Students' Comprehension of Scientific Discussion: Using Eye-tracking Technique to Investigate the Effects of Social-media Messages on Television

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Abstract

The present study explores the effects of social-media messages that are presented in television content. In particular, the retention of content and changes in attitude through watching television programs was investigated. Thirty participants were randomly assigned to one of two conditions: one that included social-media messages and one that omitted social-media messages. The participants' eye movements as well as retention performance and attitude toward the topic discussed on the television program were measured. Attitude was measured using two subscales: one concerned with positive attitude and the other with skeptical attitude. Results indicated that the retention performance of participants who paid attention to the social-media messages longer was lower than that of participants who paid less attention. The participants' attitudes changed after watching the television program but the effects of social-media messages were unclear for attitude change. The possibility of the appropriate use of social-media messages is also discussed.

1. Introduction

Television has become one of the major sources for learning new, important issues such as technology, politics, and ethical topics. The cognitive process of learning from the television can be understood in light of multimedia studies; however, studies of multimedia have not, for the most part, focused on the incorporation of social media.

Recently, we look to social media as a new source of information. It is common for us to intentionally read social-media messages on our mobile phones or computers. However, we are occasionally exposed to such messages unintentionally when mass media incorporate social media into their programs. One typical example is television programs that, during the program, screen related text messages made by viewers on social media. In such cases, social-media text messages, such as those from Twitter, seem to be more likely to be incorporated with television programs than those in which images play a central role, such as Instagram.

Social-media messages incorporated in television programs may help viewers to learn about the topics from a broader perspective by sharing their opinions, experiences, etc. However, this may also implicitly bias or affect viewers' comprehension. What kind of effect does unintentional exposure to social-media messages have on the comprehension of television programs? This is a critical question, especially when we watch television with the intention to learn.

Although social-media messages may influence our cognitive process of understanding television content, we know very little of its influence. Most research on television and social media has mainly focused on emotional aspects such as motives behind using social media while watching television [1], how viewer's motivation to engage in television programs can be increased, and analysis of attitudes towards advertisements and sponsors [2, 3]. On the other hand, only a small number of investigations have been conducted on the influence social media has on our cognitive aspects. The present study aims to reveal the effects of social-media messages on comprehension of the contents of television programs.

2. Background

2.1 Cognitive process of multimedia learning

Television programs incorporating social-media text messages can be regarded as multimedia materials that feature video and text. In particular, when a program focuses on issues that we need to understand in order to choose a policy or to find solutions to problems, such as political, environmental, or social matters, we can easily tell the purpose of learning through the multimedia used in television programs.

Past research on multimedia learning implies that additional information may hinder our comprehension. Based on cumulated studies of the effects of combining

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visual images (pictures and video) and text, Mayer [4] stated "people learn more deeply from words and pictures than from words alone (p.47)." However, we cannot jump from this to the conclusion that simply using a different format can facilitate learning. Sweller and Chandler [5] highlighted that it is necessary to consider how to avoid cognitive overload in multimedia-learning materials. Mayer and Moreno [6] suggested how animation and text can cause such an overload by conducting an experiment that examined how students learn scientific topics using animation with concurrent narration or on-screen text. The results showed that the participants who received narration outperformed the participants who received text. This was because the latter were forced to split their visual memory between the animation and the text. The effects of split-attention are not limited to the presentation format, that is, animation and text. Studies [7, 8] have shown that irrelevant information (text and pictures), although interesting, interrupt students' learning. The important theoretical consideration underlying this issue is to minimize split-attention effects; that is, attention to one presentation component may result in information in an accompanying, different presentation component being missed [6].

Social-media messages usually consist of various kinds of information that are not always consistent with what is discussed during a television program. As such inconsistency of information demands extra workload in order to process various kinds of information, it causes split-attention effects.

2.2 Using eye-tracking technology to detect individual differences in attention

Given the perspective of multimedia, we can infer that social-media text messages shown on television screens may cause cognitive overload or split-attention, and thus disturb viewer's comprehension of the program's content. It is possible that strategies for processing, paying attention to, social-media messages may differ among viewers.

The individual difference of attending to the social-media messages could be regarded as the individual difference of split-attention. We suppose that the viewers, who pay much attention to the messages, are sparing some of their cognitive capacity, which results in a weaker understanding of the contents. Other viewers, on the other hand, may ignore the social-media messages so that they can fully attend to the television content.

Thus, in order to investigate the effect of social-media messages on television, we need to measure the individual differences of attention paid to social-media messages with a reliable method. In this study, we have employed an eye-tracking methodology in order to investigate the viewers' attention. It is presumable that viewers are paying attention to a certain object when their eyes are fixed on that object [9]. It may seem more convenient to ask viewers to assess how much attention they paid to certain information. However, it is difficult for most people to monitor unintentional change of attention, and thus the self-assessment of attention could be less precise than the results of eye-tracking measurement.

2.3 Central and peripheral routes of attitude change

While learning is often described in terms of memory retention, other aspects such as building a situation model, evaluation, and forming an appropriate attitude are also regarded as important aspects of learning outcomes [10, 11]. The aspect of attitude is especially important when the program contents communicate ideas that concern policy-making or problem solving for issues we experience in our lives, since our attitude to this may affect our behavior [10].

According to the Elaboration Likelihood Model (ELM; [12]), attitude change is affected by two different processing routes: central and peripheral. The central route "occurs as the result of a person's careful and thoughtful consideration of the true merits of the information presented in support of advocacy [13]."

To consider the attitude change created by watching television programs, the key is the variables that affect the cognitive process. The cognitive process can influence attitude via the central route. The major variables that may affect changes in attitude when watching television programs are "complexity" and "modality." Previous studies [14, 15] have indicated that complex information reduces comprehensibility and, as a result, decreases positive attitude towards the issue. Also, it is known that video and television (unlike carefully designed multimedia learning materials) often require more attention and their information is more difficult to process when compared with that of print media [15, 16]. This is because with these media we cannot control our processing pace. Unlike when we read newspapers, we cannot stop if we encounter difficulty or uncertainty when watching television shows.

These studies suggest that attitude change can be yielded by television content through the central route of attitude change. Compared to other media such as printed text, television is basically a complex media. In addition, most television programs are not designed to simply deliver one idea; they often include alternative opinions, different points of view, or other sides of

stories. These characteristics of television may reduce the impact on the viewers' changes in attitude through the central route. Considering these characteristics, we should make television programs simple while also explicitly showing the merits and demerits of the issue in order to evoke attitude change.

Then, what would happen when social-media text messages are incorporated into television? Since the focus is on attitude change that is based on the cognitive process [17], the information and memory factors should have a stronger effect than the affective factors [18, 19]. One possible influence of social-media messages can be seen in the central route. As we discussed in the previous section, the social-media messages can cause split-attention effects that hinder the fluency of the cognitive process. Previous studies on attitude change provide evidence that the fluency of perceived information processes causes attitude change [20, 21].

In order to investigate attitude change, we have to consider the individual differences of processing social-media messages. We assume that split-attention effects can disturb the fluency of cognitive processing. Thus, we can make the premise that the effects of social-media messages depend on the attention paid to them. Then, we hypothesize that the attitude change in viewers who pay more attention to social-media messages would be less than that of the viewers who pay little attention to the messages or viewers who watch the television program without social-media messages.

The other possible influence of social-media messages relates to the peripheral route. The social-media messages add a certain atmosphere to the television program. The presentation of these messages produces a virtual audience that provides the viewers with an implied evaluation of the issue. The simplest possible effect is the positivity of the messages. If the messages are favorable to the argument, a positive atmosphere is produced that causes the viewers' attitudes to be more positive. However, the effect of the positivity of the messages may interact with the effects of the presence of messages: the presence of the social-media messages themselves can cause the difference.

The effect of the presence of the messages can be assumed from studies that have focused on emotional aspects of social media use. Using social media while watching television is based on a motivation to share the information and value of the content of the programs [1], and those who are exposed to social-media messages are likely to become more interested in the program and try to involve themselves more with it [2]. Based on these premises, we assume that the presence (not the content) of the social-media messages facilitate the viewers to be more engaged in considering the argument related to the topics raised on the television program. Thus, unlike the former hypothesis, we can expect that the presence of social-media messages can facilitate attitude change.

We assume that affective effects are based on the cognitive process since the attitude change in the learning results is largely based on cognitive processing and the knowledge the viewers gain from the television program. It has already been found that cognitive factors affect cognitive attitude change more than affective factors [21, 22]. Thus, we hypothesized that the key to attitude change in regard to scientific topics is the preceding fluency in the cognitive process. We also hypothesize that when social-media messages impede the cognitive processing, attitude change is unlikely to occur. On the other hand, if the social-media messages do not influence the cognitive process, this is likely to facilitate attitude change.

2.4 Aim of this study

The aim of this study is to investigate the effects of social media on the comprehension of the content of television programs. In doing so, we differentiated two aspects of comprehension: precise memory and attitude change. More specifically, we tested the following two hypotheses:

(H1) The retention of content is decreased when social-media messages are incorporated with television programs, and this effect is greater when participants pay more attention to the messages.

(H2) If the retention of content is decreased by the messages, attitude change is inhibited because the messages disturb the fluency of cognitive processing; otherwise, the peripheral route influences the motivation and increases attitude change.

3. Method

3.1 Participants

Thirty undergraduates participated in this study. The participants agreed to the terms and conditions and received a 1000 Japanese yen (approximately $9.50) cash voucher as a reward for their participation. The participants were randomly assigned to one of two conditions: the condition "with social-media messages" or the condition "without social-media messages."

3.2 Materials

3.2.1 The video contents used in this study. In order to investigate the comprehension of the television program, we needed to film a fake television program that contained a topic and story that satisfied three requirements. First, in order to measure the retention of the content, the content should be novel to all participants. Because differences in regard to the participants' previous knowledge would strongly affect the results, we controlled this factor by using a novel topic. In addition, it is important to choose a novel topic in order to motivate the participants to learn and change their attitude. Additionally, the participants may have already formed an attitude toward well-known topics that would not be changed by watching a television program. Thus, to investigate comprehension, we needed to choose lesser-known topics and a new story.

The second requirement is that the topic be relevant to the lives of the participants, but not in a very strong way. In this way, we could exclude the possibility of large discrepancies of motivation.

Finally, the program should not suggest conclusions that are so strong that it would restrict variation in the participants' attitudes after watching the program.

For a topic that satisfied the above-mentioned requirements, we chose "the effectiveness of Effective Microorganisms (EM) on water quality." EM is a kind of pseudoscience that claims that approximately 80 different microorganisms help to decompose organic matter so that it re-enters a "life-promoting" process. Although it has limitations and a lack of consistent scientific research to support it, the advocates of EM claim that EM could solve virtually all environmental and health problems, including soil management, water quality, atopic dermatitis, and radiation contamination.

In the video, two scientists (who are really actors) discuss whether "EM" is effective for improving water quality. There are three cast members in the video: a talk show host, a fake scientist (Scientist A), who promotes the use of EM for improving water quality, and another fake scientist (Scientist B), who raises doubts on the effectiveness of EM. In order to create attitude change through the video, we employed a discussion style so that opposing information is presented naturally and explicitly.

The video was approximately 18 minutes long. At the beginning, Scientist A claims that the water quality of rivers should be more closely examined and she says that many rivers need to be treated with EM so that the water quality can be improved. Then, Scientist B opposes her by claiming that the evidence she has shown is unclear and too subjective. From the middle to the end of the video, they argue over whether EM would improve the water quality of rivers. The talk show ends without any conclusion and the host states that they will continue the discussion with more data in the next show.

3.2.2 Social-media messages used in this study. To test the effects of the presence of social-media messages, we developed fake messages that simulate Twitter messages. The messages consisted of text, and each message contained one to two short sentences. To insert these messages, we divided the video into five parts based on the plot: introduction, Scientist A suggesting EM positive effects, Scientist B raising questions, discussion, and closing. The introduction and closing parts were excluded from featuring fake social-media messages. One of the authors and an undergraduate developed 102 fake messages for the remaining three parts of the video. From these messages, the author selected 12 messages that were supportive of the effects of EM and another 12 messages that were opposed it. These supportive/opposite messages were designed to be inserted into the video immediately after a clear positive/negative argument was made by one of the cast members. The rest of the messages (the neutral ones) were inserted approximately five seconds after the related topic or incident came up. As a result of this manipulation plan, 42 neutral messages were selected and inserted into the video. For the version of the video that included social-media messages, these messages were placed at the bottom of the screen (Figure 1).

We conducted a manipulation check to confirm that the three categories of social-media messages were perceived as intended, using the ratings of 10 undergraduates who did not participate in the main experiment. The participants were asked to evaluate each of the 66 messages (12 supportive, 12 opposite, 42 neutral) using a 5-point Likert scale (1: very

Figure 1. The video material used for the condition that included social-media messages.

favorable message to EM - 5: very unfavorable message to EM) after they had watched the video in which these messages were inserted. The results showed that these three categories of social-media messages were perceived differently. Messages supportive of EM were evaluated to be more favorable (M=1.92, SE=0.07) compared to messages that opposed it (M=3.93, SE=0.04) and neutral messages (M=3.01, SE=0.05). Likewise, opposing messages were evaluated to be more unfavorable than supportive and neutral messages. In addition, the small standard errors suggested that the ratings were consistent amongst the raters. These results assured us that the manipulation of social-media messages was conducted successfully with the different types of messages incorporated, and provided an overall neutral evaluation of EM.

3.3 Questionnaire

Two questionnaires were developed to measure the participants' comprehension of the topic discussed in the video: the effectiveness of EM. The first questionnaire, a pretest questionnaire, was administered before the participants watched the television show. The main purpose of the pretest questionnaire was to measure participants' attitude toward EM before they learned about it. The attitude toward EM was measured using two subscales: positive (e.g., "I think EM does something good for water quality") and skeptical ("I think the effects of EM should be tested further"). Each subscale consisted of three items that were tested using a 5-point Likert scale. The questionnaire also included a critical-thinking disposition scale (Hirayama & Kusumi, 2004), but this is not discussed in this study. Additionally, the questionnaire included questions on age, gender, and experience learning related subjects (such as biology).

The second questionnaire, a posttest questionnaire, was administered after the participants had watched the video of the television show. The posttest questionnaire included a retention test. The retention test consisted of six test items that inquired about facts provided in the video, such as "what was the job of Scientist A?" and "what example did Scientist B show to highlight the problem with EM?" The attitude toward EM was also measured using the same scale used in the pretest questionnaire. The posttest questionnaire also included items for the participants who watched the video that featured social-media messages. Using an 11-point Likert scale, this question asked the participants to self-assess how much of their attention was attracted to the messages (attention assessment). The other question, also using an 11-point Likert scale, asked how much the participants used the messages as a reference (reference assessment). With the reference assessment question, the authors intended to ask if the participants intentionally considered the social-media messages as the information for learning. In addition, an item was included that asked the participants to judge if the messages supported EM (supportiveness judgment). We also included a practical problem, but this is not analyzed in this study.

3.4 Apparatus

The video size was 1280x720 pixels. Eye tracking was performed using the Tobii X2-60 eye tracker and this was paired with a 24" LCD monitor that was set at a resolution of 1280x1024. The eye tracker sampled the position of the users' eyes at a rate of 60 Hz and with an accuracy of 0.4°. Gaze data was logged by Tobii Studio. We performed a 9-point calibration for each participant before he/she watched the video. The area of interest was set to the screen area where the fake social-media messages were presented in order to measure eye-fixation duration on the messages.

3.5 Procedures

Each participant was tested individually in an experiment room at Taisho University. Each session lasted approximately 45 minutes, including instruction and calibration of the equipment. Before beginning any measurement, the experimenter explained the terms and conditions. After participants signed a consent form, the experimenter asked the participants to answer the pretest questionnaire. Afterwards, the experimenter demonstrated the apparatus to measure eye fixation, and participants were told to maintain their head position as stable as possible. After the participant was comfortably seated, the experimenter began calibration. Each participant was instructed to fixate on a red circle that appeared and moved to different areas of the screen. After completing the calibration, the experimenter instructed the participant to watch the television show and learn from it. The experimenter reminded them to maintain their head position but, otherwise, to relax and enjoy the content. The participants were randomly assigned to a video with or without social-media messages. No instruction regarding the social-media messages was given, so the participants were not aware of the difference between the conditions. After finishing the video, the participants answered the posttest questionnaire. There was no time limit for answering the questionnaire but the participants finished within 10–15 minutes.

4. Scoring

The data of two participants were excluded from the scoring and the following analysis because, in their cases, more than three items were not answered in the pretest or posttest questionnaire.

4.1 Questionnaire

We calculated the average scores of the subscales of attitude towards EM, positive and skeptical, and used them in further analysis. The attitude change scores were calculated for both subscales by subtracting the pretest score from the posttest score.

4.2 Retention test

The retention test included in the posttest questionnaire was scored by two raters: one of the authors and one undergraduate who was unaware of the condition each participant was assigned to. The total number of correct answers was defined as the retention test score for each participant.

4.3 Eye-fixation duration

Eye movement was measured in both conditions. The data were parsed using Tobii Studio's standard fixation filter with a velocity threshold of 35 pixels and a distance threshold of 35 pixels. The participants of the condition without messages looked at the area of interest very little since, in that condition, there was nothing to see there. Thus, it was impossible to measure the fixation duration of this area for these participants. We hereafter report the eye-fixation duration of the participants from the condition that included social-media messages.

We excluded two participants from the data because of low tracking rate (less than 60%). The eye-fixation durations of the participants of the social-media message condition were measured separately for messages supporting EM, opposing EM, and neutral messages. Each duration of these three types of social-media messages was highly correlated with the others (r=.915, .799, and .727 for supportive-opposite, supportive-neutral, and opposite-neutral, respectively). Thus, the total time of eye-fixation duration on social-media messages was used for the subsequent analysis. The average time of eye-fixation duration on social-media messages was 187.233 sec. (SD=64.389).To consider individual differences in attention paid to the social-media messages, the participants of the condition with social-media messages were divided into two groups based on the total time of eye fixation on social-media messages. The participants whose fixation duration was longer than the average were categorized into the "long fixation group" (n=6), and those with shorter fixation duration were categorized into the "short fixation group" (n=6).

5. Results

The average age (M=19.00, 18.85, in the condition with social-media messages and in the condition without social-media messages, respectively) and gender (six females in both conditions) did not differ significantly between conditions. Experience in learning related subjects was also similar between the conditions. A total of 23 participants (14 in the without-message condition and nine in the with-message condition) reported experience in learning basic biology from the high school curriculum. Only two participants, one in each condition, reported experience of learning animal ecology in university.

5.1 The effects of social-media messages on the retention test

We compared the average scores of three different groups: The without social-media message group, the long fixation group, and the short fixation group. An ANOVA with one between-subjects variable was conducted on the test score (Figure 2).

The result showed that the test score differed significantly (p<.01, Cohen's d=1.669) between the short fixation group (M=5.200, SE=0.476) and the long fixation group (M=3.333, SE=0.435). There was a marginally significant difference (p=.076, Cohen's d=-.935) between the long fixation group and the without social-media message group (M=4.154, SE=0.295).

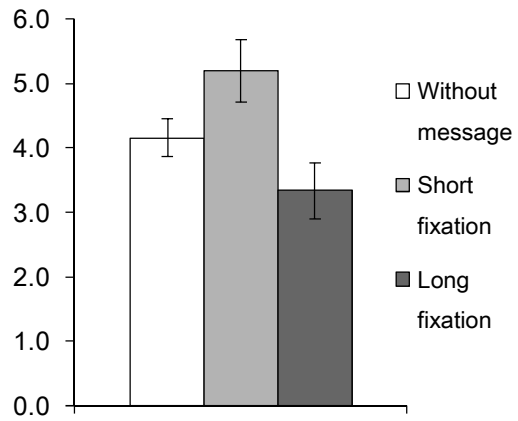

Figure 2. Test scores for each experimental group

Error bars indicate the standard error of the mean.

However, the difference between the short fixation and without social-media message groups was not significant (p=.134, Cohen's d=.734).

The correlation between retention test and attention assessment was significant (r=-.549) while the correlation between retention test and reference assessment did not reach a significant level (r=.085).

5.2 The effects of social-media messages on attitude change

Mixed ANOVAs were conducted on two subscales of attitude toward EM, with test time (pretest score and posttest score) as a within-subject variable and experimental group as a between-subjects variable (Figure 3, Figure 4).

The results showed that test time had a significant effect for both positive ($F(1,21)=6.323$, $p<.05$, partial $\eta 2=.231$), and skeptical attitudes ($F(1,21)=25.996$, $p<.001$, partial $\eta 2=.553$). Positive attitude decreased while skeptical attitude increased after watching the video. The main effects of the experimental group ($F(2,21)=0.457$ for positive attitude, $F(2,21)=1.28$ for skeptical attitude) and interaction effects of the experimental group and test time ($F(2,21)=0.147$, partial $\eta 2=.042$ for positive attitude, $F(2,21)=1.255$, partial $\eta 2=.109$ for skeptical attitude) did not reach a significant level.

For further investigation, the correlation between the participants' self-assessment scales and attitude-change score were calculated (Table 1). The results showed that there were marginally significant correlations between the attention assessment and skeptical attitude change and the reference assessment and positive attitude change.

These results indicate that the participants who realized they were paying attention to the messages tended to increase their skeptical attitude while the participants who thought they were using the messages as references increased their positive attitude.

6. Discussion

The purpose of this study was to investigate the effects of social-media messages on the comprehension of scientific discussions on television.

Our results revealed the difference between the participants who paid a lot of attention and those who paid less attention to the social-media messages. The correlation between the retention test and attention assessment score also indicated that paying attention to the accompanying irrelevant information would hinder the viewers' learning.

On the other hand, the results were unclear regarding the effects of the messages on changes in

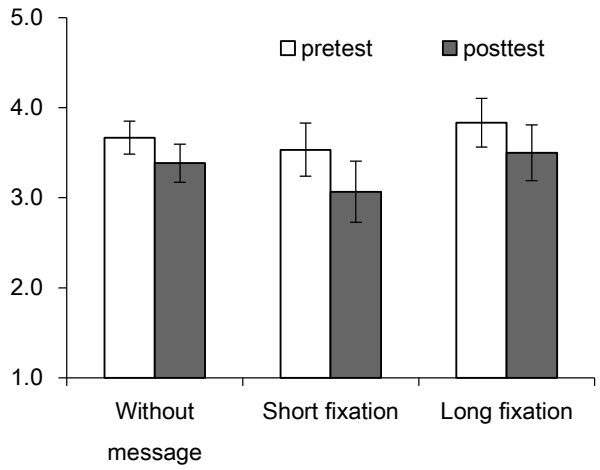

Figure 3. Positive attitude change for each experimental group

Error bars indicate the standard error of the mean.

Figure 4. Skeptical attitude change for each experimental group

Error bars indicate the standard error of the mean.

Table 1. Correlation between self-assessment scales and attitude change score

	Skeptical attitude change	Positive attitude change
Attention assessment	.462 +	.092
Reference assessment	.340	.517 +
Positivity judgment	-.399	.325

positive or skeptical attitude towards EM. Although the attitudes of the participants changed significantly after watching the scientific discussion (they became less positive and more skeptical of EM), there seemed to be no clear difference between experimental conditions.

It is important to note that the eye-tracking technique enabled us to obtain the above results. The self-assessment of the attention was moderately correlated to the eye-fixation duration, but it seems that it was difficult for the participants to fully realize how much attention they paid to certain information in the video.

6.1 The effects of social-media messages on comprehension

As we hypothesized, paying attention to the social-media messages decreased retention of the content of the television program. The process of the effects can be interpreted in terms of the split-attention effect [3, 5]. Since the social-media messages presented in this study were not always consistent and included various kinds of content, they demanded an extra cognitive load of the participants.

The results of this study conformed with the coherence principle of multimedia learning: people learn better from multimedia material when extraneous information is excluded rather than included [3]. Previous multimedia research has mainly focused on the contingency and information overlap between animation and text (or narration) [5, 8] or irrelevant interesting pictures [6] and animation [7]. Along with these studies, the present study expanded the findings to commonly watched materials: television programs. Although the video material we used in this study contained variable factors that were irrelevant to the topic, such as the facial expressions of the cast, adding social-media messages seemed to cause a split attention effect.

The results also suggested that this undesirable effect can be suppressed if the viewers control their attention. The participants who paid less attention seemed not to suffer from extra cognitive load. Thus, if viewers can learn a strategy to avoid paying too much attention to social-media messages, they will not be forced to sacrifice their comprehension. Strategies for learning from television programs should include how to cope with social-media messages.

Learning involves active processing [3, 23]. Active processing includes strategies, knowledge, and skills for "orchestrating one's knowledge to achieve a goal [3]." Some studies suggested that students use various strategies to learn from animation [24], and these strategies are effective for retention and deeper learning [24, 25]. On the other hand, while the results of the present study suggested that control of one's attention would be one of the strategies needed to learn from video materials, it seems that insufficient study has been conducted in this regard and on investigating strategies for learning from multimedia materials. We should learn more about learning from video materials and text combined with text.

We should note that the results were less clear when we compared them with the results of the participants who did not receive social-media messages. Although the effect size was large, the difference between the no-social-media-message group and long-fixation group was only marginally significant. In addition, the effect size of the difference between the no-social-media-message group and short fixation was relatively large but not significant. Since the study was conducted with a small number of participants, we need to conduct the experiment with a larger population to discuss the effects of social-media message presentation in more detail.

On the aspect of attitude change, we hypothesized that the fluency of information processing would be inhibited by the social-media messages, and this would cause an inhibition of attitude change. Although the result of the retention test suggested fluency of processing differed among the experimental groups, there was no clear difference in attitude change. Furthermore, in the analysis of changes in skeptical attitude, the simple main effects of test time were significant in the long-fixation group and the group without social-media messages. It seems that there was a larger change in skeptical attitude in the participant group who paid more attention to the messages and were not exposed to social media.

To untangle the results, we should reconsider our hypothesis. We assumed that the effects of cognitive overload was the primary factor and the motivative factor was the secondary factor. However, the results might suggest that these two factors concurrently affect information processing. The cognitive overload or the split-attention create less fluency in cognitive processing and, as a result, inhibit attitude change. In the meantime, the encouraging atmosphere facilitates attitude change. As the effects of these different factors cancel each other out, the results seem to be unchanged. The magnitude of attitude change may be determined by the relative strength of these factors.

In addition, the relationship between using social-media messages as a reference and the attitude change implies that the viewers' belief in the effectiveness of social media influences the results, and strategic use of social media may affect the process of attitude change. It is likely that viewers who believe that social-media messages are an important source may analyze the message contents more seriously. Thus, even when the

same amount of attention is paid, viewers that regard the social-media messages as a reference can be affected by them. Blankenship & Wegener [26] discussed that recognition of the importance of the information creates attitudes that resist later persuasion. As items that are valued as important motivate processing, the information that viewers regard as important is more effective in attitude change. The effects of personal beliefs and recognition of the importance of social-media messages were not focused on in the present study, but the results suggest the possibility that they are significant.

From the results of attitude change, we speculate that the effects of the social-media messages used in real television programs may be weak compared to the content itself. Despite the fact that the sample size of the present study was small, the effect size of test time was relatively large. However, it must be noted that the present study investigated the presence effect of social-media messages. Changes in the quality of the messages can yield different results. This possibility is discussed in next section in more detail.

6.2 Limitations and future directions

The present research suggested that there are undesirable effects relating to exposure to social-media messages in regard to the comprehension of scientific discussions on television. The results raise an alert concerning the unregulated use of social-media messages in mass media. However, there are some limitations that require future research.

First, in order to validate the results of the present study, we need to conduct the experiment with a larger number of participants.

Secondly, we should investigate the other aspects of social-media messages. We investigated the effects of the presence of social-media messages by making the fake messages neutral and varied. The results of the present study suggested the effects of the presence of social-media messages were relatively weak, especially in regard to attitude change. The next step should be to investigate the effects of biased social-media messages and interacting aspects. As we discussed, the effects of social-media messages may be caused not only by attention split. The quality of the messages may directly affect the attitude. Further, as we mentioned the encouraging atmospheres created by the social-media messages, individuals posting their own messages may facilitate attitude change.

In future investigations, it is also important to consider individual differences between participants. Among the various factors, beliefs toward social media and critical-thinking skills seem to be highly relevant. Feuerstein [27] highlighted that critical thinking is an important part of media literacy. We can assume individual differences in participants' media literacy and the belief of social media. Some regard social media as a useful source of information while others do not. These beliefs may influence the process of understanding television content that includes social-media messages.

Finally, by revealing the influence of social media incorporated with mass media in more detail, we would be able to develop a media environment designed to facilitate viewers' comprehension. Studies of educational investigations on critical thinking suggest that communicating with others, such as discussing a topic with classmates, facilitates factors important to the critical-thinking process [28, 29]. Thus, if social-media messages could play the role of a classroom discussion, it is possible to facilitate viewers' critical-thinking processes through these messages.

7. Concluding remarks

The present study implied the undesirable effects of mass media that incorporate social media: split-attention caused by the presence of social-media messages decreases retention of content. These results can contribute to a redesign of television programs, especially those that concern education or any other programs that concern important issues. Incorporating social-media messages should be considered carefully in order to not inhibit viewers' comprehension. Meanwhile, at present, social-media messages continue spreading without principles concerning their effective use. More research is required to unveil and discuss the effects of social-media messages on our comprehension, and to develop strategies for utilizing them to better our lives.

8. Acknowledgment

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