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Input Modality and its Effect on Memory Recall

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ABSTRACT

One's learning performance may be influenced by many internal and external factors. In addition to one's cognitive ability, matters related to the academic context such as learning materials, contents and instruction can regulate and influence learning performance. The study aimed to examine the effects of different input modalities on learning performance by measuring memory recall success. A total of 96 participants took part in an experimental study employing a between-subject design. They were randomly assigned to one of the three groups that were presented with either visual or auditory or a combination of visual-auditory inputs. In the study phase, the visual input group was asked to read the inputs which were visually presented to them. As for the auditory group, the participants were required to listen to the inputs presented auditorily to them. The visual-auditory group did both simultaneously (seeing and listening to the inputs) as the inputs combined both visual and auditory presentation. In the test phase, they were required to recall words that they could best recall from the study phase. Analysis of ANOVA revealed a statistically significant difference between the different input modalities on the participant's ability to recall words. It signifies that learning materials that are presented both in audio and visual are better recalled compared to materials learned in a single modality (either visual or audio alone). The modality effect uncovered in the present study has important instructional implications related to the presentation of learning materials to optimise learners' ability to learn.

Keywords: visual, auditory, memory recall, learning materials, modality effect

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1 INTRODUCTION

Knowledge of how one learns, thinks and process information is essential to successful learning. The cognitive perspective of learning assumes that learners are knowledge constructors who will not passively absorb any learning inputs. Rather, they are active processors of information, continually engaging inputs to construct a mental model of knowledge in long-term memory that is used to guide behavior. From a cognitive point of view, to ensure learning is impactful, it is essential to encourage learners to engage in appropriate cognitive processing of the learning materials or inputs (Meyer, 2009). Efficient cognitive processing can be dependent on matters related to teaching and learning such as course contents, learning materials, and instruction, many of which have been found to influence learning performance (Mack & Filipe, 2018). Uchechi Bel-Ann Ordu (2021) reported that one way to stimulate learners' interest in learning and strengthen their ability to recall what has been taught is by diversifying teaching and learning strategies. Hence, the mode in which the learning materials are presented to the learners may have contributed to effective and successful learning.

The cognitive processing theory of learning materials proposed that learners process learning materials differently depending on the nature or mode of the materials. According to Moreno & Mayer (1999), and later by Sweller, Ayres & Kalyuga, (2011) the cognitive processing of learning materials involves a dual channel. The visually represented materials such as printed words and images are processed in the visual channel, whereas materials in the form of spoken words or other non-verbal sounds will be processed in the auditory channel. Each of these channels is limited in its capacity to process materials (Alemdag & Cagiltay, 2018). This means providing learners with too much information might result in processing failure and hence have an adverse effect on learning. However, it is also assumed that learners are active information processors who are not just passively absorbing information. Rather, learners will continuously engage in active processes of filtering, selecting, organizing, integrating, and managing the forms of information they are interacting with. These various processes are assumed to occur in the learner's working memory system.

Human memory is one of the most studied cognitive systems in research on human cognition. It is understood as a major component of the human cognitive system which involves encoding, storing, and retrieving of environmental inputs. An influential framework of the human memory system, proposed by Atkinson and Shiffrin (1968), consists of three memory structures, namely sensory register, short-term, and long-term memory, each of which is unique in its capacity to store information and the duration of information retention. Any inputs from the environment are encoded and stored briefly in the sensory register and short-term memory. Some of the inputs are consolidated into a long-term store, while some others leave the short-term storage and are not brought for further processing. The structures of short-term and long-term memory are perceived more as storage and archival systems, leading Baddeley and Hitch (1974) to propose an alternative theory of memory called a working memory model. According to Baddeley and Hitch (1974), theoretically, working memory is an active cognitive system. It is defined as a system in which information is temporarily stored and manipulated that results in the accomplishment of complex tasks including learning (Baddeley & Hitch, 1974; Cowan, 2005; Paas & Sweller, 2012; Goldstein, 2019). While short-term and long-term memory structures (Atkinson & Shiffrin, 1968) function more as a storage and an archival system, respectively, working memory is a dynamic and active memory structure in which processing of incoming information involves multiple other types of processing such as retaining, remembering, integrating and manipulating. For example, in understanding a conversation, one has to focus, retain, make sense, and manipulate various information in a very short period. This ability to actively maintain information in the presence of ongoing cognitive processing is very fundamental and essential for everyday functioning. The highly active, transient storage and diverse types of cognitive processing is the unique defining characteristic of a working memory system which makes it different from other memory structures (Baddeley & Hitch, 1974; Cowan, 2008; 2014; Goldstein, 2019). Working memory is said to be the 'hub of cognition' (Haberlandt, 1997) and has been found to have a significant influence on many higher-order cognitive processes such as comprehending language, reasoning, and complex thought and learning (Holmes, Gathercole, & Dunning, 2009). Research on working memory becomes one of the most widely studied area in cognitive psychology and neuroscience (Miyake & Shah, 1999).

According to Baddeley & Hitch (1974), the dynamic of a working memory system is based on its three components namely the phonological loop, visuospatial sketch pad, and the central executive. The phonological loop maintains and manipulates verbal and acoustic or auditory information while the visuospatial sketch pad is responsible for processing involving visual and spatial information. The central executive component of a working memory system is regarded as the control centre and it is the component that makes working memory 'work'. It coordinates the functions of the phonological loop and visuospatial sketch pad by focusing on specific parts of a task and deciding how to divide and switch attention between different tasks (Baddeley, 1998). Interestingly, a working memory structure appears modality-specific (Miyake & Shah, 1999; Cowan, 2014, Park & Jon, 2018). This means inputs from multiple sensory modalities are processed in the working memory according to its domain-specific system. Hence, the presentation of the material in a single modality (either visual or auditory) may optimize the working memory performance and result in better learning performance.

However, empirical research comparing the single and dual-modality modes of input have been varied and yielded conflicting results. Tabbers, Martens, and Van Merrienboer (2000) found participants in visual condition performed better on the reproduction and transfer tests than those in the auditory condition. In their experiment, the presented learning materials were manipulated by presenting the experimental materials in a visual and audio condition separately. The effect of the different modes of learning inputs is then measured based on the extent to which participants could recall elements of the learning model (reproduction test) and the extent to which they could apply the model in a new situation (transfer test). They found that in both tests, performance was better following the visually presented materials compared to if the materials are audio based. Similarly, in a study by Diao and Sweller (2007), they measured participants' comprehension of learning materials in two separate conditions. The first condition is a reading-only modality condition as the experimental materials are visually presented and participants were required to read them. The second condition is the reading while listening condition in which participants were presented with the same materials as in the first condition, but they were asked to read and listen simultaneously. The finding showed that there is a significant increase in comprehension for the reading modality only than the reading while listening condition. The benefits of visual and verbal displays of learning materials found in Diao and Sweller (2007) may be strengthened if a listening-only condition was also included in the experimental design. In addition, in the study conducted by Daniel and Woody (2010), they found that recall after reading (visual presentation) was better than recall after listening (auditory presentation). Participants in their study were given an article with one group was asked to read while the other was asked to listen to a podcast of the same article. It was found that those who read scored significantly higher on a quiz than those who listened to a podcast of the same article. However, the advantage of visual information over auditory presentation mode did not find support in a study by Moyer (2011) as there is no significant differences in the recall performance following the inputs presented in visual and auditory modalities. Mayer and Moreno (2002) also found that students who read while listening to text learned the material better than those who only listened, or those whose text was accompanied by animations. Rogowsky et.al., (2016) also did not find any significant difference in the comprehension following different input modalities. In their study, participants' comprehension following different modalities of learning instructions was measured in different time frames (immediate and delayed). It was found that regardless of when the comprehension was measured, no significant difference was observed among the visual, audio, and dual-modality presented instructions.

Given the lack of consistency in the research literature pertaining to the effect of the mode of input (visual, auditory, or both visual and auditory simultaneously) presentation, more research is needed to measure the effect of the different modalities of inputs or learning materials. It is of interest to directly measure whether the presentation of the learning materials in a single modality (either visual or auditory) or dual modality (a combination of visual and auditory) might give any effect on memory recall performance.

Therefore, the present experiment aims to measure the effect of input modality (visual, auditory, or both visual and auditory simultaneously) on memory recall performance. The independent variable in this experiment is the different modes of learning inputs presentation, i.e. visual inputs, auditory inputs, and visual-auditory inputs, while the dependent variable is memory recall which is operationalized as the number of random words that are correctly recalled in the test phase. It is hypothesized that there will be a significant difference in the memory recall performance of the three groups. The number of words correctly recalled would be higher in the visual-auditory group than the visual and auditory groups.

2 METHOD

Participants

Participants who were included in the study have fulfilled the inclusion criteria, which are Malaysian undergraduate students between the ages of 19 to 25 years old, possess good English proficiency and report no history of psychological or medical problems. A total of ninety-six participants took part in the experimental study. There were more females (N= 91, 94.8%) than males (N=5,5.2%), with the age range from 19 to 25 years old (M=21.5, SD=1.45). The majority of the participants are third-year undergraduate students (N=68, 70.8%), followed by second year (N=20, 20.8%), fourth-year (N=5, 5.2%) and first-year students (N=3, 3.1%). Participants were chosen using convenience sampling, a type of non-probability sampling, in which they were chosen based on their easy accessibility and availability.

Research design

The experimental study employed a between-group design. The participants were randomly assigned into one of three groups namely visual group, auditory group, and visual-auditory group. Each participant was in one condition only and performed only one experimental task (either visual task or auditory task or visual-auditory task).

Instruments

The instruments for the experiment were self-developed, guided by the study by Rogowsky et.al (2016). There were three different groups of experimental tasks, two of which (visual and visual-auditory tasks) consist of learning inputs in the form of English random sentences shown on a total of 12 power-point slides. As for the auditory task, the learning inputs were auditorily recorded. The number of words in the sentences ranged from three (*Books are cheap*) to 12 words (*Social issue is a problem that affects many people within a society*). At the centre of the bottom part of each slide, there is an English random word, which has no semantic or pragmatic relation to the sentence (for example: *Biscuit*).

The three different experimental tasks are as the following:

Visual Task: The visual task is designed for the visual group. The learning inputs in the visual task consist of printed sentences presented on slides. Participants in the visual group could see the inputs on a computer screen and were asked to read aloud the inputs on the slides.

Auditory Task: The auditory task is designed for the auditory group. The learning inputs in the auditory task are the same as the visual task except that the inputs were in audio-based form. This means, participants in the auditory group were presented with blank slides and they only heard the inputs (sentences and random words).

Visual-Auditory Task: The visual-auditory task is designed for the visual-auditory group. The learning inputs in the visual-auditory task were the same with the above-mentioned tasks, printed and audio-based. Hence, participants doing the visual-auditory task were able to see, read and heard the learning inputs presented to them in the study phase.

Data Collection Procedure and Analysis

The experiment was conducted physically on campus. All participants gave their consent before taking part in the experiment. The experiment which took place in an experimental lab was conducted separately for the three groups and for each group, there were four to six participants per session. A total of six experimental sessions was allocated for each group. The experiment consists of a study and a test phase. In the study phase, participants in all the groups were presented with slides that consist of learning inputs in the form of random English sentences. Participants in the visual group were presented with printed inputs on the slides and they were asked to read aloud the inputs. Those in the auditory group were asked to listen to the inputs auditorily, while in the visual-auditory group, participants read and listen the inputs simultaneously. After a two-minutes break, all participants engaged in the test phase in which they were required to recall words that they remembered having seen or heard or both during the study phase. All participants were given response sheets that contain the list of random words and new words (words that do not appear in the study phase). They were asked to tick as many words as they could recall in the response sheet. Participants in all groups underwent a short practice session prior to the actual session. An actual experimental session took place once the experimenters were confident that they understood the procedure of the experiment. The present study follows ethical guidelines and was approved by the ethics committee of the faculty (ID No: S3/-1-2022-001). All participants were given informed consent forms for their agreement to voluntarily participate in the research. They were given the right to withdraw at any point without any penalties and costs. Their personal information as well as identity remain confidential and will not be disclosed for any use except for research purposes only.

As for the statistical analysis of data, IBM SPSS version 25 was used. The first type of analysis is descriptive in nature, aimed to analyse the participants' demographic information as well as the mean (M) and standard deviation (SD). The effect of the different modes of learning inputs on memory recall was analysed using inferential analysis (one-way ANOVA).

3 RESULTS AND DISCUSSION

To measure the effect of input modality (visual, auditory, or a combination of visual and auditory) on memory recall performance, the inferential statistical analysis used was one-way ANOVA.

Prior to that, a descriptive analysis was conducted to examine the frequency, and percentage of participants' demographic information (refer to Table 1), and the mean and standard deviation score for the memory recall performance for the three groups (refer to Table 2).

Table 1: Demographic data of the participants.

Demographic information	**Frequency**	**%**
Gender		
• **Male**	5	5.2
• **Female**	91	94.8
Age		
• **19**	2	2.1
• **20**	5	5.2
• **21**	48	50.0
• **22**	27	28.1

• **23**	9	9.4
• **24**	3	3.1
• **25**	2	2.1
Level of study		
• **First year**	3	3.1
• **Second year**	20	20.8
• **Third year**	68	70.8
• **Fourth year**	5	5.2

The mean for the number of words correctly recalled by the visual group is 12.63 (SD=1.10). As for the auditory group the mean for the number of words correctly recalled is 9.16 (SD= 1.95). The mean for the number of words correctly recalled was highest for the visual-auditory group (M= 17.97, SD=1.18).

Table 2. The mean of memory recall performance and standard deviation for the visual, auditory, and visual-auditory groups.

Group	**N**	**M**	**SD**
Visual	32	12.63	1.10
Auditory	32	9.16	1.95
Visual-Auditory	32	17.97	1.18

Analysis of one-way ANOVA revealed that the visual-auditory group significantly performed better than the visual and auditory groups [$F(2, 93) = 295.19$, $p < 0.05$]. Hence, the hypothesis that there will be a significant difference in the memory recall of the three groups, with the number of words correctly recalled by the visual-auditory group being higher compared to the visual and auditory groups was fully supported. This finding can be interpreted to show that there is an effect of the presentation of the different input modalities on memory recall performance. It signifies that learning inputs that are presented both in audio and visual are better recalled compared to inputs learned in a single modality (only visual or only audio). This finding supported previous studies by Low and Sweller (2014) and Castro-Alonso, Ayres & Sweller (2019) who also found that the combination of visual and audio has been generally found to improve and benefit students' learning. Another related research by Khelif et al. (2014) also found that user's satisfaction to teaching and learning was highest for the materials that combine text, images, sound, and video. The learning materials that can be visualized and heard simultaneously have been found to increase students' interest and help with their understanding (Khelif, Engkamat & Jack, 2014).

It is noteworthy that the use of different modalities of inputs could support the processing of information in the mind. This advantage relates to the modality effect (Sweller, Ayres & Kalyuga, 2011; Castro-Alonso, Ayres & Sweller, 2019; Greenberg et al., 2020), which has been proposed to occur when a dual-modality presentation is superior to a single-modality-only presentation. This means better and more efficient cognitive processing occurs when the presentation of learning materials involves a mixed mode i.e. partly visual and partly auditory compared to when a single mode (either visual or auditory) is used, hence giving an advantage to recall and learning performance. One explanation for this is that presenting learning inputs in dual modality may reduce extraneous cognitive load as the processing of each visual and auditory input involves its respective processing system in the working memory. According to cognitive load theory (Sweller, 1988; Sweller et al., 1994, Sweller et al., 2019), any learning task induces some processing load which will affect the ability of students to process past, current and new information. Better learning performance is promoted when the cognitive processing load is within the capacity of the processing system as the processing is spread between two different processors of a working memory system (visuospatial sketchpad and phonological loop) (Castro-Alonso & Sweller, 2020). Hence, the information presented in a dual-modality is maximally processed and will be recalled more compared to that presented in a single modality.

The findings from the present study also can be taken to support the classic dual-coding theory proposed by Paivio (1991) in which it was proposed that the two distinct working memory systems i.e. the visuospatial and the verbal system deal mostly with visualizations and audio or narrations, respectively. They further proposed that the two systems are interconnected and these associations produce more effective learning. Therefore, combining visualizations and narration allows for more robust and interconnected memory traces, making it easier to process and memorize information than purely providing visualizations or audio alone. The modality effect is particularly relevant to working memory, which is an important memory system that temporarily holds and processes information for cognitive tasks. Theoretically working memory is limited in capacity and duration. Hence, any technique to vary and manipulate learning inputs can enhance the efficiency of the working memory system which would result in better academic performance. In addition, information with dual-modality presentation tends to capture learner's attention more effectively. This increased attention level can lead to better encoding of the information into working memory.

The findings from the present study have multiple implications. Theoretically, the present study can add to the existing body of knowledge, that is by increasing literature in the area of understanding human cognition and ways to optimize it. Knowledge of human cognitive processes, in particular knowledge of memory organization, can give insight into the cognitive system that underlies human performance and can be used to guide teaching and learning activities. The findings of the study may also help in supporting the findings of the past research in the area and extend it to a sample involving the Asian or non-western population, in particular the university students' population. Practically, the findings from the present study are significant and may have important instructional implications associated with the presentation of learning materials. Specifically, educators can benefit from the advance in information and communication technologies to stimulate different aspects of the cognitive processes for the purpose of achieving optimal learning performance. The findings from the present study can be used to help them with the formats of the teaching and learning presentation, which should be designed in such a way that involves both modalities instead of visual or auditory alone. This can help learners to avoid unnecessary cognitive processing load by using both phonological loop and visuospatial sketch pad, rather than a single processor of their working memory system. In this way, the cognitive load can be spread over both processors, thus reducing the load on a single processor.

There are a few limitations discovered in this study. Firstly, as in other experiments, the present experiment has been conducted in controlled research laboratories. Hence, the findings may not represent how the participants would perform in their natural and real learning contexts. Future studies should be designed in such a way to enhance ecological validity, so that the findings can be more confidently extended beyond controlled setting to real-life situations. Secondly, it is possible that these findings do not represent the whole population and may be applicable only to limited university student samples. The sample in the present study was chosen using convenience sampling, which is a type of non-probability sampling technique. This means the sample in the study was not randomly selected but based on easy accessibility and availability to the experimenters. Findings from studies employing this type of sampling technique should be interpreted with caution as they may not accurately reflect the characteristics of the wider population. Replication studies can be extended by employing probability sampling such as systematic random sampling to include participants of different age group populations for wider applicability of the findings as well as to take into consideration on the possible relationship between modality effect and individual differences in cognitive processing capacities. More manipulation can also be done to evaluate the different elements or aspect of visual inputs such as comparing and/or differentiating written visual information with image or pictorial-based information.

4 CONCLUSIONS

The result of the present study boosted and broaden previous findings which showed a significant modality effect on learning performance. Different input modalities have been found to influence memory performance. The finding provides useful information for educators and researchers as well as those involved in the design of educational instructions to create and prepare learning materials that promote relevant cognitive processing in order to optimize the learning ability of learners. Reaching one’s full potential in learning may be achieved when the learning itself is tailored to the learners’ needs and in harmony with their cognitive architecture. The modality through which learning materials are presented may play a crucial role in achieving this goal.

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