The role of extraneous principles of Cognitive Theory of multimedia Learning (CTML) in managing the cognitive load of Multimedia listening tasks

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Abstract

The present study investigated the role of extraneous principles of Cognitive Theory of multimedia Learning (CTML) in managing the cognitive load (CL) of multimedia (MM) listening tasks among advanced EFL learners. To attain such goal, two sets of educational MM were designed. Set one was designed by considering five extraneous principles of CTML and set two was designed by violating these principles. 30 advanced EFL learners were randomly assigned into two groups. Their entry listening proficiency was assessed prior to the experiment. Group 1 watched the MM presentations designed based on CTML principles and group 2 watched the presentations designed without the principles. Both groups were asked to evaluate the task load of the listening tasks by completing NASA-TLX scale. The results of descriptive statistics revealed that the amount of total task load in MM designed with CTML principles is lower than those designed without CTML principles. Further, the amount of task load with respect to 6 dimensions of CL was found to be lower among those who watched MM designed based on CTML principles. The result of MANOVA however did not reveal a significant difference between the task load of listening comprehension across groups. The finding recommends certain implications for material developers and instructors to consider the role of CTML principles in designing instructional MM and doing listening comprehension activities for language learning.

Keywords: CTML, listening comprehension, task load, MM, EFL

1. Introduction

Listening comprehension is an implicit language skill and a complicated cognitive process. It requires both linguistic and non-linguistic knowledge and supplies comprehensible input into communication, and as a result is a key skill for language acquisition (Nunan, 2002; Rost, 2011; Vandergrift & Baker, 2015; Rahimi, & Sayyadi, 2019). Listening is a difficult and challenging task for EFL learners because comprehension of aural input demands learners to differentiate between sounds, comprehend the vocabulary and grammatical structure, gain experience with stress and intonation and contextualize the communication in terms of sociocultural expressions (Graham, 2011; Vandergrift, 1999).

The way listening comprehension should be taught in the curriculum has provoked considerable debate among language experts in the last centuries. The developments in psychological and linguistic arenas during the last decades from behaviorism and cognitivism to socioculturalism have had dramatic impact on the status of listening instruction. While in the 1950s the teaching of listening comprehension was hugely affected by S-R theory premises

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and listen-and-repeat techniques, in the 1980s the listening was taught based on comprehension models and listen-to-understand activities. In the following decade, listening was viewed to be an active process which needs the activation of cognitive, metacognitive, and social strategies. This caused different types of activities and instructional techniques to enter the listening instruction to facilitate the process of understanding and help people become skillful listeners.

With technological advancements in the 21st century, computer-based learning and teaching environments were effectively integrated into teaching listening in language classes. One such technique and content is MM during which different channels of working memory are engaged in processing the input. It is evident that instructional MM improves learning in general (Mayer, 2009) and language learning in particular (Liu, Jang, & Roy-Campbell, 2018; MacWhinney, 2017; Schmid, 2008). Based on listening research, it is proposed that understanding a text becomes easier, "if the information in the text is presented through multimodal input involving both audio and visual presentations" (Brown, 1995). However, based on Cognitive Theory of MM Learning (CTML), to lower CL of a learning task, the capacity of working memory in processing the audio and visual input should be taken into account. Within this framework, designing instructional MM should follow certain principles to promote learning (Mayer, 2014). In this framework, a group of CTML principles focuses on reducing the extraneous load of the tasks by adjusting the way narrations, graphics, and texts are assembled in the MM environment. While the key role of these principles in making instructional MM is underscored in the literature (Bezdan, Kester, & Kirschner, 2013; Ritzhaupt, Gomes, & Barron, 2008; Pastore, 2012), it is still unknown if incorporating these principles into designing listening tasks can help language learners manage the CL of listening activities. As a result, this study aims at comparing the role of two sets of MM presentations in managing EFL learners' listening task load: the one that has been produced by considering the principles of CTML and the one that has been designed by violating those principles. The main research question of this study is thus:

Do extraneous principles of CTML have any significant role in managing the CL of MM listening tasks?

1.1. Listening Comprehension

Listening comprehension as an unobservable language skill is a challenging and to some extent daunting task for many EFL learners. Many language learners feel they are under constant pressure while they are listening to the foreign voices due to speakers' speed of speech and time limitation they have to process both linguistic and mon linguistics elements. At the same time, the listeners take the dual rule of listener-speaker and while trying to understand the message, prepare their accurate and appropriate answers. This demands neurological, linguistic, semantic and pragmatic processes (Rost, 2011) to take place almost at the same time.

While in neurological phase the message is decoded by ears in the form of sound waves, during the linguistic phase, the listeners apply the bottom-up processing of the input while they (Clark and Clark, 1977, as cited in Richards, 2003, p. 4)

- take in raw speech and hold a phonological representation of it in working memory.
- they immediately attempt to organize the phonological representation into constituents, identifying their content and function.
- they identify each constituent and then construct underlying propositions, building continually onto a hierarchical representation of propositions.

- once they have identified the propositions for a constituent, they retain them in working memory and at some point purge memory of the phonological representation. In doing this, they forget the exact wording and retain the meaning.

When the listeners are decoding the message from a formal perspective, they need to activate their background knowledge or schemata to understand the meaning as well. This is basically done in semantic phase of listening while the listeners apply top-down processes to make a bridge between what they have already filed in their long term memory and what is coming in the form of an aural input. There are three types of schema that can be activated in the process of reading and listening comprehension (Field, 2006), i.e., world knowledge (the encyclopedic knowledge that constructs the previous knowledge of the speaker or write); knowledge built up from the text; and the text schemata (the previous experience of the type of text processed before). The pragmatic phase involves socio-cultural dimensions of people and their role in the process of listening and/or speaking. This is actually related to the way the conversation is maintained by giving and receiving appropriate feedback while observing the status of the interlocutors and the social distance between them.

Handling these processes at the same time involves different elements of the cognitive enterprises of the mind hugely with the intervening effect of many other factors within and out of the listener's brain. Revealing this multidimensional nature of listening comprehension demands multiple areas of research (Figure 1). As Imhof (2011) states

> …it needs to be recognized that the process and product of listening depend on the constellation of variables pertaining to the listener, the speaker/the source, the message and the situation, and the mutual interactions. The mindmap can be used both to illustrate effects in listening behavior and to generate hypotheses about causes, effects, and covariation of processes involved in listening. (pp. 109–110)

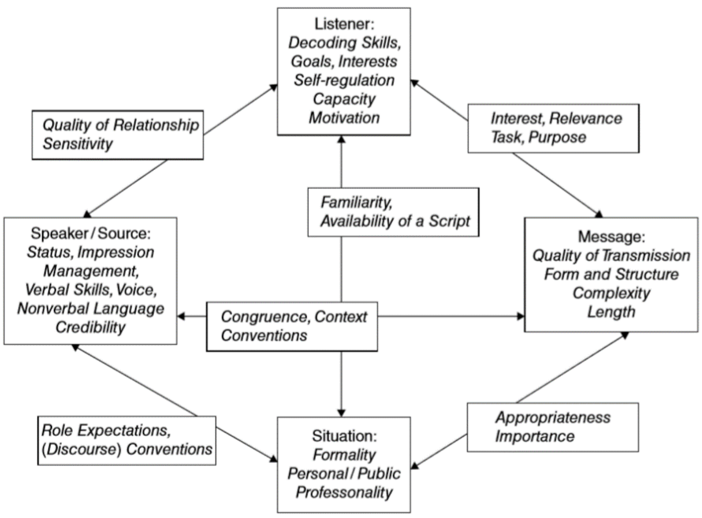

Fig 1. Imhof's (2010) mindmap of potential listening variables (Worthington, 2018, p. 88)

These variables can be related to the CL of listening task as the mental effort a given task demands, loads the working memory and may lead to frustration and withdrawal from doing the task. In listening literature, the CL of listening is much attributed to the text and its content. For instance, the texts that have fewer individuals/objects with distinctive features, the ones that involve simple spatial relationships, are related to people's background knowledge or have fewer inferences are considered to carry less CL (Brown,1995). From a purely cognitive perspective, however, CL involves human cognitive architecture and the way different types of input are processed by the working memory.

1.2. CTML and its components

One noticeable theory within MM field of study is CTML (Mayer, 2005, 2009). This theory supposes that in order to profit from MM instruction, learners need to participate in active processing of the information (Figure 2). That is, they have to pick appropriate data from MM, arrange it into an organized pictorial and verbal mental portrayal and combine this mental portrayal with each other and with their pervious knowledge (Schüler, Scheiter, & Gerjets, 2013). According to the CTML, the cognitive system in charge with these procedures includes two data processing channels, an auditory-verbal and a visual-pictorial channel (Paivio, 1986, 2007; Mayer, 2005).

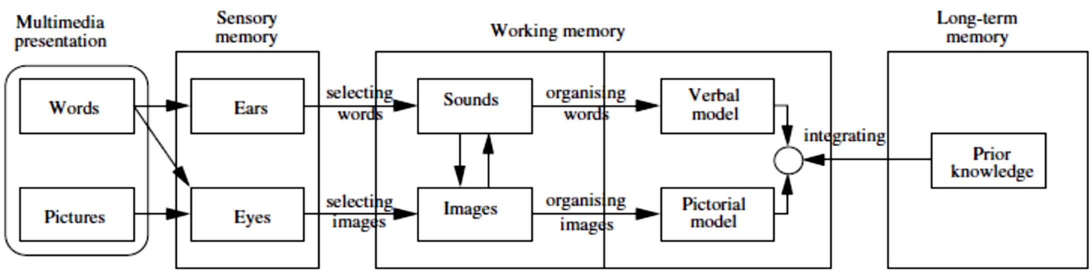

Fig 2. Cognitive Theory of MM Learning (Mayer, 2005, p. 37).

Based on CTML, when both the auditory and the visual channel in working memory (WM) are used, to an analogous extent learning becomes optimum (Mayer, 2005; Mayer & Fiorella, 2014). When learners encounter different origins of basically the same data such as written and spoken text, they may require to attempt to synchronize them. Randomly searching for association between components from different origins of data that are not linked to the learning goal can cause heavy requirements on WM and thus to be destructive to learning. The effect supplies a clear instance of extraneous and interacting component. If crucial information is supplied along with redundant information, the components accompanied with redundant information are expected to be processed resulting in extraneous load (Sweller, Ayres, & Kalyuga, 2011). Audiovisual materials provide learners with contextualized visual representations that could promote the perception of verbal input (Plass & Jones, 2005). A mixture of verbal and imagery data could make L2 input more understandable and easily recoverable from memory as the activation of both nonverbal and verbal procedures result in more desirable learning (Paivio, 2007).

‘‘An advantage of MM and computerized instruction is the possibility of adjusting the instruction to the student’s level. This might be done partly on the basis of success; if the student succeeds, the materials can be made more challenging whereas, if the student fails, the materials can be made easier’’ (Cowan, 2014, p.214).

There are three principles of CTML (Mayer, 2005):

(1) there are dual channels for auditory and visual processing of data;
(2) each of these channels has only restricted capacity to deal with the data; and
(3) learning happens when cognitive procedures are synchronized. In order to provide a useful instructional MM consideration of these principles seems to be essential.

Based on these three assumptions, the principles that target the way instructional materials should be designed are called reducing extraneous processing principles of CTML. There are five principles in this category namely coherence principle (delete extraneous material.), signaling principle (highlight essential material.), redundancy (absence of onscreen caption to narrated graphics), spatial contiguity principle (adjacency of printed words and corresponding graphics), and temporal contiguity principles (spoken and graphics be presented simultaneously) (Mayer, & Moreno, 2010; Mayer, & Johnson, 2008; Liu, Lin, Tsai, & Paas, 2012).

With regard to the profitable learning of knowledge and the improvement of comprehension, the usage of MM is discussed to have the possibility to considerably develop instructional effectiveness (Miller, Chang, Wang, Beier, & Klisch, 2011); however, concerns remain about the degree to which its arrangement and application have accomplished or optimized such possibility (Massa & Mayer, 2006; Sweller & Chandler, 1994). The utilization of CTML principles (Liu, Jang, & Roy-Campbell, 2018; Mutlu-Bayraktar, Cosgun, & Altan, 2019) has approved the importance of incorporating the MM principles in designing instructional materials and improving learning outcome of the MM instruction (Mayer, 2003, 2009; Mayer & Moreno, 2002). To the knowledge of the researchers, the role of observing extraneous principles of CTML in listening instruction has not yet been investigated. As a result, the current study aims at finding the role extraneous principles of CTML in managing the CL of MM listening tasks.

2. Method

2.1. Participants

Thirty advanced EFL learners participated in the study. The participants ranged in age between 18-21. They enrolled in an advanced conversation course in one state university in Tehran in the academic year 2018-2019.

2.2. The Instruments

2.2.1. Listening Proficiency Test

In the present study, listening comprehension proficiency was assessed by the listening section of IELTS. The listening section of IELTS has four parts consisting of different listening tasks with naturalist settings and topics (conversation, interview, asking and answering questions, and listening to a lecture on a specific topic). The test includes 40 multiple-choice questions and its administration took 40 minutes. Each part of the test was played only once. The reliability of the test was found to be .71 in this study.

2.2.2. NASA-TLX scale

NASA-TLX (Hart, & Staveland, 1988; Hart, 2006) was used to measure the CL (CL) of MM presentations. The NASA-TLX is one of the most widely used instruments to assess overall subjective workload. It is a multi-dimensional instrument with six subscales: mental demand, physical demand, temporal demand, performance, effort, frustration. The rating scale ranges from 0 to 100, whereby high rates demonstrate a high level of CL or high difficulty in understanding the listening respectively. Total reliability coefficient of .87 (Tubbs-Cooley, Mara, Carle, & Gurses, 2018) has been reported in the literature for the scale. The reliability of NASA-TLX was found to be .80 in this study.

2.3. The MM Presentations

Two sets of MM presentations were prepared considering two criteria: considering extraneous principles of CTML and violating them. The MM presentations were reviewed by four experts, two computer engineers and two applied linguistics. The presentations were revised based on the suggestions of the reviewers several times. The presentations were given to two EFL teachers along with the scale of ELT MM courseware evaluation questionnaire (Jiang, Renandya, & Zhang, 2017) that assesses the appropriacy of integrating CTML principles in designing courseware and MM. Upon getting satisfactory results, the final version of the presentations was prepared for the experiment. The features of the presentations are summarized in Table 1.

Table 1. The features of MM presentations

Task	Condition of designing	Duration
Archeology	Considering extraneous principles of CTML	6 min 46 sec
Astrology	Considering extraneous principles of CTML	5 min 41 sec
Archeology	Violating extraneous principles of CTML	6 min 46 sec
Astrology	Violating extraneous principles of CTML	5 min 41 sec

2.4. The procedure

The students were randomly assigned into two groups. Their entry English listening proficiency was assessed by listening section of IELTS. Group 1 was asked to watch two MM presentations designed based on extraneous principles of CTML and group 2 were asked to watch two MM presentations designed by violating extraneous principles of CTML. Immediately after each task, the participants were asked to judge the task load of the MM by completing NASA-TLX scale.

3. Results

The descriptive statistics of NASA-TLX for two sets of MM across groups of participants are shown in Table 2.

Table 2. The descriptive statistics of NASA-TLX

	Variables	Group 1 (with principles of CTML)		Group 2 (without principles of CTML)	
		Mean	**SD**	**Mean**	**SD**
Task 1 Topic: Archelogy	Mental Demand	55.000	27.902	59.333	17.511
	Physical Demand	42.333	22.429	39.333	24.338
	Temporal Demand	59.333	25.555	59.666	24.746
	Performance	38.666	29.366	43.333	26.502
	Mental Effort	56.000	28.043	66.000	20.976
	Frustration	34.333	33.266	54.333	29.752
	NASA-TLX	47.611	18.027	53.666	11.219
Task 2 Topic: Astrology	Mental Demand	61.000	30.248	70.000	17.423
	Physical Demand	43.333	29.378	47.666	25.345
	Temporal Demand	54.333	25.485	65.000	22.519
	Performance	39.666	29.668	43.000	22.424
	Mental Effort	55.000	27.516	62.333	23.593
	Frustration	35.666	27.701	42.333	29.146
	NASA-TLX	48.166	18.027	55.055	15.037

As Table 2 shows, the task loads of the MM presentations designed by considering the extraneous principles of CTML were lower on both MM presentations (M=47.61, SD=18.02; M=48.16, SD=18.02 respectively) in comparison to the presentations that were prepared by violating the principles of CTML (M=53.66, SD=11.21; M=55.05, SD=15.03 respectively). The comparison of the components of both sets of MM across groups also shows that with one exception (i.e. Physical Demand of task1), all task loads were higher for MM presentations designed by violating the principles of CTML.

In order to assess if there were any significant difference between task load of two sets of MM presentations across groups, two one-way Multivariate Analysis of Variance (MANOVA) were done on the scores of NASA-TLX. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance metrics, and multicolinearity, with no serious violations noted. As the results of Multivariate Tests were not significant (Table 3), Tests of Between-Subjects effects were not considered (Pallant, 2007).

As it shown in Table 3, no significant difference between two groups' task load in task 1 (the Archeology MM) on the combined variables, F (6, 23) = .767, p= .603; Wilks' Lambda = .84; partial eta squared = .16) was observed. Also, there is no significant difference between two groups' task load in task 2 on the combined variables, F (6, 23) = .260, p= .950; Wilks' Lambda = .94; partial eta squared =.06). The result implies that although the means of task load of MM presentations prepared with CTML is lower than those violating these principles, these differences could not reach statistically significant values.

Table 3. Multivariate Tests to compare the task load of two sets of MM presentations (Tasks 1 and 2) across groups

Task	Effect		Value	F	Hypothesis df	Error df	Sig.
Task 1	Group	Pillai's Trace	.167	.767	6.000	23.000	.603
		Wilks' Lambda	.833	.767	6.000	23.000	.603
		Hotelling's Trace	.200	.767	6.000	23.000	.603
		Roy's Largest Root	.200	.767	6.000	23.000	.603
Task 2	Group	Pillai's Trace	.063	.260	6.000	23.000	.950
		Wilks' Lambda	.937	.260	6.000	23.000	.950
		Hotelling's Trace	.068	.260	6.000	23.000	.950
		Roy's Largest Root	.068	.260	6.000	23.000	.950

4. Discussion

The aim of this study was to investigate the role of extraneous principles of CTML in managing the CL of MM listening tasks. In order to attain such goals, five principles of reducing extraneous principles of CTML were focused on and two sets of MM presentations were produced with and without incorporation of the principles in the designing phase. Both descriptive and inferential data analysis were used to analyze and interpret the data.

The results of descriptive statistics primarily revealed that the task load of MM presentations prepared by considering extraneous principles of CTML was lower than those MM presentations prepared by violating extraneous principles of CTML. This holds true for the whole scale and all its dimensions but the ‘physical demand’ in task 1.

This corroborates the findings of several other studies on different subject matters such as nursing (e.g. Colligan, Potts, Finn, & Sinkin, 2015; Tubbs-Cooley, et. al, 2018), medical education (e.g. Bridges, Stefaniak, & Baaki, 2018), human-machine interface (e.g. Akyeampong, Udoka, Caruso, & Bordegoni, 2014), and instructional design models (e.g. Nikulin, Lopez, Piñonez, Gonzalez, & Zapata, 2019) that note additional attention on CL management is essential and consideration of it seems to be necessary for more effective performance and learning outcome.

The reason why controlling the extraneous factors based on CTML principles results in lowering the task load, can be attributed to redundancy effect as redundant data impose redundant load on the restricted capacity of working memory (Schmidt-Weigand, & Scheiter, 2011; Sweller, van Merriënboer, & Pass, 1998). This made the students perform differently while processing the information presented in MM presentations as the cognitive condition of two groups’ working memory was different. Students with higher levels of memory for figurative meaning had a greater capability for encoding data into their memory and thus were less restricted by the requirement on attentional means. In other words, they could unify different portrayal (verbal-pictorial) on the screen more easily and could preserve this data as a meaningful chunk. For the low memory students, it could have been more complicated to decode and assimilate different portrayal on the screen, prompting to a more cursory coverage of the data which was less effortlessly preserved (Ardac, & Unal, 2008; Hughes, Costley, & Lange, 2019).

The instructional designers must consider the situation where these principles implemented. The coherence of node arrangement caused by graphical overviews cannot consider for learning consequences in isolation. Alternatively, the use of remarkably dynamic overviews, for reinforcing coherence at latter phases of learning procedure may become redundant, having unwilling consequence on comprehension. Although the absence of significance differences for mental demand between various types of MM instruction makes clear the requirement for further study in this section. Thus, this study indicates that consideration of the situation in MM instruction seems to be essential. Plass and Jones (2005) assert that some MM principles may not be appropriate to L2 accurately, and that there is a lack fo research on the appropriateness of such principles to L2 learning. From a theoretical point of view, the results of this study recommend that present theories of instructional patterns such as CLT (e.g., Pass, Tuovinen, Tabbers, & Van Gerven, 2003) and CTML (e.g. Mayer, 2009) might require to be specified for extraneous principles effect in foreign language learning milieus.

It was also found that, these mean differences did not reach the statistical significance. One interpretation for this outcome may exist in the particular essence of the MM instructional component and the amount of CL it enforces on the visual working memory. It seems that adding auditory materials has negative effect on quality of knowledge and causes less effective learning. However, it is set forth that the application of visual media can diminish extraneous load as it enables learners to deduce meaning and implement reason (Goldstone, & Son, 2005). It has also been proposed that visual media better expedites the cognitive procedure by making it more straightforward for data to be combined into long-term memory (Schnotz & Rasch, 2005; Mayer & Moreno, 2003). The reason of this can be related to negative redundancy effects on knowledge transfer, but not on genuine retention of knowledge (Knoop-van Campen, Segers, & Verhoeven, 2018, 2020).

There are different stores for verbal and auditory material (Williamson, Baddeley, & Hitch, 2010), even with enough viewing time, and in the absence of text, probably distracting media, only examining complicated visual representation does not precede to a high level of memory for pictorial components (Schwan, Dutz, & Dreger, 2018). The finding is in line with MM principle (Mayer, 2009; Glaser, & Schwan, 2015; Cierniak, Scheiter & Gerjets, 2009) implying that when pictures and audio are simultaneously presented, learners expand a more complicated mental portrayal of content by concentrating on both related parts and simultaneously integrate information with each other and transport them into WM.

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