PAS_after). In the PAS, participants were required to indicate, using a five-point Likert scale ranging from "very slightly or not at all" to "extremely", the degree to which they were feeling 10 different positive feelings: interested, excited, strong, enthusiastic, proud, alert, inspired, determined, attentive and active. The total score for each participant was then calculated.

In previous validation efforts, the PAS has been shown to have high internal consistency and to be largely uncorrelated (42–45), regardless of whether the PAS was used to assess past, present, or general mood or tested using participants from a variety of cultural backgrounds and countries. The PAS has also been used to measure the effect of mood manipulation in prior emotional design studies (8, 9, 35, 46).

Cognitive load scale (CLS)

The Cognitive Load Scale (CLS) developed by Leppink et al. was used to measure IL, EL and GL (47). A modified version of the scale was used in which some items were removed due to their irrelevance to an anatomy learning context. The participants were asked to rate their agreement with statements related to one of the three types of cognitive load on a 10-point Likert scale, ranging from "not at all the case" to "completely the case". The statements were as follows: IL1: "The topics covered in the lecture were very complex"; IL2: "The lecture covered theories that I perceived as very complex"; IL3: "The lecture covered concepts and definitions that I perceived as very complex"; EL1: "The instructions and/or explanations during the lecture were very unclear"; EL2: "The instructions and/or explanations were, in terms of learning, very ineffective"; EL3: "The instructions and/or explanations were full of unclear language"; GL1: "The lecture really enhanced my understanding of the topics covered"; and GL2: "The lecture really enhanced my knowledge and understanding of [topic of lecture]".

The participants' scores for IL, EL and GL were computed by averaging their scores for the pertinent items. The CLS has previously been used to measure cognitive load in educational research, including in emotional design studies (35, 46). Its construct (47–49) and external validity (49) are high. Additionally, Hadie and Yussoff validated its construct in a population similar to that of the present study: Malaysian undergraduate medical students (48).

Memory retention test (MRT)

The participants' learning performance was assessed solely on memory retention. Memory retention is defined as "the degree to which the learners were able to recall and reproduce facts that were presented in the material" (50) and has been used as a learning performance variable in previous emotional design studies (37, 46, 50, 51). In other words, only a superficial measure of learning, within the "knowledge" hierarchy of Bloom's taxonomy (52), was assessed. For each lecture, five multiple-choice questions were used. This was to align the questions with the learning objectives since each lecture had 4–5 learning objectives. The questions were provided by the lecturer in charge and were vetted by two anatomy professors and a medical educationist. The participants' scores were calculated by awarding one point for correct answers, with no points deducted for incorrect ones. A sample question from Lecture 2 is shown in Figure 2.

"Which muscle divides the neck into anterior and posterior triangles?" A. Mylohyoid B. Scalenus anterior C. Sternocleidomastoid D. Sternohyoid

Figure 2: Sample MRT question from Lecture 2.

Procedure

Before each lecture, the participants received a brief overview of the study procedure. Since the study occurred during live lectures, it was difficult to control external factors, such as distractions from peers or mobile devices. Hence, the participants were advised not to communicate with each other. After the briefing, the pre-lecture questionnaire was given in the form of an online questionnaire, which was answered using their mobile devices via Google Forms (see Figure 3).

Page 1: Details of study, confidentially policy, risk disclosure and a consent check-box Page 2: Personal details (email, age and gender) Page 3: Prior engagement with anatomy questionanaire Page 4: The Positive Affect Scale (PAS)

Figure 3: Items in the pre-lecture questionnaire.

After completing the questionnaire, the lecture was conducted. Each lecture lasted no more than 50 minutes. Immediately following the lecture, participants were requested to fill out the post-lecture questionnaire (Figure 4).

Page 1: The Positive Affect Scale (PAS) Page 2: The Cognitive Load Scale (CLS) Page 3: The Memory Retention Test (MRT)

Figure 4: Items in the post-lecture questionnaire.

Data Analysis

For each lecture, the homogeneity between the groups was analysed in terms of the following key attributes: age (via a Mann-Whitney U test), gender proportions (via a chi-squared test), prior engagement with anatomy score (via a Mann-Whitney U test), and baseline mood (via a Mann-Whitney U test).

Post-hoc power analyses were conducted for each lecture due to variations in the sample sizes. The statistical powers (1-β) for a medium effect size (Cohen's $d = 0.5$) were calculated for the sample sizes in each lecture and are reported in the results section. If any of these attributes showed significant differences between the groups, a bivariate correlation analysis was conducted to identify whether the attribute was correlated with any of the dependent variables. If a correlation was identified, the attribute was considered a covariate when analysing the correlated dependent variable.

A generalised estimating equation was employed to analyse the effect size of the mood change within groups (PAS_before vs PAS_after). The effect sizes were then compared between the groups. To compare IL, EL, GL and MRT scores between the groups, a generalised linear model was utilised. A between-lecture analysis was also conducted, for which data from the control and experiment groups were merged for each lecture. This allowed for a comparison of IL, EL, GL and MRT scores among lectures (via a generalised linear model). All analyses were conducted using IBM SPSS Statistics 26.0 using a confidence level of 95%.

RESULTS

The statistical powers (1-β) for a medium effect size (Cohen's $d = 0.5$) calculated for each lecture were 85.1% for Lecture 1, 78.1% for Lecture 2 and 90.4% for Lecture 3.

Homogeneity of Groups

Table 1 summarises the participants' characteristics (gender, age, prior engagement with anatomy score, and baseline mood) for all three lectures, along with the outcomes of the between-group analysis.

For all three lectures, the baseline mood and prior engagement scores were not significantly different between the groups. However, age was significantly different for all three lectures, and gender was significantly different for Lecture 3.

Bivariate correlation analyses revealed that age was significantly correlated with GL in Lecture 1 ($\rho = 0.207$, $p < 0.05$), and gender was significantly correlated with EL in Lecture 3 ($z = 2.144$, $p < 0.05$). Hence, these attributes were included as covariates during the analyses of their respective correlated variables.

Table 1: Descriptive statistics for control and experiment groups in all three lectures

Lecture	Variable		Control	Experiment	X^2/z	*p*-value
Lecture 1	Gender (count)	Female	50	35	0.29†	0.825
		Male	20	15		
	Age (Mean±SD)		20.06±0.376	19±0.286	−9.649‡	< 0.001*
	Prior engagement (Mean±SD)		13.33±2.791	13.52±2.674	0.356‡	0.722
	Baseline mood (Mean±SD)		35.44±6.23	33.06±6.32	−1.467‡	0.142
Lecture 2	Gender (count)	Female	68	19	0.96†	0.756
		Male	41	10		
	Age (Mean ± SD)		20.06±0.376	19.79±0.559	−2.965‡	0.003*
	Prior engagement (Mean±SD)		11.41±3.013	12.28±2.789	1.273‡	0.203
	Baseline mood (Mean±SD)		33.84±7.97	33.83±4.91	−1.482‡	0.138
Lecture 3	Gender (count)	Female	75	36	4.697†	0.03*
		Male	56	12		
	Age (Mean±SD)		19.98±0.823	19.71±0.582	−2.186‡	0.029*
	Prior engagement (Mean±SD)		13.18±2.532	12.88±2.472	−0.56‡	0.575
	Baseline mood (Mean±SD)		36.77±7.0	34.19±7.3	−1.742‡	0.082

Notes: *Statistically significant ($p < 0.05$); †Based on the Chi-squared test; ‡Based on the Mann-Whitney U test.

Effect of Emotional Design on Self-Perceived Mood

Table 2 shows the differences in self-reported change in mood between the groups for all three lectures.

Table 2: Comparison of PAS scores across time for all three lectures

Lecture	Variable	PAS_before (Mean±SE)	PAS_after (Mean±SE)	Comparison within groups (before vs after)	
				p-value	Cohen's *d*
Lecture 1	Control	35.44±0.745	36.41±0.742	0.161	0.156
	Experiment	33.06±0.895	38.8±1.145	< 0.001*	0.79
Lecture 2	Control	33.84±0.763	36.15±0.802	0.002*	0.283
	Experiment	31.83±0.912	34.83±1.133	0.004*	0.542
Lecture 3	Control	36.77±0.612	38.5±0.704	0.033*	0.229
	Experiment	34.19±1.055	39.69±1.041	< 0.001*	0.757

Note: *Statistically significant ($p < 0.05$)

Across all lectures, a significant increase in perceived positive mood was observed among the experiment participants. Unexpectedly, in Lectures 2 and 3, the control group also experienced significant increases. However, when considering the effect sizes, the experiment groups exhibited a larger increase than the control groups (as indicated by Cohen's *d*: 0.542 vs 0.283 for Lecture 2 and 0.757 vs 0.229 for Lecture 3). Figure 5 illustrates these results.

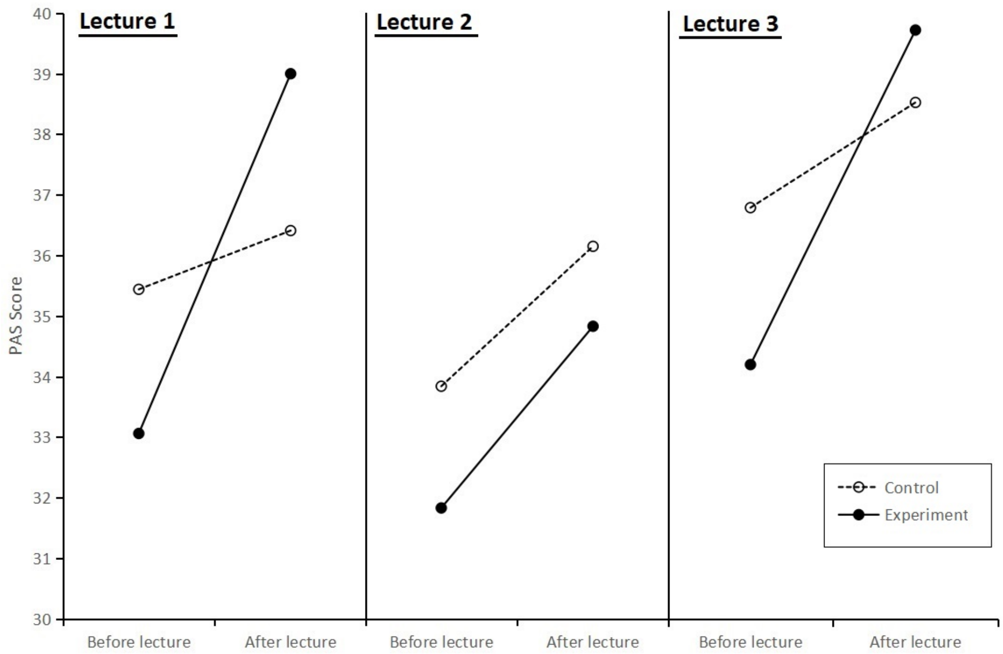


Figure 5: Comparison between the groups for changes in PAS scores for all three lectures.

Effect of Emotional Design on IL, EL, GL and MRT Scores

For all three lectures, IL, EL and GL were not significantly different between the groups. In addition, MRT scores were not significantly different in Lectures 1 and 3. However, in Lecture 2, MRT scores were significantly lower in the emotional design group. These results are summarised in Table 3.

Table 3: Comparison of IL, EL, GL and MRT scores between the groups for all three lectures

Lecture	Variable	Control (Mean±SE)	Experiment (Mean±SE)	*p*-value	Cohen's *d*
Lecture 1	IL	5.329±0.2467	5.94±0.2955	0.125	0.294
	EL	2.51±0.1997	2.54±0.2392	0.926	0.018
	GL	7.948±0.2534	7.493±0.3302	0.381	0.204
	MRT	4.46±0.096	4.26±0.115	0.191	0.247
Lecture 2	IL	6.766±0.17	6.306±0.330	0.216	0.259
	EL	3.616±0.186	3.407±0.361	0.607	0.108
	GL	6.861±0.180	6.592±0.349	0.493	0.143
	MRT	3.84±0.116	2.91±0.226	< 0.001*	0.766
Lecture 3	IL	4.497±0.184	4.624±0.307	0.370	0.153
	EL	2.3±0.0118	2.104±0.1984	0.400	0.200
	GL	8.163±0.1497	7.868±0.2503	0.316	0.171
	MRT	4.47±0.07	4.29±0.118	0.187	0.222

Notes: *Statistically significant. Analysis for all variables included covariate adjustments for change in mood (PAS_after – PAS_before). Additionally, age was a covariate for GL analysis in Lecture 1, and gender was a covariate for EL analysis in Lecture 3.

Did the Cognitive Load Scores Differ between Lectures? – A Supplementary Analysis

Since cognitive load was statistically similar in both the experiment and control groups, the data from the two groups were combined for all three lectures to perform between-lecture analyses of IL, EL, GL and MRT scores using a generalised linear model. This approach aimed to investigate the impact of lecture topics, or lecture delivery on cognitive load, which may have a greater influence than emotional design. Additionally, this analysis potentially helps lecturers understand the cognitive and learning processes in different anatomy lectures. The results are shown in Tables 4 and 5.

Table 4: Mean and standard error for IL, EL, GL and MRT scores for all three lectures, with control and experiment groups merged in each lecture

Lecture	IL (Mean±SE)	EL (Mean±SE)	GL (Mean±SE)	MRT (Mean±SE)
Lecture 1	5.583±0.183	2.522±0.154	7.758±0.161	4.38±0.090
Lecture 2	6.669±0.171	3.572±0.144	6.804±0.150	3.64±0.084
Lecture 3	4.860±0.150	2.248±0.126	8.084±0.132	4.42±0.073

Table 5: The *p*-values and effect sizes for comparisons of IL, EL, GL and MRT scores among Lectures 1, 2 and 3, with control and experiment groups merged in each lecture

Lecture	IL		EL		GL		MRT	
	p-value	Cohen's *d*	*p*-value	Cohen's *d*	*p*-value	Cohen's *d*	*p*-value	Cohen's *d*
Lecture 1 vs Lecture 2	< 0.001*	0.544	< 0.001*	0.62	< 0.001*	0.541	< 0.001*	0.75
Lecture 2 vs Lecture 3	< 0.001*	0.902	< 0.001*	0.784	< 0.001*	0.725	< 0.001*	0.795
Lecture 1 vs Lecture 3	0.002*	0.36	0.168	0.162	0.118	0.185	0.704	0.041

Note: *Statistically significant ($p < 0.05$)

DISCUSSION

The present study aimed to explore the effects of the emotional design of PowerPoint slides on the self-perceived mood; intrinsic, extraneous and germane cognitive loads; and memory retention in first-year anatomy students studying medicine and dentistry. First, emotionally designed slides were observed to successfully increase the participants' self-reported mood in all three lectures. Although the same outcome was demonstrated using the control groups (for Lectures 2 and 3), the effect sizes of the increase were greater in the emotional design group in both cases. These findings are consistent with previous studies (8, 9, 36) and two meta-analyses (10, 11). However, in this study, the findings were demonstrated within an authentic lecture setting when applied to lecture slides. Unlike computer-based studies, lecture hall settings are more representative of the usual learning experience. Therefore, the results of the present study set an important precedent for future studies, as they provide a model for more ecologically valid investigations, which are lacking in emotional design research. Emotional design effects should be further investigated in real learning environments, as they may have significant implications in the pedagogy of lectures.

Although external validity was generated from the methods used, this study is not without limitations. For instance, neutral emotional design was demonstrated to elevate positive mood in Lectures 2 and 3. This may be attributed to factors external to the emotional design of slides, which are largely not present in computer-based multimedia learning and are difficult to control in field studies. This includes elements in the physical environment as well as the presence of a teaching agent (lecturer), whose teaching skills can affect learners' enjoyment, mood and motivation (53, 54).

Whether emotional design had any effect on cognitive load is inconclusive. The effect of emotional design was possibly overshadowed by some combination of external and internal factors. For instance, external distractors (e.g., noise, mobile devices) can contribute to EL, reducing WM capacity (55–57). Furthermore, although low IL and EL due to good lesson design/delivery can free up WM, they can only meaningfully impact learning performance if students are motivated and engage with the lecture. This is described in the affective mediation assumption of CATLM (32). Hence, future studies should consider measuring learning motivation or attention to observe potential interactions between mood change, motivation, cognitive load and learning performance. A potentially useful tool for this purpose is Webster and Ho's Learner's Engagement and Motivation Questionnaire (58). Furthermore, active learning practices (e.g., note-taking) and individual variations in cognitive strategies may also affect cognitive load and learning performance. This is described in the individual differences assumption of CATLM (32). Finally, IL could also have significantly decreased if students prepared for the lesson beforehand (e.g., by reading the lecture notes). Uncertainties of this nature are to be expected when conducting research that lacks the precise control of lab-based studies (59). Therefore, the results prevent us from contributing to the discussion regarding the role of positive emotions in broadening or narrowing cognitive resources.

Another possible explanation for the results is that the lecture topic, as well as the teaching strategies employed by the lecturer, may have a more significant impact on cognitive load than emotional design. The results of the between-lecture analyses are illuminating. Lecture 2 on the Anatomy of the Neck and Thyroid Gland showed significantly higher IL and EL and significantly lower GL when compared to Lectures 1 and 3. This suggests that the content taught in Lecture 2 was generally more challenging to understand, process and consolidate into LTM. Lecture 2 discussed the neurovascular contents of the neck in great detail, relating it to structures serving digestive, respiratory and endocrine functions. Understanding the fascial planes in the neck and their clinical significance may be more challenging for students to comprehend.

In contrast, Lectures 1 and 3 had statistically similar EL and GL, although IL was significantly higher in Lecture 1. This indicates that Lecture 1 was more "difficult" to understand than Lecture 3, although they were similar in terms of external distractions experienced and ease of consolidation. A possible explanation, based on the topic of the lecture, could be that students found Lecture 3 (Birth Defects) more interesting than Lecture 1 (Histology of the Respiratory System). Lecture 3 highlighted developmental anomalies associated with pregnancy and exposure of the embryo/foetus to diverse teratogens. Lecture 3 also discussed some preventive techniques and the availability of prenatal diagnostic tools. Conversely, reports of student perception have shown that histology is seen as a "dry" and challenging subject (60).

The trends in cognitive loads could also explain the MRT scores across lectures. Lectures 1 and 3 had statistically similar MRT scores. However, Lecture 2 had significantly higher MRT scores than both Lectures 1 and 3. These results suggest that some combination of lecture topics or lecturers may have had a significant effect on cognitive load and, therefore, retention of the learned materials. Educators could use similar information to tailor their content delivery to ensure that challenging topics, such as anatomy, are presented in a way that optimises understanding, manages cognitive load and enhances memory consolidation. This can be done via student feedback and evaluation questionnaires that incorporate the CLS.

In the between-group analysis, the experiment group had lower MRT scores compared to the control group in Lecture 2. This result was unexpected and contradicts the findings of previous studies that have investigated the effect of emotional design on memory retention (37, 51). However, it should be noted that prior research has also shown that positive mood may interfere with WM and executive function (61–63), which is consistent with the hypothesis that emotions are a source of EL (22). Their findings, along with the findings of the present study, seem to provide support for the hypothesis of emotion-as-suppressor of learning. Unfortunately, speculations regarding the mechanisms for the suppression effect cannot be made with the present study's results, as a cognitive load was not significantly different between the groups. For instance, it cannot be concluded that emotions are a source of EL (22). In addition to measuring cognitive load, future studies could measure the amount of task-irrelevant processing among participants. The resource allocation model (34) describes how ruminative thoughts due to positive mood states may take up WM resources, a phenomenon that has been documented in previous research (64–66). Future studies could benefit from self-report questionnaires targeted at observing task-irrelevant processing. One example of such a measure can be found in Seibert and Ellis's study (67), in which participants estimated the frequency, intensity and irrelevance of their thoughts during the learning task. This approach would be beneficial, as the items associated with EL in the CLS (i.e., "The instructions and/or explanations during the lecture were very unclear", "The instructions and/or explanations were, in terms of learning, very ineffective", "The instructions and/or explanations were full of unclear language") do not account for ruminative or irrelevant thoughts that may arise due to elevated mood during the lesson.

Lastly, memory retention as a measure of learning performance is meaningful only if the information is retained over long periods of time. Numerous reports have demonstrated a decline in the retention of anatomical knowledge among students in medical/dental and other healthcare-related courses (68–73). The potential long-term effectiveness of implementing emotional design in lectures should be explored in anatomy education for this reason.

CONCLUSION

The findings concerning the effectiveness of emotional design on mood elevation likely have high generalisability, primarily because of the design's external validity. The non-significant findings regarding cognitive load were probably a result of factors other than emotional design, such as lecturer skills or lecture topics. The results from the between-lecture analysis demonstrate the necessity of employing effective teaching strategies that manage the cognitive load of anatomy students. The negative effect of emotional design on memory retention obtained in one lecture adds to the already existing ambiguity regarding the role of emotions in learning, whether as suppressors or facilitators. Since non-significant findings were obtained for cognitive load and memory retention, further investigation into the use of emotional design in live lecture contexts is essential. To gain deeper clarity on emotional design effects and explore the potential applicability of emotional design to real educational settings, more field studies of this nature are needed alongside the rigorously controlled studies that have been conducted thus far for the sake of methodological plurality.

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ETHICAL APPROVAL

Ethical approval for this study was obtained from the Universiti Malaya Research Ethics Committee (Reference number: UM.TNC2/UMREC_2089).

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