# An Evaluation of the Modality Effect:

# The Impact of Presentation Style and Pacing on Learning, Mental Effort, and Self-Efficacy

by

Tyler Krause

A Thesis Presented in Partial Fulfillment
of the Requirements for the Degree
Master of Science

Approved July 2018 by the
Graduate Supervisory Committee:

Scotty D. Craig, Chair
Robert Gray
Russell Branaghan

ARIZONA STATE UNIVERSITY

August 2018

ABSTRACT

The current study investigated how multimedia pacing (learner-control versus system-paced) and presentation styles (visual-only versus audio/visual) impact learning physics concept material, mental effort, and self-efficacy. This 2X2 factorial study randomly assigned participants into one of four conditions that manipulated presentation style (visual-only versus audio/visual) and pacing of the content (system-paced versus learning-controlled). Participant's learning was measured by recording their retention of information and ability to transfer information. Measures of perceived difficulty (mental effort) and perceived ability (self-efficacy) were also obtained. No significant effects were observed in this study which does not support the existence of either the modality or reverse modality effect at least in these noisier online learning environments. In addition, the hypothesis that their effects could be an artifact of experimental design could not be proven as the learner control condition did not yield any significant results.

TABLE OF CONTENTS

## LIST OF TABLES

# INTRODUCTION

Online education has become far more accessible in recent years allowing individuals to take courses that would otherwise be too difficult to enroll in. There are estimated to be 5,750,417 students enrolled in distance education courses (NCES, 2017). These 5.8 million students account for 28% of the current student population and are part of a growth trend of online learning which has continued for the last 13 years in the United States (Allen & Seaman, 2016). During the transition to this new medium, instructors often create their own instructional videos (Herreid & Schiller, 2013). While there is a sound research on the design of instructional multimedia in general (Mayer, 2017), little guidance exists that specifically addresses how instructional videos should be designed (Schroeder & Craig, 2017).

Multimedia tools allow time and location flexibility with an applicability in both higher and lower education. Multimedia education can involve the use of full-motion video, audio, animation, or CD-ROMS to create an integrated package for educational use (Yadav, 2006). Multimedia learning can occur when learners receive information presented in more than one mode (Mayer, 1997). With such a large form of mediums and audiences it is important to study specific implementations and how they impact the effectiveness of learning. Currently, there are competing theories of optimal delivery for multimedia education with regard to learning and effort. This study aims to clarify those competing theories and offer an alternative implementation while accounting for participants mental effort and self-efficacy.

# LITERATURE REVIEW

## Cognitive Load Theory

Cognitive load is described by the mental effort required to perform a task and often associated with the limitations of an individual's working memory capacity (Clark, Nguyen, & Sweller, 2006). The limitations of our working memory creates the need to refine the efficiency of tasks, specifically in regard to learning and education. Cognitive load is a multidimensional concept with two components, mental load and mental effort. Mental load is influenced by instructional paramaters such as task structure or the sequence of presented information. Mental effort is the amount of capacity devoted to the instructional demands (Pass, 1992).

Cognitive load theory (CLT) is a universal set of learning principles proven to result in efficent instructional environments. CLT defines cognitive load in to three types: extraneous, intrinsic, and germane. Extraneous, or irrelevant, load imposes mental work that is irrelevant to the learning goal and is usually the result of poorly designed instruction. Intrinsic load is determined by the interaction between the instructional objective and the expertise of the learner in that knowledge or skill. A large factor in intrinsic load is a task's element interactivity, or the amount of knowledge or skills an individual has to coordinate to complete the task. Germane, or relevant, load directly contributes to learning. It is the mental work imposed by instructional activities that benefit the instructional goal (Clark, Nguyen, & Sweller, 2006; van Merrienboer, Kester, & Paas, 2006). When an individual is attempting to complete a complex task, reducing extraneous load improves the efficiency of the learning. However, there are several factors to consider when trying to increase the efficiency of a learning system.

**Reducing Cognitive Load in Multimedia Learning and the Modality Effect**

An effective learning system induces a participant's germane load with methods like feedback and guidance provided during the task (van Merrienboer, Kester, & Paas, 2006). However, the type of feedback required changes based on the nature of the task or who is performing it. For example, performance during simple tasks is increased by extensive guidance, but learners performed better in post-task assessments when they received minimal guidance. In situations with a high intrinsic load, or non-expert learners, immediate feedback is most effective for teaching complex tasks (van Merrienboer, Kester, & Paas, 2006). In Krigolson, Heinekey, Kent and Handy (2012) underlying neurological symptoms indicated that complex tasks requiring a high cognitive load reduced the participants ability to make behavioral adjustments following error feedback. Participants that were already experts in the assigned task were the exception to this finding. Otherwise, for complex tasks, concise and immediate feedback is necessary to maximize germane load.

An increasingly popular medium for teaching is multimedia learning. Multimedia learning is learning from words and pictures that are intended to foster learning (Mayer & Moreno, 2003). This can include the use of on screen text or narration in combination with static or dynamic images to teach a specific concept or task. As previously discussed, learning is a nuanced activity that depends on a number of contextual factors, so it is important that teaching methods such as multimedia learning promotes meaningful learning. Meaningful learning is described as a deep understanding of the material, ability to apply what was taught to new situations, and construction of a mental model of how the causal system works (Mayer & Moreno, 2003). The key is to get learners to engage in substantial cognitive processes without causing cognitive overload.

Mayer and Moreno's 2003 paper suggests nine ways to reduce cognitive load in multimedia learning often by reducing incidental processing. These are cognitive processes that are not necessary for making sense of the material, but included in the learning task. Learner's can quickly be overwhelmed by information and suffer from cognitive overload. Designers have to consider pacing of the material being taught. Allowing time between portions of a presentation, or segmenting, and introducing the learners to the conceptual foundation of the material before the lesson can help lighten their cognitive load. Both Mayer and Sweller agree reducing extraneous load helps with learning (Clark, Nguyen, & Sweller, 2006; Mayer & Moreno, 2003). Mayer and Moreno's call this method of reducing extraneous load weeding. When it is not possible to remove all embellishments signally important information to the learner by stressing key words in speeach, using arrows, adding outlines, or headings is a viable approach.

Multimedia learning is most effective when it avoids presenting the material in a confusing way. Aligned words and pictures can be a simple way to reduce incidental processing. There is a spatial contiguity effect that indicates students better understand multimedia presentations when printed words are presented in a closer proximity to the corresponding pictures or animations (Mayer & Moreno, 2003). Another option is to present similar information, or information that references each other, and synchronize relevant material to a single segment. However, presenting identitical material concurrently creates redundancy in the lesson. The key to an efficient multimedia learning platform is to present relevant information in a non-redundant, concise, and meaningful way.

Perhaps the most replicated finding was that on-screen text appearing while an informative animation is happening splits the user’s attention. Instead, it would be more effective to use Mayer’s off-loading method to divide the information across senses, having the text appear as narration so that the learner can divert more visual resources to the animation. This was coined as the modality effect. Mayer and his collaborators have conducted numerous studies that demonstrate the superiority of narrated explanations (Mayer & Moreno, 1998, 2003; Moreno & Mayer, 1999).

These techniques all indicate that learning needs to consider contextual and specific applications of feedback and presentation. Careful considerations need to be taken in regard to the task or subject being taught. In cases of minimal guidance or discovery based learning research suggests, almost uniformly, that strong instructional guidance is more effective than constructivist based minimal guidance during the instruction of novice to intermediate learners  (Kirschner, Sweller, & Clark, 2006).

**The Reverse Modality Effect**

In several studies, an interesting finding known as the reverse modality effect has been found (Kalyuga, 2012). In one study, participants actually scored higher in retention and transfer after learning the material through a visual only exposure in contrast to a split narration and visual condition (Tabbers, Martens, & van Merrienboer, 2004). It is suggested that the length of learning exposure impacts the effectiveness of the modality effect, alluding this effect only applies to shorter content that is low in element interactivity. Instead, if the material is presented in text instead of narration, learners can quickly scan it, re-read it while integrating it with the visual diagram, then continue on to the next statement. This segmented integration with a textual reference may be necessary with working memory limitations and may be the cause of this reverse modality effect (Leahy & Sweller, 2011). This confirmed the existence of a reverse modality effect some researchers were finding. For example, Witteman and Segers (2010) found a reverse modality effect using materials explaing the structure of the human eye. They noticed improved scores on a retention test from those in the text condition as well in transfer questions given a day later.

**Self-Efficacy in Learning**

Self-efficacy is the conviction that one can successfully execute the behavior required to produce the intended outcome (Badura, 1977). Expectations of efficacy affect both initiation and persistence of coping behavior. For example, people tend to avoid situations that exceed their coping skills. However, they get involved in activities and are more assured when they judge themselves capable of handling situations that would otherwise be intimidating (Badura, 1977). Bandura believed that expectations of personal efficacy are derived from 4 main principles; performance accomplishments, vicarious experience, verbal persuasion, and psychological state (Badura, 1977). Knowledge, skill, and prior accomplishments are poor predictors of future accomplishments because the beliefs individuals hold about their abilities and about the outcome of their efforts powerfully influence the ways in which they will behave (Pajares, 1996). Efficacy expectations can be such a powerful predictor for proficiency in a certain skill because of how self-efficacy affects motivation. Efficacy expectations determine how much effort individuals will expend and how long they will endure any face-to-face obstacles and aversive experiences (Badura, 1977). Concepts of self-efficacy transfer to the educational applications of multimedia platforms (Paolacci & Chandler, 2014; Casler, Bickel, & Hackett, 2013).

Multimedia learning offers countless advantages such as being easily updated or accessible to a large number of students. Its affordances for interactivity have increased multimedia learning's use in medical learning (de Araujo Guerra Grangeia, et al., 2016). As we use multimedia learning for more complex knowledge and material, it is even more important to heed the advice of Mayer and other researchers who study cognitive load.

# HYPOTHESIS

In the 2003 article by Mayer & Moreno, they found that dual modality presentations are more effective than a purely visual presentation in reducing the learner's cognitive load. This modality effect is suspected to be less effective when more lengthy and complex material is presented. In this case, a condition with only a visual display of information would allow the learner to re-read, reference, and integrate material at their own pace (Leahy & Sweller, 2011). However, we hypothesize that these phenomena are artifacts created by experimental conditions. When learners are given control of the content, emulating what they would experience in real life learning scenarios, these effects will not be found. If Mayer's modality principle holds true, learners in the audio/visual condition will be significantly better than those in the visual only condition. If Sweller's theory holds true, participants in the visual only condition should perform better than those in the audio/visual condition because of the length and complexity of the material (Kalyuga, 2011). However, when the learner has control of the pacing of the material, there should be no significant difference in performance across the Audio/visual or visual-only conditions, which would make these competing theories an artifact of experimental design.

# METHOD

## Participants

A randomized pretest-posttest design was implemented. Participants (n=131) with a 95% or above Human Intelligence Task (HIT) approval rating and who have completed at least 50 tasks recruited through Amazon.com's Mechanical Turk (MTurk). This rating indicates the participant's ability to successfully follow directions and complete at least 95% of the previous tasks they had undertaken. This approval rate was encouraged by Paolacci and Chandler (2014) to ensure reliable data. Casler, Bickel, and Hackett (2013) performed evaluations of MTurk samples to show they have performance equivalent to lab-based participants.

Each participant was compensated with $1.00 USD for their participation in this study. They were randomly assigned to either a visual only system-paced condition (n=27), visual only learner-controlled (n=36), audio/visual system-paced (n=32), or an audio/visual learner-controlled (n=30) condition. The average age of each participant was 32.2 years and as is consistent with the MTurk population, the majority of the participants were college graduates, which is higher than the general population (Ryan & Bauman, 2016).

Six (N=6) participants were removed from the current study results. Four spent an abnormally long time in the condition as indicated by their time on task z-scores being greater than 3; two from audio/visual system-paced (3.54, 4.81), one from visual-only system-paced (5.47), and one from visual-only learner-control (5.58). Two participants were removed for receiving perfect scores on the pretest assessment giving no opportunity to measure; one from visual-only learner-control, and one from the audio/visual learner-control. A power analysis determined that at least a participant pool of (n=128) would be needed for a medium effect size (f=0.25) and a power of .8, $\alpha$=0.05.

**Design**

This study was a 2x2 factorial design. Participants were randomized into 2 different conditions (Audio/visual & visual only) by the Qualtrics survey system. The audio/visual condition emulated the modality effect with information split between audio and visual information during the teaching of complex and lengthy physics material. The visual only condition utilized strictly visual information to emulate the reverse modality effect in terms of more lengthy and complex material needing a textual reference on the screen for learner reference. Each condition had two different pacing styles the learner was randomized into (system-paced or learner-controlled). In each condition, the participant is tested on their retention of the material and perceived mental effort. Retention was measured as the ability to learn and apply the present material. Mental effort was measured to infer which teaching method was the easiest to learn from (Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

**Materials**

**Learning Content & Assessment.** The learning content consisted of physics concepts of force with regard to weight, mass, friction, and inertia. Previous studies have determined that this material is sensitive enough to detect learning (Craig, Gholson, Brittingham, Williams, & Shubeck, 2012).

**Conditions.** This experiment had 2 different conditions (Audio/Visual & Visual-only). The audio/visual condition emulated the modality effect by including audio and visual information while teaching complex and lengthy physics material. The visual only condition utilized only visual information to emulate the transient effect; that lengthy and complex material needs a textual reference on the screen. Each condition consisted of two different pacing styles the learner was randomized into (system-paced or learner-controlled). System-Paced is ideally when the learner no control of the video and they can only view it one time. The video was edited using Camtasia with the script audio file read by agents from Media Semantics. In this experiment, html coding was used to restrict the user's ability to skip material and restricted key-binding short cuts. Videos being suggested through YouTube upon video completion were also removed and the video would autoplay when the page loaded. Learner-controlled pacing is when the video, created through the same program, was embedded in the experiment as a YouTube video as well, but allowed it to be fast-forwarded, rewound, or paused as the learner desired. To control for time spend reviewing the video in the learner control condition the videos were made at different lengths. The system-paced video was 524 seconds long and the learner-control video was 425 seconds long. Those in the learner control condition were forced to stay on the page with the video until approximately the same amount of time as the system-paced video had passed, specifically 540 seconds.

**Mental Effort.** Online tools have an important impact on ideas of knowledge acquisition in cognitive load theory as they represent intelligent interactive learning modules that are flexible and responsive to the individual needs of the participant, which theoretically removes several detriments to learning and optimizes efficiency (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). This mental effort scale was originally developed by (Pass, 1992), who based it on a measure of translating perceived mental effort into a numerical value.

This was a nine-point symmetrical scale survey ranging from 1 (very, very low mental effort) to 9 (very, very high mental effort) (Paas, 1992). The reliability of the scale was estimated with Cronbach's coefficient alpha with a reliability (α) of .90 for test problems and condition independent instructional problems. The Mental Effort scale questions were used to calculate an efficiency score € for learning (training efficiency scores) and testing (Instructional Efficiency scores) for each of the four learning measures using the equation below (Pass & van Merrienboer, 1993).

$$E = (Zperformance - Zmental\ Effort) / \sqrt{2} \qquad (1)$$

**Self-Efficacy.** Each participant will complete a pre-test and post-test questionnaire to measure self-efficacy. The self-efficacy survey is based on Artino & McCoach (2008) model for self-efficacy with self-paced online training course. The wording was slightly changed to make them relevant to the material of physics. The participant answered 5 questions on a seven-point Likert scale format from 1 (Completely Disagree) to 7 (Completely Agree).

**Demographic Survey.** At the end of the study, participants were asked to complete a demographic survey asking gender, highest level of education completed, age, ethnicity, and if they had and if their previous education taught physics.

**Procedure**

Participants were recruited from Amazon's Mechanical Turk (MTurk). They were given a link to the Qualtrics survey, which will begin with a consent form. After selecting, "I agree" on the consent form, participants completed a pretest survey for self-efficacy to determine how confident they are in learning material related to physics. Afterwards, participants completed a pre-test assessment for the physics material presented. The pretest assessment was one of two possible options consisting of a 10-question multiple choice exam covering the material they learned in each condition (Appendix B). Some of the conditions involve audio stimuli so the participant had to do a sound check and enter a code given in an audio file before being assigned a condition. The participants were randomized into an audio/visual or visual-only condition. Then, within each of those two conditions, they were randomized again into a system-paced or a learner-controlled video. The system-paced video condition presented the material at a slightly slower pace than the learner-controlled condition. This was to make two conditions have a more time equivalent exposure in case participants in the learner control condition decide to go back and re-watch sections of the video. In addition, participants in the learner control condition could not continue to the next page until an equivalent amount of time to the system-paced video had passed. Participants then completed a learning mental effort questionnaire (Appendix C), followed by a self-efficacy posttest (Appendix A). Then they completed a posttest physics assessment, the 10-question assessment they didn't take as the pretest, followed by an assessment mental effort questionnaire. After completion, the participants will answer a demographic survey and be debriefed on the purpose of the study.

RESULTS

The current study is an alternative treatment with a pretest (Shadish, Cook, & Campbell, 2002) with dependent measures of learning, self-efficacy, and mental effort. There were 2 independent measures (presentation style & pacing) with 2 levels (audio/visual & visual only) and (system-paced & learner-control). We want to look at group differences and their interactions so the ANCOVA was a better method to analyze the data and is more common in the literature regarding multimedia learning. A 2x2 factorial analysis of covariance, ANCOVA, was conducted on the post-test learning assessment and self-efficacy scores with their respective pre-test scores as their covariate.

Mental effort questions were analyzed using the mental effort scale (Pass, 1992). The mental effort questions were given twice, after the multimedia learning video and after the posttest learning assessment. After being converted to their respective mental effort efficiency scores using the equation previously provided and ANOVA was used to determine significance. A Levene’s test was conducted for each analysis to verify assumptions and make sure there is equal variance.

**Learning Measures**

A 2x2 factorial ANCOVA was conducted on the student’s learning post-test scores with the pre-test scores as a covariate was used to examine the differences among the presentation style, pacing and the interaction between the two groups. There was no observed differences among presentation style ($F$ (3,121) = .93, $p$ = .34, $\eta^2_p$ = .01), pacing ($F$ (3,121) = .76, $p$ = .39, $\eta^2_p$ = .01), or the interaction between the two groups ($F$ (3,121) = 2.99, $p$ = .09, $\eta^2_p$ = .024). Means and Standard deviations for all learning measures by condition are presented in Table 1.

Table 1

*Means and standard deviations for participant's scores on the multiple-choice learning assessment.*

| Training Condition | N | Pre-Knowledge M(SD) | Post-Knowledge M(SD) |
|---|---|---|---|
| Visual-only | | | |
| System-paced | 27 | 3.15(1.35) | 4.41(2.34) |
| Learner-controlled | 36 | 4.39(2.43) | 4.47(3.03) |
| Audio/Visual | | | |
| System-paced | 32 | 3.03(2.22) | 3.34(2.51) |
| Learner-controlled | 30 | 3.13(1.74) | 3.73(2.13) |

**Cognitive Load (Mental Effort)**

Cognitive load (mental effort) efficiency scores were collected after the video lesson and after the post-test learning assessment using the mental effort scale from (Pass, 1992). An ANOVA was used to assess the participants' mental effort efficiency in relation to learning and testing. No significant differences were found in mental effort after watching the learning video among both pacing ($F$ (3,121) = .07, $p$ = .79, $\eta^2_p$ = .001), presentation style ($F$ (3,121) = .60, $p$ = .44, $\eta^2_p$ = .01), or the interaction between the two groups ($F$ (3,121) = .78, $p$ = .38, $\eta^2_p$ = .01).

No significant effect was found after the post-test assessment for either the pacing ($F$ (3,121) = .80, $p$ = .37, $\eta^2_p$ = .01) the presentation style ($F$ (3,121) = 2.33, $p$ = .13, $\eta^2_p$ = .02) condition, or the interaction between the two groups ($F$ (3,121) = 3.02, $p$ = .09, $\eta^2_p$ =

.024). Means and Standard deviations for all learning measures by condition are presented in Table 2.

Table 2

*Means and standard deviations for participant's mental effort efficiency scores.*

| Training Condition | N | Learning Efficiency M(SD) | Testing Efficiency M(SD) |
|---|---|---|---|
| Visual-only | | | |
| System-paced | 27 | .11(.82) | .24(1.01) |
| Learner-controlled | 36 | .01(1.00) | .09(1.04) |
| Audio/Visual | | | |
| System-paced | 32 | -.15(.90) | -.35(1.11) |
| Learner-controlled | 30 | .03(.70) | .13(.89) |

**Self-Efficacy**

An ANCOVA was performed on participants perceived self-efficacy scoring or how confident they were to apply material from the learning video to the real world. No significant effects were found in the pacing ($F$ (3,121) = .01, $p$ = .92, $\eta^2_p$ = .02), the presentation style ($F$ (3,121) = .59, $p$ = .44, $\eta^2_p$ = .01), or the interaction between the two groups ($F$ (3,121) = .28, $p$ = .60, $\eta^2_p$ = .002). Means and standard deviations by condition are presented in Table 3.

Table 3

*Means and standard deviations for participant's self-efficacy scores.*

| Training Condition | N | Prior Self-Efficacy M(SD) | Post Self-efficacy M(SD) |
|---|---|---|---|
| Visual-only | | | |
| System-paced | 27 | 5.11(1.17) | 5.33(.95) |
| Learner-controlled | 36 | 5.29(1.03) | 5.29(.77) |
| Audio/Visual | | | |
| System-paced | 32 | 5.41(.89) | 5.38(1.04) |
| Learner-controlled | 30 | 5.20(.76) | 5.37(.78) |

**Participant's System Usage by Condition**

Each participants' time spent on the page with the training video and the number of clicks on that page were recorded. An ANOVA was used for these two variables to help assess user engagement. No significant differences were found in time spent on task for the pacing ($F$ (3,121) = 3.47, $p$ = .07, $\eta^2_p$ = .03), the presentation style ($F$ (3,121) = .71, $p$ = .40, $\eta^2_p$ = .01), or the interaction between the two groups ($F$ (3,121) = .02, $p$ = .88, $\eta^2_p$ = .001). No significant differences were found for number of clicks in the pacing ($F$ (3,121) = 1.28, $p$ = .26, $\eta^2_p$ = .01), the presentation style ($F$ (3,121) = .91, $p$ = .34, $\eta^2_p$ = .01), or the interaction between the two groups ($F$ (3,121) = 1.93, $p$ = .17, $\eta^2_p$ = .02). Means and standard deviations by condition are presented in Table 4.

Table 4

*Means and standard deviations for participant's time on task and number of clicks.*

| Training Condition | N | Time on Task M(SD) | Number of Clicks M(SD) |
|---|---|---|---|
| Visual-only | | | |
| System-paced | 27 | 755.57(396.43) | 1.21(1.66) |
| Learner-controlled | 36 | 658.52(323.00) | 1.11(1.59) |
| Audio/Visual | | | |
| System-paced | 32 | 716.45(373.13) | 1.03(1.55) |
| Learner-controlled | 30 | 602.38(128.82) | 2.10(3.59) |

# DISCUSSION

This study found no significant differences in the system-paced vs learner-controlled and the visual-only vs audio/visual conditions. There were two mental effort measures taken at two points in the study; after the video and after the post-test learning assessment. A self-efficacy survey was given prior to the pre-test and post-test. None of these were found to be significant among groups.

The current study aimed to clarify the presences of two previously established competing theories about how best to increase learning and reduce cognitive load in multimedia educational material. It also explored providing conditions to mimic access of information as individuals would experience it in real life, learner-control, to see if these effects were artifacts created by experimental design.

This study predicted that if Mayer's theory on the modality effect held true then there would be an increase in learning and decrease in mental effort in the audio/visual conditions when compared to the visual only conditions. If reverse modality effect held true then we would expect to have seen an increase in learning and a decrease in mental effort in the visual only condition (Leahy & Sweller, 2011).

## Limitations

Measures taken of participants' pre-existing knowledge of physics concepts material showed that some participants received a perfect 10/10 score on the pre-test assessment. This created a ceiling effect that required removing that participants data. Additionally, over half of the participants had previous lessons in physics concept material, which is higher than what we would expect to see if we ran the experiment on undergraduate college students (White & Tesfaye, 2014). The overall mean and standard deviation of the pretest scores before exclusions of perfect scores was 3.52(2.20) and after exclusion they became 3.42(2.07). Due to this minimal difference, especially when broken down by means and standard deviations of individual conditions, it is unlikely these ceiling effects had a significant effect on the overall results

Taking into account exclusions this experiment collected data from 125 participants. The power analysis determined that 128 participants would be required for a medium effect size (f = .25). However, only missing three participants from the desired sample size is unlikely to have a significant impact since the effect sizes in the conditions were already very low with the highest being mental effort in presentation styles (f = .02).

Another explanation for the null finding in the pacing conditions is a failure of treatment implementation. While the current data set does not allow for review of Participant's specific actions, the system was able to record the number of clicks that participants made during interactions. As can be seen from Table 4, the mean number of interactions recorded for all conditions were around 1 or 2. Such a small mean number of clicks indicate that participants implemented very limited user controls with most performing one click to continue after the video. Thus, it might not be surprising that there was not an effect for pacing effect or an observed interaction in the data. However, there is the possibility that the participants used key binding shortcuts as a user control in the video. This is unlikely since click to skip is the more standard method of video manipulation.

## Conclusion

The current study attempted to evaluate established multimedia principles with consideration for the modality effect. Four conditions were created to clarify the presences of two previously established competing theories about how best to increase learning and decrease cognitive load in multimedia educational material. This experiment did not support the existence the modality effect as the audio/visual condition did not outperform the visual only condition (Mayer & Moreno, 2003). However, most implementations of the learning material were delivered in a controlled lab setting, to undergraduate students, and the learning material was relatively short (2-4 minutes) (Mayer, 2009). Given these differences we did not expect to find the modality effect. In contrast, while no significance was found our results more closely supported the reverse modality effect. This effect has been found with younger year 6 students approximately 11-12 years in age, but also in noisier classroom settings with more complex material (Leahy & Sweller, 2011). By extension the hypothesis that both effects exist because of commonly used system-paced format for the learning material in previous experimental designs could not be proven. None of the four conditions were found to be significantly more effective for learning, require less mental effort, or lead to an increase in self-efficacy.

For the current study, neither of the modality effects held within this online setting covering physics content. The current study did not find evidence for either effect. While additional research is needed, it is possible that the modality effect does not have the fidelity to translate to noisier online learning settings, but instead only appear during highly controlled lab studies. It is also possible that the reverse modality effect needs even more complex material for the higher performing MTurk population in comparison to younger students. If the current patters continue to be observed outside of controlled laboratory settings, it is possible that modality of presentation is not an issue that instructional designers or instructors need to consider for building online learning environments. Thus, freeing them to use the medium that is more convenient or appropriate for their current content. Regardless, these effects still need to be disambiguate and we recommend more research to provide succinct details on how to instructionally design multimedia educational videos in the hopes to clarify the degree of difficulty, complexity, length of material, or other factors that may be responsible for these two effects.

# REFERENCES

Allen, I. E., & Seaman, J. (2016). Online Report Card: Tracking Online Education in the United States. Babson Survey Research Group.

Artino, A., & McCoach, B. (2008). Development and Initial Vaalidation of the Online Value and Self-Efficacy Scale. The Journal of Educational Computing Research, 38(3), 279-303.

Badura, A. (1977). Self-efficacy: Toward a Unifying Theory of Behavioral Change. Psychological Review, 84(2), 191-215.

Casler, K., Bickel, L., & Hackett, E. (2013). Seperate but Equal? A Comparison of Participants and Data Gathered via Amazon's MTurk, Social Media, and Face-to-Face Behavioral Testing. Computers in Human Behavior, 29(6), 2156-2160.

Clark, R., Nguyen, F., & Sweller, J. (2006). Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load. Pfeiffer. Retrieved January 24, 2018, from <http://www.myilibrary.com.ezproxy1.lib.asu.edu?ID=44866>

Craig, S. D., Gholson, B., Brittingham, J. K., Williams, J. L., & Shubeck, K. T. (2012). Promoting Vicarious Learning of Physics Using Deep Questions with Explanations. Computers & Education, 58, 1042-1048.

de Araujo Guerra Grangeia, T., de Jorge, B., Franci, D., Martins, S. T., Silvia Vellutini Setubal, M., Schweller, M., & Antonio de Carvalho-Filho, M. (2016). Cognitive Load and Self-Determination Theoris Applied to E-Learning: Impact on Student's Participation and Academic Performance. PLoS ONE. Retrieved January 29, 2018, from http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0152462

Herreid, C., & Schiller, N. (2013). Case Studies and the Flipped Classroom. Journal of College Science Teaching, 42(5), 62-66.

Kalyuga, S. (2011). Effects of Information Transiency in Multimedia Learning. Social and behavioral Sciences, 30, 307-311.

Kalyuga, S. (2012). Instructional Benefits of Spoken Words: A review of Cognitive Load Factors. Educational Research Review, 7, 145-159.

Kirschner, P., Sweller, J., & Clark, R. (2006). Why Minimal Guidance During Instruction Does Not Work: An Analysis of the Failure of Constructivist, Discovery, Problem-Based, Experiential, and Inquiry-Based Teaching. Educational Psychologist, 41(2), 75-86.

Krigolson, O., Heinekey, H., Kent, C., & Handy, T. (2012). Cognitive Load Impacts Error Evaluation Within Medial-Frontal Cortex. Brain Research, 1430, 62-67.

Leahy, W., & Sweller, J. (2011). Cognitive Load Theory, Modality of Presentation and the Transient Information Effect. Applied Cognitive Psychology. doi:10.1002/acp.1787

Mayer, R. (1997). Multimedia Learning: Are We Asking the Right Questions? Educational Psychologist, 32(1), 1-19.

Mayer, R., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. Journal of Educational Psychology, 73, 187-198.

Mayer, R., & Moreno, R. (2003). Nine Ways to Reduce Cognitive Load in Multimedia Learning. Educational Psychologist, 38, 43-52.

Mayer, R. (2009) Multimedia Learning (2nd ed.). New York, NY, US: Cambridge University Press.

Mayer, R. (2017) Using multimedia for e-learning. Journal of Computer Assisted Learning, 33, 403-423

Mestre, J., & Brian, R. (2011). Cognition in Education: The Psychology of Learning and Motivation. Academic Press. Retrieved January 24, 2018, from <http://www.myilibrary.com.ezproxy1.lib.asu.edu?ID=320957>

Moreno, R., & Mayer, R. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. Kournal of Educational Psychology, 91, 358-368.

National Center for Educational Statisitics (NECR). (2017). Distance Learning Fast Facts. Retrieved from https://nces.ed.gov/fastfacts/display.asp?id=80

Paas, F., Tuovinen, J., Tabbers, H., & Van Gerven, P. (2003). Cognitive Load Measurement as a Means to Advance Cognitive Load Theory. Educational Psychologist, 38(1), 63-71.

Pajares, F. (1996). Self-Efficacy Beliefs in Academic Settings. Review of Educational Research, 66(4), 543-578.

Paolacci, G., & Chandler, J. (2014). Inside the Turk: Understanding Mechanical Turk as a Participant Pool. Current Directions in Psychological Science, 23(3), 184-188.

Pass, F. (1992). Training Strategies for Attaining Transfer of Problem-Solving Skills in Statistics: A Cognitive Load Approach. Journal of Educational Psychology, 84(4), 429-434.

Pass, F., & van Merrienboer, J. (1993). The Efficiency of Instructional Conditions: An Approach to Combine Mental Effort and Performance Measures. Human Factors, 35(4), 737-743.

Paas, F., Tuovinen, J., Tabbers, Huib., & van Gerven, P. (2003). Cognitive Load Measurement as a Means to Advance Cognitive Load Theory. Educational Psychologist. 38(1), 63-71.

Ryan, C., & Bauman, K. (2016). Educational attainment in the United States: 2015. Retrieved July 1, 2018, from https://www.census.gov/content/dam/Census/library/publications/2016/demo/p20-578.pdf

Schroeder, N., & Craig, S. D. (2017). The Effect of Pacing on Learners' Perceptions of Pedagogical Agents. Journal of Educational Learning, 0, 1-14.

Shadish, W., Cook, T., & Campbell, D. (2002). Experimental and Quasi-Experimental Designs for Generalized Causal Inference. Wadsworth: Cengage Learning.

Tabbers, H., Martens, R., & van Merrienboer, J. (2004). Multimedia Instruction and Cognitive Load Theory: Effects of Modality and cueing. British Journal of Educational Psychology, 74(1), 71-81.

van Merrienboer, J., Kester, L., & Paas, F. (2006). Teaching Complex Rather Than Simple Tasks: Balancing Intrinsic and Germane Load to Enhance Transfer of Learning. Applied Cognitive Psychology, 20(3), 343-352.

White, S., & Tesfaye, C. (2014). High School Physics Courses & Enrollments: Results from the 2012-13 Nationwide Survey of High School Physics Teachers. College Park: AIP Statistical Research Center. Retrieved June 11, 2018, from https://www.aip.org/sites/default/files/statistics/highschool/hs-courses-enroll-13.pdf

Witteman, M., & Segers, E. (2010). The modality effect tested in children in a user-paced multimedia environment. Journal of Computer Assisted Learning, 38, 87-107.

Yadav, V. (2006). Using Multimedia in Education. Pragun Publications.

# APPENDIX A

# SELF-EFFICACY SURVEY

Even in the face of technical difficulties, I am certain I can learn the physics material presented.

- Completely Disagree (1)
- Disagree (2)
- Somewhat Disagree (3)
- Neither Agree Nor Disagree (4)
- Somewhat Agree (5)
- Agree (6)
- Completely Agree (7)

I am confident I can learn physics material without the presence of a human instructor to assist me.

- Completely Disagree (1)
- Disagree (2)
- Somewhat Disagree (3)
- Neither Agree nor Disagree (4)
- Somewhat Agree (5)
- Agree (6)
- Completely Agree (7)

I am confident I can do an outstanding job on activities applying physic materials presented.

- Completely Disagree (1)
- Disagree (2)
- Somewhat Disagree (3)
- Neither Agree nor Disagree (4)
- Somewhat Agree (5)
- Agree (6)
- Completely Agree (7)

I am certain I can understand the most difficult physics material presented.

- Completely Disagree (1)
- Disagree (2)
- Somewhat Disagree (3)
- Neither Agree nor Disagree (4)
- Somewhat Agree (5)
- Agree (6)
- Completely Agree (7)

Even with distractions, I am certain I can learn the physics material presented.

- Completely Disagree (1)
- Disagree (2)

- Somewhat Disagree (3)
- Neither Agree nor Disagree (4)
- Somewhat Agree (5)
- Agree (6)
- Completely Agree (7)

# APPENDIX B

## MULTIPLE-CHOICE PHYSICS LEARNING ASSESSMENTS

**Test A – Correct answers are bolded**

1. How do physicists think about matter?

a. Matter is resistance to change in motion.

**b. It has mass and takes space.**

c. It cannot really be distinguished from sample size.

d. It is really how easily one can change the motion of an object at rest.

2. What causes an object to resist changes in its state of motion?

a. How big it is and how much space it occupies.

b. Any outside force that has no effect on the object's state of motion.

**c. Inertia causes the object to resist changes in its state of motion.**

d. Outside forces, such as air pressure or friction cause an object to resist changes in its state of motion.

3. How can an object's inertia affect its state of motion?

**a. Inertia causes objects to resist changes in its state of motion.**

b. Inertia causes objects to speed up or slow down depending on how Newton's Second Law applies.

c. Inertia has a greater effect on a car's movements than, say a space shuttle orbiting the earth.

d. An object in a state of constant motion will always reach a natural state of rest.

4. If you are pushing on the eraser of a pencil with your finger, what will happen if you stop pushing taking into account Newton's first law and assuming that your finger is the only force on the pencil?

**a. The pencil will continue at a constant rate of speed.**

b. The pencil will continue to accelerate at the same rate you were pushing.

c. The pencil will curve off to the side without your finger guiding it.

d. The pencil will slow to a stop.

5. How does the physicist change the mass of an object?

a. He can make it take up more space like when you place a gas like a specific amount of helium in a larger container or tank.

b. He makes it bigger than it originally was.

c. He heats up an object to make it expand in size.

**d. Add particles.**

6. When you pull sideways on an object what determines the amount of force you need to move the object from rest?

**a. By the object's weight and friction.**

b. The heavier the object the more force must be applied.

c. Only friction affects the amount of force needed.

d. Only the object's weight affects the amount of force needed.

7. If I pull sideways on an object what might I be fooled into believing?

**a. That the object's weight is what I am pulling.**

b. That the object's inertia is making it hard to move.

c. That is the tension of the object interacting with its inertia that is responsible to the force needed to move it.

d. That it is friction that makes it hard to pull sideways.

8. Galileo corrected what incorrect idea held by the Greeks?

a. An object at rest tends to remain at rest.

b. Friction is an outside force, like tension.

**c. The natural state of an object is to rest.**

d. Friction, like tension is an outside force.

9. How did the Ancient Greeks think about the natural state of motion of all objects.

a. The natural state of motion of all objects is to remain in motion if they are in motion.

b. The natural state of motion of all objects was to not be affected by inertia.

c. The natural state of motion of all objects was to not be affected by tension.

**d. None of these.**

10. According to Galileo's experiments, what happened if a moving ball rolled down a frictionless ramp onto a completely flat and frictionless surface?

**a. The ball would roll forever.**

b. The ball would eventually stop, but it cannot be determined where that will be.

c. The ball's acceleration from moving down the ramp would cause it to move to a greater distance from the top of the ramp before it stopped.

d. The ball would roll until it reached a distance equal the top of the ramp and stop.

**Test B**

1. What exactly is matter?

a. It has to do with how fast it rolls down an inclined plane as Galileo showed.

**b. Space occupied and the number of particles.**

c. All that is important is the object's inertia.

d. It is really how much the object resists any change in its state of motion.

2. What exactly is inertia as the physicist thinks about it?

**a. An object with more mass is more resistant to changes in its movement.**

b. If it takes up more space it has more inertia than if it takes up less space.

c. If an object is not affected by any outside forces it is said by physicists to have inertia.

d. Inertia causes an object to accelerate when an outside force is applied, like what happens in an elevator.

3. How can we make an object more resistant to changes in its state of motion?

a. We can add an outside force to cause it to accelerate.

b. We can make it take up more space by making it bigger.

**c. We can increase the number of particles it contains.**

d. We can take into space on the space shuttle and put it in orbit around the earth.

4. If you are pushing a ball with your finger, assuming that your finger is the only force on the ball, what will happen if you stop pushing according to Newton's first law?

a. The ball will slow to a stop.

b. The ball will continue to accelerate at the same rate you were pushing.

c. The ball will curve off in one direction without your finger guiding it.

**d. The ball will continue at a constant rate of speed.**

5. When I try to catch something, how is it that some things are harder to control than others, like a bowling ball versus a baseball?

a. A bowling ball is bigger than a baseball.

b. More space occupied by bowling ball.

**c. The bowling ball has more mass.**

d. The bowling ball is heavier than the baseball and takes up more space.

6. How is it that pulling sideways on an object takes so much effort?

**a. When you pull sideways on an object you are fighting friction.**

b. When you pull sideways on an object you are fighting the object's tension.

c. When you pull sideways on an object you must overcome its inertia.

d. When you pull sideways you are fighting its weight.

7. What common misinterpretation do people make about pulling an object sideways?

a. It seems to be due to the object's mass instead of friction.

**b. It seems to be due to the object's weight instead of friction.**

c. It seems to be due to the object's friction instead of weight.

d. It seems to be due to the object’s mass instead of weight.

8. Galileo **corrected** which statement with his experiments that rolled a ball down inclined planes?

a. The inertia of an object causes it to move down a ramp and when the force from inertia is depleted the object will stop.

b. The mass of an object determines its momentum.

**c. An object in motion eventually reaches it natural state of rest.**

d. The tension on an object determines it state of motion.

9. According to Aristotle and the ancient Greeks, what misconception was obviously true?

a. An object in motion remains in motion.

b. Outside forces can only affect the direction in which an object is moving.

**c. An object in motion will seek its natural state of motion, which is to rest.**

d. None of these.

10. If a moving ball rolls down a completely flat surface what happens according to Galileo assuming that friction was eliminated?

a. The ball’s acceleration from moving down the ramp would cause it to move to a greater distance from the top of the ramp before it stopped.

b. The ball would roll until it reached a distance equal the top of the ramp and stop.

c. The ball would eventually stop, but it cannot be determined where that will be.

**d. The ball would roll forever.**

APPENDIX C

MENTAL EFFORT SURVEY

In studying the preceding video I invested

- Very, very low mental effort (1)
- Very low mental effort (2)
- Low mental effort (3)
- Rather low mental effort (4)
- Neither low nor high mental effort (5)
- Rather high mental effort (6)
- High mental effort (7)
- Very high mental effort (8)
- Very, very high mental effort (9)

APPENDIX D

CONSENT FORM

Dear participant:

I am graduate student under direction of Dr. Scotty Craig in the Human Systems Engineering Program at Arizona State University. I am conducting a research study to investigate the ability to learn physics material and concepts after completing a training session.

You are invited to take part in our study if you are 18 or older. You will fill out a demographical questionnaire and view training modules regarding physics concept materials. Afterward, you will complete a brief multiple-choice test. The study will take about 60 minutes, and we expect around 128 people will participate. Participation in this research is completely voluntary. You have the right to say no. You may change your mind and stop participating at any time. You will receive $1.00 USD for participating in this study. If you do not wish to participate in this study, you may end it at any time. There are no foreseeable risks to your participation.

The data for this study includes the data from the tests. Your data will be stored confidentially and anonymously. To secure your data, your data files will be encrypted. The results of this study may be used in reports, presentations, and publications, but under no circumstance will your personal information be used.

If you have questions, concerns, or complaints, please contact the research team at: (Tyler.Krause@asu.edu). This research has been reviewed and approved by the Social Behavioral IRB. You may talk to them at (480) 965-6788 or by email at research.integrity@asu.edu if you have questions about your rights as a research participant or any concerns about this research.

Sincerely,

Tyler Krause

# APPENDIX E

# DEMOGRAPHIC SURVEY

Next you will complete a demographics questionnaire. Please answer each question to the best of your ability.

What is your gender?

- Male (1)
- Female (2)

Please indicate the highest level of education you have completed.

- Grammar school (1)
- High school or equivalent (2)
- Vocational/technical school (2 years) (3)
- Some college (4)
- Associates degree in Nursing (ADN) (5)
- College graduate Nursing (BSN; RN) (6)
- College graduate (4 years) (7)
- Master's Degree Nursing (MSN, also NP and CRNA) (8)
- Master's Degree (MS) (9)
- Doctoral Degree (PhD) (10)
- Professional Degree (MD, JD, etc.) (11)
- Other (12)

How old are you?

__________

What is your ethnicity?

- White/Caucasian (1)
- Hispanic or Latino (2)
- African American (3)
- Asian (4)
- Native American (5)
- Pacific Islander (6)
- Other (7)

Do you have any previous education regarding physics material?

- Yes (1)
- No (2) 45