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The effect of an agent tutor's integration of cognitive and emotional gestures on cognitive load, motivation, and achievement

Soonri Choi [1,2]
0000-0003-3479-6126

Soomin Kang [2]
0000-0002-5056-6382

Kyungmin Lee [1,2]
0009-0008-7408-5293

Hongjoo Ju [1]
0000-0003-1549-1829

Jihoon Song [1*]
0000-0003-2784-2358

[1] Hanyang University, Seoul, SOUTH KOREA
[2] Kwangwoon University, Seoul, SOUTH KOREA
[*] Corresponding author: psu.jihoonsong@gmail.com

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ABSTRACT

This study proposes that the gestures of an agent tutor in a multimedia learning environment can generate positive and negative emotions in learners and influence their cognitive processes. To achieve this, we developed and integrated positive and negative agent tutor gestures in a multimedia learning environment directed by cognitive gestures. The effects of emotion type on cognition were examined in terms of cognitive load, learning motivation, and achievement. The subjects were 46 university students in Gyeonggi Province, South Korea. The students were divided into three learner groups: cognition, cognition + negative emotion, and cognition + positive emotion. The learners watched a tutorial lecture on the Notion note-taking app by an agent tutor. Data analysis was conducted using one-way ANOVA to determine the cognitive load, learning motivation, and achievement. The results showed that the positive emotion design was more effective in terms of intrinsic cognitive load, learning motivation, and achievement but had a higher extrinsic cognitive load. However, even the negative + passive group showed more positive learning than the cognition group. Although this study focused on gestures by an agent tutor, it implies that such gestures in multimedia learning contexts must be informed by emotional as well as cognitive design to provide a more meaningful learning experience.

Keywords: agent tutor, gesture effect, cognitive theory model, cognitive-affective model

INTRODUCTION

Using an agent tutor is an approach to multimedia learning that replaces instructors and guides the entire learning process. The agent tutor design method encourages active cognitive processing and promotes quality learning outcomes, which in turn generates social responses (Li et al., 2022). Learning is a complex process involving cognitive and emotional processes (Schunk, 2011). This study of gestures in agent tutors takes a different approach based on cognitive load theory and cognitive affective theory. From the perspective of cognitive load theory, the gestures of the agent tutor should only be used for elements that are relevant to the learning content in order to reduce extrinsic cognitive load (Sweller et al., 2011). Based on the signaling principle (Mayer, 2021), the agent tutor's gesture can help cognitive processing of key learning information by focusing attention. From the perspective of cognitive affective theory, the agent tutor's gestures should be used for elements that can promote the learner's emotions and motivation (Mayer, 2020b). The agent tutor can act as a social partner; therefore, its gestures generate emotional interactions, stimulate positive emotions, and allow immersion in a state, where learning is effectively carried out through positive emotions (Lawson et al., 2021).

In terms of cognition, the design of an agent tutor's gesture is more effective when connected with learning content (Wang et al., 2018; Xie et al., 2019), and in terms of learners' emotion, such a connection can induce deeper learning outcomes when social cues are positively assigned unified explanations (Mayer, 2020b). While the integration of cognition and emotion into one design method seems synergistic (Heidig & Clarebout, 2011), there could be side effects that need theoretical elaboration. Currently, relevant studies consider external factors such as agent tutor's gender, voice, gesture, and expression in terms of implementing agent tutors. In addition, theories of cognition and emotion have been referred to separately, not considering the integration of cognition and emotion. Ba et al. (2021) attempted to validate the integrated effects of cognition and emotion by using an agent tutor. However, these studies attempted to uncover the relationship between cognition and emotion through affective design alone, leaving a theoretical gap.

In the context of learning, we show that the relationship between cognition and emotion is not a single relationship, but an interdependent one (Pessoa, 2008; Phelps, 2004; Plass & Kaplan, 2016). Previous studies have identified the effects of cognition and emotion on learning separately, and research on agent tutor has been divided into cognitive design (e.g., Dincer & Doğanay, 2017; Yung & Pass, 2015) and emotional design (e.g., Horovitz & Mayer, 2021; Lawson et al., 2021; Park, 2016; Pi et al., 2022). However, the complementary relationship between the integrated design principles of cognition and emotion and agent tutor gestures has not been explored, which limits the extension of learning design theory and practice.

Therefore, it is necessary to develop an integrated model of cognition and emotion a learner can recognize that can support the overall learning. The necessity of this study is first, to determine whether the integration model of cognition and emotion can effectively handle the learner's cognition and emotion in a learning situation using an agent tutor. A learner who recognizes a positive emotion reaches a higher cognitive immersion and motivation, leading to a more efficient learning process (Veletsianos & Russell, 2014). This suggests that if an ordinary social cue could facilitate a sense of immersion (Li et al., 2019), an emotional social cue could further enhance immersion and motivation even more, leading into a higher achievement in learning. Second, the emotional social cue that is induced by agent tutor's gestures can be used as basic data that enhances the process of cognitive processing.

The purpose of this study is, as follows: First, this study aims to evaluate the effect of cognitive and emotional gestures of an agent tutor developed based on an integrated model of cognition and emotion. When an agent tutor is effectively designed for learning, how learners perceive the tutor can lead to higher immersion. Through cognitive gestures, learners can experience lower extrinsic cognitive load and higher germane load while experiencing higher intrinsic motivation through emotional gestures. By studying these effects, this study aims to contribute to theoretical integration by evaluating effects of gesture type of each agent tutor that was created for different purposes, based on integrated model of cognition and emotion.

Second, this study aims to develop social cues according to positive and negative emotions to see if there is a difference in how learners perceive an agent tutor, as Russell (2003) proposed. If learners perceive the agent tutor as a partner, they are more likely to pay attention more closely to what is being taught (Lawson & Mayer, 2022; Mayer, 2020b). In other words, the relationship between the learner and the agent tutor could change the process and result of the learning. Therefore, this study aims to evaluate an agent tutor's emotional gesture and how this would affect the degree of the emotional bond perceived by the learner. Ultimately, the study will extend the theory of cognitive processing by expanding existing dual coding theory to include the gesture effect combined with the emotional aspect. Research questions are, as follows:

Study question 1 How do agent tutors' cognitive gestures (instructions) and emotional gestures (happiness-active, boring-passive) affect cognitive load?

Study question 2 How do agent tutors' cognitive gestures (instructions) and emotional gestures (happiness-active, boring-passive) affect learning motivation?

Study question 3 How do agent tutors' cognitive gestures (instructions) and emotional gestures (happiness-active, boring-passive) affect learning achievement?

THEORETICAL BACKGROUND

Relationship Between Emotion & Cognition

Cognition and emotion are complexly constructed, and they share the process of conscious events processing (Pessoa, 2008). Emotions emerge while recognizing and processing a new event (Russell, 2003) and affect the area of cognition (LeDoux & Brown, 2017). According to Russell (2003), emotions are classified based on the axes of activation-deactivation and pleasure-displeasure, as shown in **Figure 1**. Based on the leaner's emotional perception of the selected information, intrinsic motivation can either increase or decrease (Petri & Govern, 2012). Reyes et al. (2012) and Rolland (2012) have shown that learners can immerse themselves in learning more deeply when they experience positive emotions, whereas they have lower levels of achievement when experiencing negative emotions. To summarize, learners reach a higher sense of immersion in learning when emotions lead toward the axis of enjoyment but are distracted when emotions get closer to the axis of dissatisfaction.

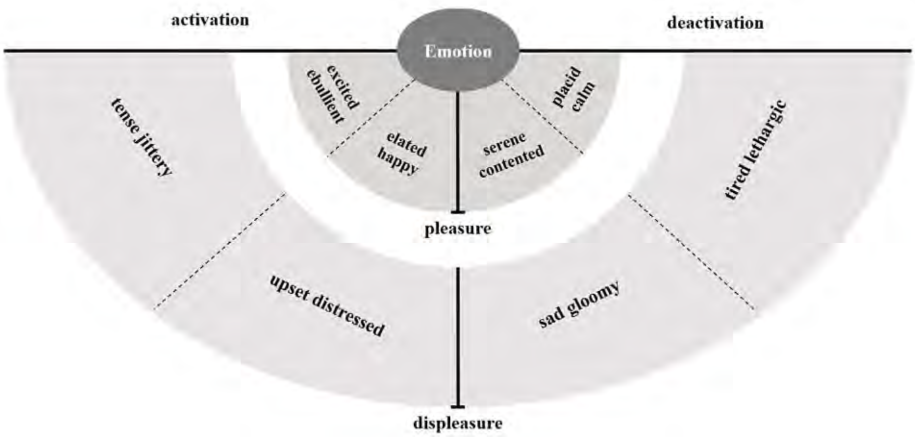

Figure 1. Classification of different emotions (Russell, 2003)

Process of emotional processing interacts with information selection, emotional change, and cognition (Plass & Kaplan, 2016). At the same time, the process of cognitive processing consists of information selection, organization, and integration (Mayer, 2021). While doing so, cognition constructs schema by combining the information newly accepted and the information stored in long-term memory (Cowan, 2014). **Figure 2** shows the process by which learners select the recognized information and organize it by integrating focused cognition and activated emotion. As a consequence, general knowledge and emotional aspects of information are integrated and processed in the schema stored as long-term memory, and when new information is perceived, the combined information and emotion are further elaborated and encoded in long-term memory.

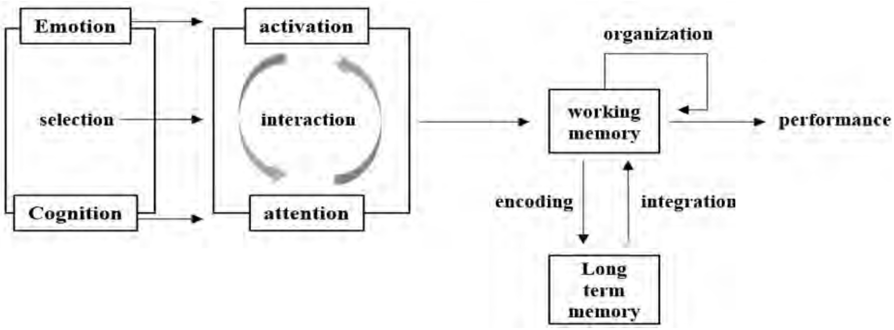

Figure 2. Information processing process of cognition & emotion (Adapted from Cowan, 2014 and Plass & Kalyuga, 2019)

Multimedia Integration Model of Cognition & Emotion

In the context of multimedia learning, cognition and emotion share the processing principle of dual coding theory. Dual coding theory explains that verbal and non-verbal information presented in sensory memory are processed through their own respective working memory channels. Mayer (2021) presented a model of multimedia cognitive theory based on dual coding theory. As shown in **Figure 3**, cognition perceives text and image information through sensory memory, vision, and hearing, and then processes the selected, focused information in working memory.

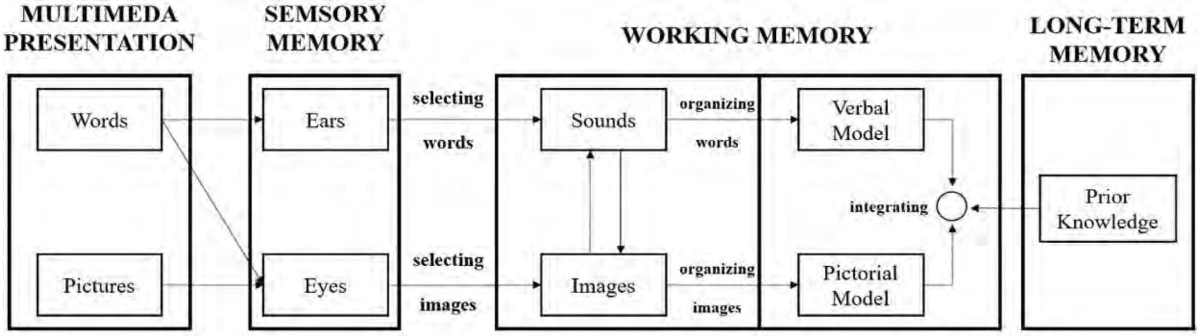

Figure 3. Cognitive theory model (Revisiting Mayer, 2021)

At the same time, cognition integrated with emotion can play an important role in learning. **Figure 4** is a model combining positive emotion with **Figure 3**; in this context, emotion affects the process of constructing information from working memory by an interaction that is similar to the cognitive process (Plass & Kalyuga, 2019). Emotions triggered by a learning environment affect the early stages of perception and also facilitate storing information into working memory, which is focused by sensory memory (Phelps, 2004). Working memory is better integrated depending on a positive or negative emotional state (Bless et al., 1996), expanded resources (Fredrickson, 2001), or reduced resources (Fredrickson, 2003). During the cognitive process, the learner also experiences positive or negative emotions through text and image information and determines the immersion level by deciding how much mental effort should be put into a learning process (Paas & van Merriënboer, 2020). By maintaining a positive emotional state and constructing integrated knowledge, these methods allow for a more effective transition into long-term memory (Sharot & Phelps, 2004). Thus, cognition is the mental process of converting information into knowledge, and emotions can affect the intensity of a learner's mental activities as it shares the same cognitive paths.

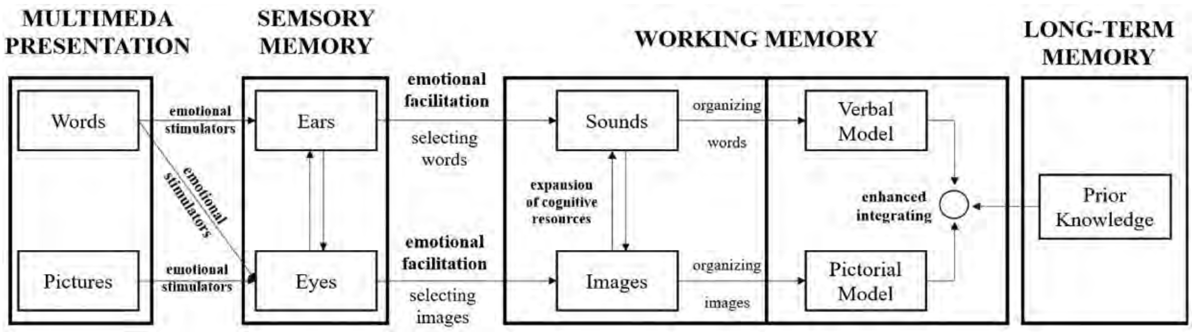

Figure 4. Cognitive-affective model of learning with media (Adapted from Mayer, 2021 and Plass & Kalyuga, 2019)

Agent Tutor & Gestures

Concept of an agent tutor

An agent tutor is a virtual tutor presented on a screen in a multimedia learning context (Lawson et al., 2021). Agent tutors can be designed with elements of verbal speech and nonverbal gestures, facial expressions, gaze, and gender. Such human-like characteristics promote persona effect (Veletsianos, 2012), promote social interaction (Heller & Procter, 2010), and emotional interaction (Kim & Baylor, 2016). Social interaction occurs as a response to information supported from the agent to the learner (Martha & Santoso,

2019) and forms social relationships as personified characters. Emotional interaction refers to emotional expressions that are conveyed by nonverbal aspects (Tsai et al., 2012). From an agent tutor based on these aspects, the learner can reduce the gap between computer-based programs and the tutors (Veletsianos & Russell, 2014) as well as gain a higher sense of immersion and motivation with increased interest in learning.

Use of gestures in an agent tutor

Careful construction of an agent tutor helps learners enhance the process and motivation to acquire knowledge (Park, 2016) by personifying the tutor in a variety of ways, as shown in a previous study (Baylor & Kim, 2005). Learners can learn more in-depth when agent tutor direct information rather than just present it in a static position (Baylor & Kim, 2009; Wang et al., 2018). In a study, where the facial expression of the agent tutor was removed, Baylor and Kim (2009) verified that this single directing motion design factor had a positive effect on cognition. Wang et al. (2018) also conducted an experiment using an eye-tracking method and reported an agent tutor with gestures leased to a higher learning transfer than an agent tutor with a static position. In addition, learners reduce cognitive depletion when learning with an agent tutor showing positive gestures (Pi et al., 2022). Studies done by Pi et al. (2022) expected that gestures that induce happy emotions would impose more of cognitive load as it would distract the learners from the learning contents, but the gestures that induce happy feelings did not affect the cognitive load. Consequently, in terms of cognition, an agent tutor's gesture type helped the learners to focus on the learning contents when combined with a specific type of information. Gestures that induce positive emotions increased the motivation to continue learning by lowering the cognitive load.

Changes in Learning Elements in Multimedia Learning Contexts Using Gestures

Gestures & cognitive load

In a multimedia environment, a directing gesture is a type of gestures in the visual signaling principle (Mayer, 2021). Appropriate gestures can make learning more effective by signaling the areas, where the learners must pay attention, thereby guiding the learners to important concepts and contents (Mayer, 2021). Directing gestures can draw attention to the important information that needs to be processed and help transfer the information into sensory memory. This then leads to directing the information to be processed in working memory, effectively managing limited memory capacity. In other words, these gestures can aid a successful cognitive process of important information (Lozano & Tversky, 2006). Atkinson's (2002) study found that having an agent pointing to a specific part, where auditory explanation is used can enhance the learner's concentration and increase learning transfer. In a study to determine the effect of visual cues on the learning environment, Moreno et al. (2010) found that showing an agent tutor directing the learning contents was more effective than using arrows. Consequently, gestures using an agent tutor can be effective in enhancing concentration and improving immersion when gestures are incorporated with the relevant learning contents.

Gestures & motivation

The gestures of an agent tutor promote the social and emotional interaction of the learners (Kim & Baylor, 2016). Social interaction gives an agent personality, causing personification (Heller & Procter, 2010; Lawson & Mayer, 2022) while emotional interaction involves a learner recognizing emotional expression of the agent and being responsive to it (Lawson et al., 2021). Mayer (2020b) proposed that social and emotional interaction can generate social relationships with positive emotions transferred from the agent tutor, according to the cognition-emotion model shown in **Figure 5**.

Positive emotions are classified into positive-active happiness and positive-passive satisfaction based on the emotional valence and the dimension of activity, as suggested by Russell (2003). The designing principle utilizing an agent tutor is the same as designing emotions in general (Lawson et al., 2021), and it can lead to learner motivation and high mental effort (Horovitz & Mayer, 2021; Paas & van Merriënboer, 2020). As a designing element for emotions, Lawson et al. (2021) developed gestures demonstrating positive and negative motions with arms open and closed, and active and passive motions with body leaning forward and backward, respectively. This shows that gestures that were embodied in action can lead learners to perceive a social partnership and that gestures embodied in emotional valence can enhance the learner's motivation by appealing to their emotions.

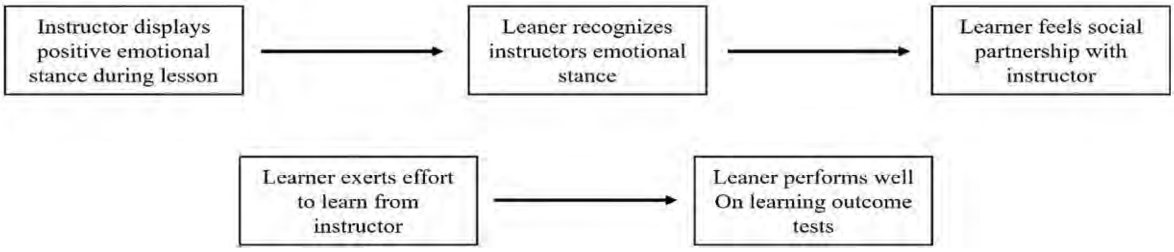

Figure 5. Cognition-emotion stages (Lawson et al., 2021)

Gestures & achievements

In a multimedia learning environment, the design of agent tutor's gestures allows the learner to effectively process the recognized learning information by facilitating the positive emotions of the learners. Learning is essentially a cognitive process of selecting the necessary information, organizing the selected information into a coherent mental representation, and integrating such information with other knowledge (Plass & Kalyuga, 2019). This process allows the integrated knowledge to become a resource for the learners to solve problems. Therefore, learners should store cognitive resources for problem solving and have a strong connection to those resources. Positive emotion felt by learners can enhance motivation for learning and increases focus on the learning environment (Phelps, 2004), allowing for more information to be driven into working memory. This state of immersion allows the learners to have an opportunity to continuously focus on the information relevant to a higher-level plan when lower-level information is concurrently being processed in working memory. This allows the information to be integrated. Thus, learner is able to acquire knowledge more effectively by agent tutor's gestures: their cognitive gesture cues can guide learners to cognitively process information, while their emotional cues intensify cognitive processing of that information.

RESEARCH METHOD

Study Population & Design

For this study, 58 students from Shinhan University located in Gyeonggi Province, South Korea, were recruited, and 46 students participated in the study. There were 17 males and 29 females with an average age of 22.76, ranging from 20 to 26 years old. The experiment had three different groups structured as 1 (cognitive activity: information instruction) × 3 (emotion activity: none vs. positive + active vs. negative + passive). The participants in the three groups of the study were, as follows: 15 people were allocated to group 1 (G_1) (cognition activity/no emotion activity; design for focus and attention), another 16 people were allocated to group 2 (G_2) (cognition/positive emotion + active; design for focus/attention and happiness condition), and last 15 people were allocated to group 3 (G_3) (cognition/negative emotion + passive; design for focus/attention and bored emotion). The sample size was sufficient for a large effect size (d=.4) at a power of .8, which was confirmed by G*power 3.1 analysis

Materials

Pre-testing tools

A pre-test was conducted as a part of this study. The pre-test was designed to collect demographic information from the participants about their gender, major, age, and year level. Their prior knowledge of the Notion app and their capability of using the app were also tested. Their prior knowledge level was assessed on a scale of 1 (very low) to 5 (very high), and the capability level was assessed by yes (1 point) or no (0 point) questions. The eight questions asking about the student's ability included 'embed', 'repeat weekly', 'master table and linked database' and 'storage to information' (e.g., 'I have watched a lecture on Notion app', 'I know how to use Notion to embed YouTube videos'). Considering both the testing effect, which demonstrates that participants might learn learning materials from the pre-test, and the priming effect, which the participants might intentionally pay more attention to the contents that were covered in the pre-test (Mayer, 2020a), the prior knowledge test consisted of questions asking for more of a broad background knowledge, prior to the main experiment (e.g., Lawson et al., 2021).

Video lessons

To examine the effect of cognitive and emotional gestures of an agent tutor, we developed video lessons in which the agent tutor instructs learners on important learning contents of the Notion app. In addition, considering the three different types of emotions considered in this study, we developed three types of learning materials. The agent tutor's gestures were created by Autodesk 3ds Max 2022, as shown on left and right images in **Figure 6**. We placed the screen as close as possible to the agent tutor to prevent distraction.

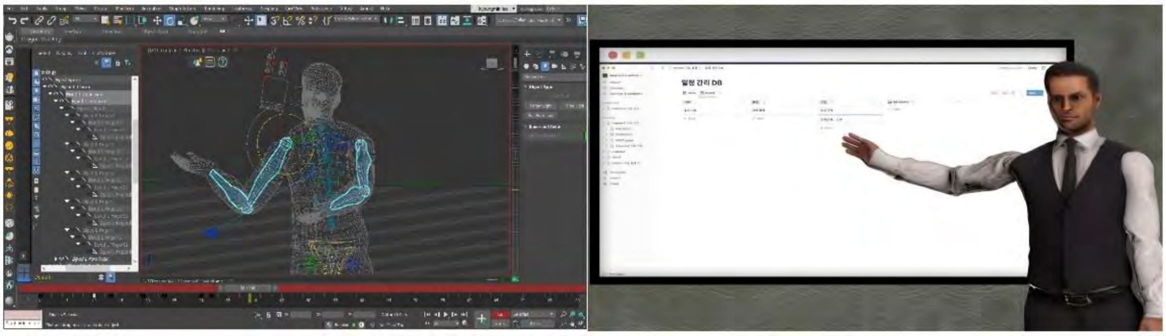

Figure 6. Gesture developing process (Source: Authors, using Autodesk 3ds Max 2022)

First, the cognitive gestures of the agent tutor were designed to direct the on-screen material when the contents on learning goals were presented. The agent tutor's hands were adjusted to not be raised above shoulder level. The reason for this adjustment was, if the hands were raised above shoulder level, the gesture could be construed as simply raising hands rather than pointing at the learning material. Gestures that convey emotions were also created. In order for the tutor to convey positive and active emotions, the agent tutor's position was adjusted to maintain an open position, as well as leaning the upper body forward. As for the negative and passive emotions to convey, the agent tutor was designed to have a closed body position as well as leaning the upper body back.

Finally, the respective designs for emotion and cognition in a multimedia environment were integrated to demonstrate cognitive and emotional cues. As shown on the right side of **Figure 6**, the gestures with cognitive effects were activated in the context of learning achievement test. Also, as shown in **Figure 7**, the gestures with emotional effect were shown 10 seconds before the open and closed stance, which convey positive and negative feelings, respectively, so that the gestures would look more natural.

Figure 7. Gestures indicating emotional cues (left: positive + active gesture/right negative + passive gesture) (Source: Authors, using Autodesk 3ds Max 2022)

Post-test tools

Cognitive load test: A cognitive load test was adapted by Leppink et al. (2013) and was conducted to measure the learner's focus and attention depending on the agent tutor's presentation methods. There were 10 questions to test learners' cognitive load; three questions for intrinsic cognitive load, three questions for extrinsic cognitive load, and remaining four questions for germane cognitive load. Each question was answered on a 10-point scale, where 0 was 'not at all' and 10 was 'very much'. This measurement had a Cronbach's alpha of intrinsic cognitive load=.834, extrinsic cognitive load=.794, and germane cognitive load=.771.

Learning motivation test: A learning motivation test was performed to examine whether the design of an agent tutor considering emotion and valence would positively affect the student's intrinsic motivation. The tool was adapted and devised by Ryan et al. (1990), who adapted the intrinsic motivation inventory, the tool was reconstructed consisting of nine items: five questions on enjoyment, two questions on perceived competence, and two questions on anxiety. Each item was scored in a scale of 1 to 7, where 1 is 'strongly disagree' and 7 is 'strongly agree'. In this study, we changed the phrase of the questions from 'while reading' to 'while watching', considering the context of the experiment. This tool had a Cronbach's alpha of .726.

Learning achievement test: As for the learning achievement test, we evaluated the learner's understanding of how to use the functions of the Notion app such as 'categorization', 'embed', 'repeat weakly', 'database linked to master table' and 'storage and information'. These functions were instructed by the agent tutor using gestures with cognitive effects. An example question is, as follows: [Question: 'What should be done to create a database in Notion app?'/Answer: A: Inline; B: Full page C: Embed D: Create bookmarks]. The learning achievement test consisted of 10 multiple choice questions, and the learners received 1 point for each correctly answered item, and 0 points for a wrong answer, for a total of 10 points. This tool had a Cronbach's alpha of .747.

Study Procedures

The pre-test and experiment were conducted in a computer lab equipped with 30 PCs and personal headphones. The participants who were deemed to qualify for the study were divided into three groups according to the order that they applied to participate in the study; G_1 was an agent tutor-directed group (n=15 or more), G_2 was an agent-tutor instructing the necessary information while showing an open body position as well as upper-body forward-leaning gesture (n=15 or more), and G_3 was an agent-tutor instructing the necessary information while showing a closed body position and upper-body backward-leaning gesture (n=15 or more).

The pre-test and the main experiment were conducted in two separate sessions, as shown in **Table 1**. During the first session, a pre-test was conducted via an online test link using an individually allocated PC for 15 minutes. In the second session, the main experiment was performed, as follows: One of the researchers gave instructions for the study for five minutes, and the learners watched the learning material on Notion app for 20 minutes. Then, at the end of the video, the cognitive load and learning motivation tests were immediately conducted for eight minutes. After that, the learners were asked to close their eyes and organize what they had learned for five minutes before the learning achievement test was conducted for 10 minutes.

Table 1. Research procedures

Classification	Group			Time spent
	G_1	G_2	G_3	
Session 1		Pre-test		15 minutes
Session 2		Orientation to study		5 minutes
		Watching instruction video		20 minutes
		Cognitive load and learning motivation test		8 minutes
		Closed-eye rest		5 minutes
		Learning achievement test		10 minutes

Note. G_1: Information instruction only group; G_2: Instruction + upper body leaning forward + open body gesture; & G_3: Instruction + upper body leaning backward + closed body gesture

Analysis Method

The independent variables of the study were

(1) the agent tutor's instructional gestures and

(2) the agent tutor's upper body direction.

The dependent variables were cognitive load, learning motivation, and learning achievement test score. The data analysis was performed using SPSS 24.0 at a significance level of .05 to examine the effect of each independent variable on the dependent variables.

RESULTS

Differences in Prior Knowledge Between Groups

A pre-test on prior knowledge was conducted to ensure that the groups were comparable. The analysis of prior knowledge on the Notion app showed no statistically significant differences between the groups: $F(2, 43)=.1140$, $p=.892$). Therefore, the level of prior knowledge between the groups was assumed to be similar.

Effect of an Agent Tutor's Interactive Gestures with Cognitive & Emotional Cues on Cognitive Load

The differences in the answer to [study question 1] in terms of cognitive load between the groups are shown in **Table 2**. First, the result of Levene's test for the equality of variance showed that the difference in distribution between the groups was not statistically significant at the significance level of .05, which satisfies the assumption of the equality of variance to perform a one-way ANOVA. As shown in **Table 3**, the extrinsic cognitive load was significantly different statistically between the groups depending on the gesture types ($F[2, 43]=.9730$, $p<.001$, partial $\eta^2=.31$) as well as the germane cognitive load ($F[2, 43]=.1331$, $p<.001$, partial $\eta^2=.38$). However, it was not significantly different statistically in the intrinsic cognitive load between the groups ($F[2, 43]=.2400$, $p=.790$).

Table 2. Levene's assumption on equality of variance, mean, & standard deviation on cognitive load type

Classification	Group	Number of cases	Levene	p	Mean	Standard deviation
Intrinsic cognitive load	G_1	15	1.42	.25	8.67	1.50
	G_2	16			8.30	1.70
	G_3	15			8.50	1.06
Extrinsic cognitive load	G_1	15	.85	.43	8.40	.91
	G_2	16			9.81	1.17
	G_3	15			9.53	.64
Germane cognitive load	G_1	15	.92	.41	12.27	1.10
	G_2	16			14.44	1.31
	G_3	15			13.67	1.11

Note. G_1: Information instruction only group; G_2: Instruction + upper body leaning forward + open body gesture; & G_3: Instruction + upper body leaning backward + closed body gesture

Table 3. ANOVA result on types of cognitive load

Cognitive load	Variance groups	Sum of squares	Degree of freedom	Mean squared	F	p	ES (η^2)
Intrinsic cognitive load	Between groups	.996	2	.50	.24	.790	
	Within group	90.500	43	2.11			
	Total	91.500					
Extrinsic cognitive load	Between groups	17.099	2	8.55	9.73	.000*	.31
	Within group	37.770	43	.88			
	Total	54.870					
Germane cognitive load	Between groups	32.274	2	18.64	13.31	.000*	.38
	Within group	60.200	43	1.40			
	Total	97.480					

Note. *p<.001

To examine the details on the significant differences between the groups, a post-hoc test using the Scheffe method was conducted. As shown in **Table 4**, extrinsic cognitive load showed a significant difference between G_1 and G_2 ($p<.010$). The results of G_1 and G_3 showed a statistically significant difference ($p<.010$). The post-hoc test considered the G_1 group as a control group and checked Cohen's d value between G_2 and G_3, which is the ES of each group's extrinsic cognitive load. The results were 1.35 and 1.44, respectively, which showed a significant difference.

Table 4. Post-hoc analysis (Scheffe) results by cognitive load type

Classification	Group	G_2	G_3
Extrinsic cognitive load	G_1	-1.41 (.001*, 1.35)	-1.13 (.008*, 1.44)
	G_2		
Germane cognitive load	G_1	-2.17 (.000**, 1.79)	-1.40 (.009*, 1.27)
	G_2		

Note. G_1: Information instruction only group; G_2: Instruction + upper body leaning forward + open body gesture; G_3: Instruction + upper body leaning backward + closed body gesture; *p<.010; & **p<.001/mean difference (p-value, ES[d])

As for the germane cognitive load, there was a significant difference between G_1 and G_2 (p<.001), as well as G_1 and G_3 (p<.010). The post-hoc test considered the G_1 group as the control group and checked Cohen's d value between G_2 and G_3, which is the ES of each group's germane cognitive load. The results were 1.79 and 1.27, respectively, which showed a significant difference.

Effect of an Agent Tutor's Interactive Gestures with Cognitive & Emotional Cue on Learning Motivation

For [study question 2], the differences in learning motivation between the groups were analyzed, as shown in **Table 5**. First, Levene's test for the equality of variance showed that the variation between the groups was not significant at a significance level of .05, which satisfies the assumption of equal variance to perform ANOVA. As shown in **Table 6** indicating the result of ANOVA, the difference in learning motivation for each group based on the agent tutor's gesture type showed a statistically significant difference: F(2, 43)=.1011, p<.001, partial η^2=.32.

Table 5. Levene's assumption on equality of variance, mean, & standard deviation on learning motivation

Classification	Group	Number of cases	Levene	p	Mean	Standard deviation
Learning motivation	G_1	15	1.76	.19	34.20	1.7
	G_2	16			37.19	2.2
	G_3	15			35.27	1.7

Note. G_1: Information instruction only group; G_2: Instruction + upper body leaning forward + open body gesture; & G_3: Instruction + upper body leaning backward + closed body gesture

Table 6. ANOVA result on learning motivation

Classification	Variance groups	Sum of squares	Degree of freedom	Mean squared	F	p	ES (η^2)
Learning motivation	Between groups	71.38	2	35.69	10.11	.000*	.32
	Within group	151.77	43	3.53			
	Total	223.15	45				

Note. *p<.001

To determine the details on the significant differences among the groups, a post-hoc test using the Scheffe method was conducted. As shown in **Table 7**, the learning motivation showed a significant difference between G_1 and G_2 (p<.001), and G_1 and G_3 showed a statistically significant difference (p<.001). The post-hoc test considered the G_1 as the control group, and Cohen's d value was between G_1 and G_2. The ES was 1.52, which showed a significant difference. Likewise, considering the G_1 as the control group, Cohen's d value between G_1 and G_3 was .63, which was a moderately significant difference.

Table 7. Post-hoc analysis (Scheffe) on learning motivation

Classification	Group	G_2	G_3
Learning motivation	G_1	-2.99 (.000**, 1.52)	-1.07 (.000**, .63)
	G_2		1.92 (.025*, .98)

Note. G_1: Information instruction only group; G_2: Instruction + upper body leaning forward + open body gesture; G_3: Instruction + upper body leaning backward + closed body gesture; *p<.050; & **p<.001/mean difference (p-value, ES[d])

A significant difference was also found between G_2 and G_3 in terms of learning motivation (p<.050). The post-hoc test (Scheffe) considered the G_2 as the control group and checked Cohen's d value between G_2 and G_3. The Cohen's d value, which is ES, was .98, which showed a significant difference.

Effect of an Agent Tutor's Interactive Gestures with Cognitive & Emotional Cues on Learning Achievement

For [study question 3], the differences in the learning achievement among the groups were analyzed in **Table 8**. First, Levene's test for the equality of variance showed that the variation between the groups were not significant at the significance level of .05, which satisfies the assumption of equal variance to perform ANOVA.As shown in **Table 9**, the result of ANOVA showing the difference in learning achievement for each group based on the agent tutor's gesture type had a statistically significant difference: F(2, 43)=.6090, p<.010, partial η2=.22.

Table 8. Levene's assumption on equality of variance, mean, & standard deviation on learning achievement

Classification	Group	Number of cases	Levene	p	Mean	Standard deviation
Learning achievement	G_1	15	.167	.85	3.87	.83
	G_2	16			4.75	.68
	G_3	15			4.06	.70

Note. G_1: Information instruction only group; G_2: Instruction + upper body leaning forward + open body gesture; & G_3: Instruction + upper body leaning backward + closed body gesture

Table 9. ANOVA result on learning achievement

Classification	Variance groups	Sum of squares	Degree of freedom	Mean squared	F	p	ES (η^2)
Learning achievement	Between groups	6.70	2	3.35	6.09	.005*	.22
	Within group	23.67	43	.55			
	Total	30.37	45				

Note. *p<.010

For a more detailed analysis between groups, a post-hoc test using Scheffe method was conducted. As shown in **Table 10**, the learning achievement showed a significant difference between G_1 and G_2 (p<.010). The post-hoc test considered the G_1 as the control group and compared the mean difference between each group's learning achievement. Cohen's d value was found to be between G_1 and G_2, and the ES was 1.16, which showed a significant difference.

Table 10. Post-hoc analysis (Scheffe) on learning achievement

Classification	Group	G_2	G_3
Learning achievement	G_1	-.883 (.008**, 1.16)	
	G_2		.680 (.047*, .99)

Note. G_1: Information instruction only group; G_2: Instruction + upper body leaning forward + open body gesture; G_3: Instruction + upper body leaning backward + closed body gesture; *p<.050; & **p<.010/mean difference (p-value, ES[d])

Learning achievement also showed a significant difference between G_2 and G_3 (p<.050). A post-hoc test considered the G_2 as the control group and checked the mean difference between G2 and G_3. Cohen's d, which is the ES, was 0.99, which was a very large difference.

DISCUSSION

The cognitive gestures of an agent tutor can induce attention and focus, which guide a meaningful cognitive process (Li et al., 2019; Lozano & Tversky, 2006; Mayer 2021). Emotional gestures with social and emotional interactions can strengthen the motivation of learners by inducing a deeper level of immersion in learning (Lawson et al., 2021). However, the issues and effect of different gesture types and their different combinations as well as their purpose have not been analyzed accurately. This study revealed three main findings on the combinations of cognitive and emotional gestures by using an agent tutor.

First, research question 1 showed that adding emotional gesture to cognitive gestures lowered the extrinsic cognitive load. Positive emotional gestures had higher germane load compared to negative emotional gestures. Second, research question 2 revealed that cognitive gestures accompanied with positive emotional gestures increased learning motivation. Lastly, research question 3 showed that cognitive gestures accompanied with positive emotional gestures improved learning achievement.

Effect of an Agent Tutor's Interactive Gestures with Cognitive & Emotional Cues on Cognitive Load

According to cognitive load theory, elements that are not directly related to learning contents, such as gestures, can cause distractions in learning and should thus be minimized to ensure effective uses of cognitive capacity and resources (Chen et al., 2018; Sweller et al., 2011). However, assumptions based on a single theory limits a more comprehensive study. This study has overcome this limitation by proposing a cognitive process based not only on the multimedia cognitive theory but also on the integrated cognitive-emotion theory and found partial support from the result. First, emotional gestures can induce more positive emotions when it is combined with cognitive gestures, thereby increasing motivation, which leads to more positive learning outcomes. Furthermore, it was shown that learners were able to focus better when emotional and cognitive gestures are combined, compared to presenting only cognitive gestures. This confirms previous research suggesting that emotion and cognition shares processing space biologically, even during the learning process (Plass & Kalyuga, 2019).

Effect of an Agent Tutor's Interactive Gestures with Cognitive & Emotional Cues on Learning Motivation

A negative emotional gesture accompanied with a cognitive gesture enhanced the learning motivation compared to when only a cognitive gesture was provided. The result verified previous study results (Baylor & Kim, 2005; Mayer. 2020b; Reeves & Nass, 1996), where the emotional aspect shown by an agent tutor was recognized as more than a mere artifact but rather as part of the partner.

While some previous studies (Chen, 2012; Lin et al., 2013) have claimed that incorporating an agent tutor in learning resources does not have an effect on the level of learning achievement, this research verified that a design integrating positive emotional gesture and cognitive gesture enhanced learning motivation as well as allowed the learners to be more deeply immersed in the learning contents fostering cognitive process. This result is consistent with previous studies that have demonstrated that inducing positive emotions enhances learning motivation (Plass et al., 2020; Plass & Kaplan, 2016; Um et al., 2012).

Effect of an Agent Tutor's Interactive Gestures with Cognitive & Emotional Cues on Learning Achievement

It is evident that learning achievement also improved as it was affected by enhanced learning motivation (Dincer & Doğanay, 2017; van der Meij et al., 2015). On the other hand, while the study by Yung and Paas (2015) was not able to verify the differences between the types of cognitive load as the study analyzed cognitive load as a whole, this study revealed that providing cognitive gesture accompanied with a positive emotional gesture increases germane load and lowers extrinsic cognitive load, thus enabling a more meaningful learning process.

CONCLUSIONS

Theoretical Implications

According to cognitive load theory, elements that are not directly related to the learning content, such as gestures, can cause distractions in learning and should therefore be minimized to ensure effective use of cognitive capacity and resources (Chen et al., 2018; Sweller et al., 2011). However, assumptions based on a single theory limit a more comprehensive study. The present study overcomes this limitation by proposing a cognitive process based not only on multimedia cognitive theory, but also on an integrated cognitive-emotional theory.

First, this study demonstrated that emotional gestures could induce more positive emotions when combined with cognitive gestures, which increases motivation, leading to more positive learning outcomes. It was also shown that learners were able to concentrate better when emotional and cognitive gestures were combined, rather than when only cognitive gestures were presented. This supports previous research suggesting that emotion and cognition biologically share processing space even during the learning process

(Plass & Kalyuga, 2019). Therefore, when using agent tutors in multimedia learning, it is important to consider the emotional aspects of the learner in addition to the cognitive aspects.

Second, no difference in extrinsic and germane cognitive loads were shown between the positive and negative emotional gestures in which we may assume that with limited cognitive capacity (Chen et al., 2018; Sweller et al., 2019), extrinsic cognitive load is maintained while the germane cognitive load is not effectively managed. We can also suggest that this may be due to the cognitive resource depletion effect (Sweller et al., 2019). As the different types of the agent tutor's gestures had kept being presented, it caused cognitive resources depletion, leading to the poor performance. Therefore, if cognitive capacity is considered in the design of agent tutor gestures that integrate emotional and cognitive aspects, higher levels of learning motivation and learning achievement can be expected.

Practical Implications

Further support for the findings of this study can be found in cognitive emotion theory, which argues that when the learner recognizes an agent tutor as a social partner, it enhances the learner's motivation and increases the learner's focus (Mayer, 2020a). As our findings show, incorporating cognitive and emotional cues in agent tutors can enrich the learning experience for learners.

First, when cognitive gesture was combined with emotional gesture, the extrinsic cognitive load was lower, in contrast to the germane cognitive load, which was higher. Furthermore, when a positive emotional gesture was combined, the cognitive load has a greater effect size, than a negative emotional gesture being combined with a cognitive gesture. As for learning motivation and learning achievement, a positive emotional gesture was more effective than a negative emotional gesture. Therefore, the emotional gesture of an agent tutor should be provided prior to the cognitive gesture in order to enhance learning motivation and increase attention in the cognitive process. Instructors should ensure that emotional cues from the agent tutor are incorporated from the beginning of multimedia learning, preferably by providing positive emotions rather than negative emotions, to ensure that the whole learning experience takes place.

Second, as for gestures that could enhance learning motivation, a positive emotional gesture (upper body leaning forward + opened gesture) combining emotional valence and activity increases the learning motivation and achievements (Lawson et al, 2021). Likewise, the integration of emotional gesture type proposed by Russell could aid development of an agent tutor into a more elaborate artifact, thus ultimately forming a strengthened bond with the learner. Also, when learning in a multimedia context, incorporating the emotional valence and gestural activities of an agent tutor can immerse learners at a higher level.

Future Implications & Recommendations

The suggestions and limitations for future research are, as follows: First, this study combined emotional and cognitive gestures consecutively to identify indirect differences by comparing the effect sizes of the two types of gestures with cognitive gesture. It was found that, providing positive emotional gestures was more effective than other methods the cognitive load has a greater effect size. However, we were unable to identify the effect of the interaction between the different types of gestures according to an integrated model of cognition and emotion. Future studies should utilize video analytics to analyze the cognitive patterns of response from gestures on emotions and cognition. Second, the emotional and cognitive component of an agent tutor was limited to gestures. According to a previous preceding study (Wang et al., 2018), gestures could increase learning motivation when connected to a gaze, and the development of extrinsic components can lead to more immersive learning. A future study should develop an emotional and cognitive aspect of each component and determine if better cognitive processing can be derived by a specific, more effective combination of configurations of an agent tutor.

Third, consuming cognitive resources leads to resource depletion as well as poor performance, and it should be recovered through rest (Sweller, 2020). Though positive emotional gesture showed no difference in cognitive load when compared with negative emotional gesture, it led to a higher level of learning motivation and learning achievement. This suggests that there may have been some cognitive depletion from the agent tutor's gesture, but higher motivation may have led to a partial cognitive recovery. Therefore, future research should explore the changes that may contribute to cognitive processes when learning motivation is activated in methods that utilize positive emotional gesture.

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