

The effects of music with and without words on knowledge acquisition from text and simulations: an eye-tracking study

A Major Qualifying Project submitted to the Faculty of the
Worcester Polytechnic Institute
In partial fulfillment of the requirements for the
Degree of Bachelor of Science

Submitted by Lisa Rossi
April 2011

Advisors: Janice Gobert and Frederick Bianchi

Table of Contents

Abstract.....	3
Introduction	4
Background	4
Music.....	4
Eye-tracking	6
Methodology.....	8
Participants	8
Materials	8
Procedure.....	10
Data	12
Eye-tracking	12
Assessments.....	13
Results.....	13
Reading/Viewing Times	14
Number of Fixations.....	17
Discussion.....	20
Implications for Music and Language	21
References	22
Appendix A: Microworlds.....	24
Appendix B: Multiple Choice Questions on Pre- and Post-tests.....	26
Appendix C: Open Response Questions on Post-test	28
Appendix D: Scoring of Eye-tracking Data	29

Abstract

The objective of this study was to examine the effects of music and music with words on learning using three sections of an expository text about plate tectonics, eye-tracking data with respect to eye fixations and reading and viewing times, and subsequent assessment of the reader's comprehension on the topic. The experimental design included conditions in which the reader simultaneously listened to either instrumental music or music with words, allowing us to examine how the stimuli of both music alone and music containing words affect knowledge acquisition and reading comprehension. The eye-tracking data was used as one of the primary methods of data collection, as the effects of music on learning, to our knowledge, have not yet been assessed using eye-tracking. The eye-tracking data provides us with a means to analyze each participant's reading/viewing patterns and eye fixations while reading and viewing the assigned materials in either the music or music with words condition, as well as to accurately determine reading and viewing times for each participant. It is expected that reading and viewing times will increase for the music with words condition due to the interference of words in the music with the words being read. No statistically significant differences were found for the number of fixations across the two conditions, and no statistically significant differences were found for time across the two conditions; however the music with words group had a tendency to have longer reading/viewing times for the first two sections of the text/graphics, while the opposite was found for the final section, possibly suggesting that participants were able to adapt by screening out the words in the music.

Introduction

This study is concerned with the primary question of how listening to music, either with or without words, affects knowledge acquisition processes, namely search and comprehension, from text and simulations when presented simultaneously. Many people like to study with music on, but little research has been done regarding whether instrumental music or music with words significantly affects one's ability to acquire knowledge and comprehend material. More specifically this study delves into what readers look at when reading text and viewing simulations, and the difference in the amount of time spent on the task and the difference in the number of reading/viewing fixations in two conditions. These measures will provide insight into whether learning is affected by the different conditions. It is possible that longer reading times may be an indication of deeper information processing, as is a common assumption in eye-tracking research (Just & Carpenter, 1980), or on the other hand, intuitively, longer reading/viewing times could be an indication of distraction in these learning conditions caused by the words when presented alongside the music.

Background

Music

The effects of listening to music while studying or doing homework has been a widely disputed argument for years (Furnham et al., 1999; Furnham & Strbac, 2002; Ophir et al., 2009). There are numerous reasons to investigate this question further. There has been surprisingly few studies undertaken on the subject, and much of the past research in this area has yielded mixed or insignificant results. For example, some researchers claim that the added stimulus is a distraction to productivity and learning (Ophir et al., 2009), while some defend the potential beneficial effects of background music on productivity and concentration (Fox, 1972). A study by Fox (1972) investigated the relationship of background music to shopfloor productivity on repetitive tasks and found that when music was played for a portion of their time at work, the music acted as a motivator and improved performance on the task.

There is also the theory that listening to Mozart's music may temporarily improve certain spatial-temporal reasoning skills involving mental tasks such as visualizing spatial patterns and mentally manipulating shapes. This proposed theory is known as the Mozart effect (Rauscher et al., 1993). It is believed that this occurs because of similar activation areas of the brain (right cerebral hemisphere) for spatial cognition and listening to complex music (Aheadi et al., 2010). The Mozart effect should only be observed in non-musicians since they process melodic information primarily in the right hemisphere, while musicians process melodic information in both hemispheres. Aheadi et al. (2010) sought to examine how the Mozart effect may influence musicians and non-musicians differently on a mental rotation task in which participants are asked to compare two shapes displayed in differing orientations by rotating them mentally. The findings were consistent with the hypothesis, namely that due to activation of similar brain regions when performing mental rotation as when processing complex music, the Mozart effect will not be exhibited for musicians. The results showed that only the performance of a non-musician was improved as a result of the Mozart effect. This study demonstrates the clear differences that can be found between musicians and non-musicians when it comes to how the processing of music may affect the processing of other information in the brain.

In another study, Furnham et al. (1999) questioned the effect of vocal and instrumental music on introverts and extraverts, finding trends that the performance of introverts on several cognitive tasks were hindered in the presence of music while that of extraverts was enhanced, however these results were not statistically significant. Another study (Furnham & Strbac, 2002) again focused on the cognitive performance of introverts and extraverts, but in the presence of noise, music, or silence. In this study, performance by all participants was negatively affected by noise and music as compared to silence, while the performance of extraverts in the noise and music conditions was higher than that of introverts.

As is suggested in the studies reviewed above, background music will have different effects depending on the type of person and the type of task. That is, it is inconclusive as to whether music, either with or without words, has a positive or negative effect on performance and

learning. It appears that the constructive or detrimental effect exhibited depends at least in part on the specific interaction of what the task is and who is performing it. Fox's (1972) study revealed the positive effects of music on a menial, repetitive task due to its ability to stimulate workers when they were bored. Meanwhile Furnham and Strbac's (2002) study revealed the negative effects on both introverts and extraverts on cognitive tasks in the presence of noise and music. Both Furnham (1999, 2002) and Aheadi's (2010) studies are among the few that have taken individual attributes into account. They have made clear that there are potential effects that variables such as introversion and extraversion, as well as musical training, can have on performance while participants are listening to music. It seems important to note what the effect of multi-tasking may have in the presence of music. Ophir et al. (2009) investigated whether information processing styles differs between heavy and light multi-taskers. It was found that heavy multi-taskers were negatively affected by distracters, while light multi-taskers were not affected. It seems that the reason for the variability and inconclusiveness on this topic is the fact that there are so many possible variables and interactions to take into account. If as many of these interactions are controlled for as possible, then more significant and consistent results might be found.

Eye-tracking

An increasingly common tool for output data in many studies is the usage of eye-trackers. These devices are very accurate in providing an additional source of data that can either be triangulated with other data or studied on its own. While self-reports, performance scores, and other behavioral observations can provide us with concrete quantitative data, they are not the only insightful behavioral output of participants in studies. Self-reports can be inaccurate and biased (Kolar et al., 1996), while pre-post scores often merely represent the final overall effects of an intervention or stimulus. Since eye-trackers allow us to capture data *during* a knowledge acquisition task rather than after, eye-tracking analysis can provide us with unbiased results of behaviors as they relate to attention, concentration, and in turn, reading comprehension (Just & Carpenter, 1980).

Day et al. (2009) conducted research on the effects of music tempo combined with the difficulty of a delegated task on decision-making. The data collected from the eye-trackers were used to analyze the participants' search pattern, percent of information searched, and speed of information processing. It was found that the search pattern scores were significantly lower with the presence of the faster tempo than the slower tempo. Also, it was revealed that a higher percentage of information was examined for the difficult decision task than for the easy one.

Similarly, a study by Wiebe (2008) observed how the degree of integration between text and graphics interacts with text density, static or dynamic graphics, and audio narration within multimedia instructional material. Participants viewed a slideshow of information, which they were told they would be teaching afterward. The slideshows consisted of text of varying density, static or dynamic graphics, or with supplemental audio narration of the content. Eye-trackers captured the distribution of visual attention between text and graphics on each slide. Results revealed that the narration group spent significantly more gaze time under the conditions of high integration with low text density, low integration with low text density, and high integration with high text density.

Several past and recent studies have utilized eye-tracking technology as a major component of their data analysis. Hegarty and Just (1993) examined the effects of presenting information about pulley systems as text only, diagram only, or both stimuli integrated, on reading comprehension of the presented material and on creating mental models. Hegarty used eye fixation data to analyze how participants integrate the information in combined media (text and diagram presented simultaneously). Her data suggested that text or diagrams alone were sufficient for conveying system configuration, but text and diagram combined help facilitate understanding of how the pulley system moved. Eye fixation data was used to suggest that readers construct mental models in increments when integrating information in text-and-diagram material.

Eye-tracking has also been useful in assessing the presentation of reading materials in the form of information graphics, in which visual representations are used to aid in the presentation of certain complex information. Holsanova et al. (2008) examined the effects of the spatial layout of reading material on the eye movements of the reader. Participants were asked to read a newspaper in which the graphics were either separated from the text or integrated with the text. Eye-tracker data revealed there to be fewer integrative saccades (eye movements) between related pieces of information when the graphic was separate from the text, meaning that the two were treated separately. On the other hand, when the graphic was integrated with the text, the two pieces of information were processed together.

In the same vein of research, we are investigating the effects that listening to music, either lyrical or instrumental, may have on the reading task. With the added analysis of eye-tracking data, we hope to enhance our understanding of exactly “how” one reads under the varying conditions of music or music with words.

Methodology

Participants

A total of 13 students, grades 5-8, participated in the study, (5 male and 8 female). Participants were recruited from local middle schools in Central Massachusetts. Eye-tracking data for 3 participants have been disregarded due to failure of the eye-tracker to gather eye-tracking data during the activity.

Materials

Eye-tracker

A Mirametrix S1 eye-tracker was used to unobtrusively monitor each participant’s saccades (eye movements) and fixations. The eye-tracker is a small inconspicuous webcam-like device that sits below the computer monitor aimed at the participant’s eyes. The device outputs point of gaze data at a rate of 60 times per second and the software for this device allows for on-screen video capture of these eye movements in relation to what is being viewed on the

monitor. These videos provide rich, qualitative data for the study and accurately represent viewing patterns and fixations.

The Science ASSISTments Learning Environment

All learning materials were managed and accessed through the Science ASSISTments learning environment (www.scienceassistments.org; Gobert et al., 2007, 2009). The Science ASSISTments project is directed by Dr. Janice Gobert and the Science ASSISTments learning environment was developed from the original Math ASSISTments platform (Razzaq et al., 2005) in order to assist students in learning new science concepts via the use of interactive microworlds.

Microworlds

The three reading tasks each consist of a piece of text and a corresponding simulation depicting the processes described in the text, namely, 1) the spatial layout of the earth and convection currents, 2) mountain formation, and 3) volcanic eruption, respectively. These sections, referred to as microworld, were designed with progressive model building approach in mind (Gobert & Clement 1999; Gobert, 2000) and were adapted from an earlier project (mtv.concord.org; Gobert & Pallant, 2004). In other words, students can better understand material, i.e., construct mental models, when the text and accompanying materials are presented in a way that fosters progressive model-building. Thus, in the present study, the order and information contained in each of the three sections is designed to promote progressive model-building: 1) set up a spatial model of the earth and develop an understanding of convection currents, 2) understand the role of convection currents and converging plates of similar densities in the process of mountain formation, and 3) understand the role of convection currents and converging plates of different densities in the process of volcanic formation. The screen shots of each microworld used in this study can be seen in Appendix A.

Assessments

These materials include a pre-survey for acquiring demographic information, a pre-test to assess prior knowledge, a post-test to assess knowledge acquisition, and a post-survey to determine if the participant was familiar with the music played during the study. The pre-test, made up of grade-level appropriate released items from NY Regents and MCAS exams, served to determine a baseline of prior knowledge for each participant (these can be seen in Appendix B). The post-test consisted of the same multiple choice questions as the pre-test with the exception of four additional open response questions, including one transfer question (Appendix C). These serve as an indicator of how much each participant has learned after reading the texts, and also demonstrates the participant's skill at transferring this newly acquired knowledge to answer a related question which was not specifically addressed in the microworlds.

Music

The music used in the study consists of three different songs by the same artist ("Collect Call," "Gimme Sympathy," and "Sick Muse" by Metric). The music was selected based on its generic qualities shared in the genre of alternative/pop rock (a familiar genre), however the band hasn't experienced mainstream popularity thus it was expected that participants would not have previously heard the songs (no familiarity or mental associations). The three songs were of similar tempos (119 bpm, 129 bpm, and 139 bpm, respectively). Instrumental tracks were created by mixing out the vocal tracks for each song, such that both versions of each song sound exactly the same, save for the presence of the vocal track. Each participant listened to the music in this study on a pair of Sony MDR-G42 headphones.

Procedure

For the first 5 participants, all data was collected on an individual basis, however for the remaining participants all of the pre- and post-data was collected in a group setting in the interest of collecting data from a greater number of participants. For those whose data was

collected in a group setting, the reading task during which eye-tracking data was collected still took place individually. A coin toss determined the random selection of experimental condition: instrumental music or music with words. First it was necessary to calibrate the eye-tracker for each participant. For this the screen would display a series of 9 dots on different parts of the screen sequentially, which were to be focused on by the participant. Eye-tracking accuracy was determined by the device's software during calibration. A numerical rating below 40.0 indicated "excellent" accuracy and below 80.0 indicated "good" accuracy. Another number, out of 9, represents the number of points on the screen during calibration for which the accuracy was adequate for the numerical standards. Once this was done to a sufficient degree of accuracy, the child was instructed to put on the headphones and shown how to adjust the volume to a comfortable level. All participants were initialized at the same volume, and none changed this volume. Next, the video capture was set to record and the participant began the study within the Science ASSISTments website (www.scienceassistments.org).

First, participants were given a pre-survey which is important in order to be aware of substantial musical training that he or she may have, as this may affect how the background music is processed and thus may affect performance on the reading task. Then the participant was given the pre-test on plate tectonics content. After finishing these assessments, the participant was then presented with the first plate tectonics microworld in the sequence of three, in which the randomly assigned music (instrumental music or music with words) began playing throughout the activity. As the participant completed each microworld the next microworld was presented which began playing a new song consistent with the condition they were put in initially. Once all three screens had been read, the participant was then given the post-test to assess the amount of knowledge acquired through the activity. Following the post-test was a post-survey in which participants are asked if they were familiar with the music played during the experiment, and also to what degree they found it distracting.

Data

Eye-tracking

As previously mentioned, a calibration rating below 40.0 indicated “excellent” accuracy and below 80.0 indicated “good” accuracy. The highest (least accurate) rating in the study was 40.18, and the average was 25.65. After data was collected in the form of eye-tracking output videos and assessment responses for each participant, reading/viewing times and number of fixations were then scored in terms of reading region (RR), viewing region (VR), and by microworld (MW) for both of these eye-tracking factors. In order to score these videos, it was necessary to define certain regions and key words within each microworld. The images in Appendix D show these regions in their respective microworld.

Fixations

In order to determine the number of fixations for each participant in each microworld, all of the eye-tracking videos were viewed at half-speed since eye movements tend to be fairly abrupt. While watching, fixations on any of the pre-defined key phrases were tallied. For example, if someone fixated on every phrase in RR1 of Microworld 1, “four layers,” “crust,” “mantle,” “outer core,” and “inner core” then they would receive a tally of 5. A screen shot of one of the eye-tracking videos from the study can be found in Appendix D, in which you can see that this student fixated on the phrases “outer,” “dense,” and “liquid layer.” Red circles indicate a fixation, their size indicates their relative duration, and the lines in between are saccades. The components of each RR and VR could be viewed in any order considering search patterns can vary from person to person. The tally of all key phrases makes up the RR total, and the same is true for the VR total. The final tallies included categorizations as total, total RR, total VR, MW 1 total, MW 1 RR, MW 1 VR, MW 2 total, MW 2 RR, MW 2 VR, MW 3 total, MW 3 RR, and MW 3 VR.

Reading/Viewing Times

Again, in order to score the data for reading and viewing times it was helpful to view the eye-tracking videos in half-speed. Then a simple computer program was developed by Ermal Toto of

the Science ASSISTments group (www.scienceassistments.org), which enabled the use of keyboard inputs to indicate the point in time that the reader entered a specific region and another key to indicate the point in time that reader exited that region, and time stamps were created for each of these events in the video. By calculating the difference between the time stamp on all “entrances” and “exits,” it was possible to determine the time spent in that region. Thus the summation of these times, divided by 2 to account for half-speed video, is the total time spent in all regions of that type (reading or viewing). Reading and viewing times were obtained for all three microworlds, and these totals were broken down into the same categories as tallied for the number of fixations.

Assessments

The ASSISTments infrastructure (Razzaq et al., 2005) provides the ability to output the student response data and conduct automatic scoring of the multiple choice questions. Open response questions were scored out of a possible 3 points and the transfer question was also graded out of 3 for quality of knowledge transfer and one additional point for correctness. After scoring of the assessment it was found that a significant portion of participants, regardless of condition, exhibited decreased scores on the post-test compared to their pre-test. This is likely due to a lack of motivation in the participants to answer these questions a second time after already answering them in the pre-test. Since these items seem to be highly affected by students’ motivation levels, these data should not be included as indices of differences in learning due to condition (music or music with words). Thus it was decided to disregard these data and to instead focus on the number of fixations and reading/viewing times in order to examine knowledge acquisition differences between conditions.

Results

In summary, two types of analyses were conducted: those dealing with number of fixations, and those dealing with time on task. Each will be addressed in turn. The tables in this section display mean number of fixations as a percentage of total possible for each category, and reading/viewing times. The means for the instrumental music condition are compared side by

side with the means for the music with words condition. A two-tailed independent means analysis was performed and the p-value for each variable is included in the tables below.

Reading/Viewing Times

Despite the general lack of statistical significance in the results, it is interesting to note a certain trend that occurs in the data. For the reading/viewing times, it can be observed that the MW 1 total is noticeably higher for the vocal condition than for the instrumental condition, that the MW 2 total is still slightly higher for the vocal condition, and that the MW 3 total reverses such that the instrumental condition is higher. This trend may be attributed to the fact that while those in the music with words condition may have been distracted initially by the presence of words in the music and interference with the words in the text, they may have become accustomed to it by the third microworld and were able to do selective processing to “tune out” the words.

Table 1 – Analysis of reading/viewing times by region and microworld

Mean Reading/Viewing Time	Instrumental	Vocal	p =
Total	147.16	169.91	0.478
Total RR	126.98	139.80	0.651
Total VR	20.18	30.11	0.467
MW 1 Total	62.81	93.37	0.106
MW 1 RR	58.08	79.76	0.234
*MW 1 VR	4.73	13.61	0.044
MW 2 Total	35.03	38.36	0.686
MW 2 RR	28.42	29.47	0.873
MW 2 VR	6.61	8.90	0.650
MW 3 Total	49.32	38.18	0.506
MW 3 RR	40.49	30.58	0.456
MW 3 VR	8.84	7.61	0.823

The graph below indicates a slight difference in total reading/viewing times, with the music with words (vocal) condition exhibiting longer reading times for both reading regions and viewing regions.

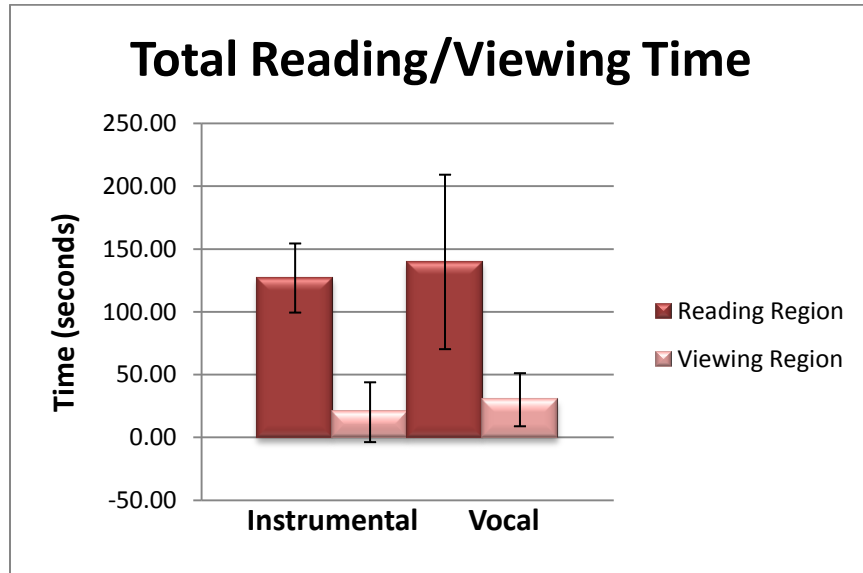


Figure 1 – Total reading/viewing time for instrumental and vocal conditions by reading region and viewing region

For this variable it was found that the mean VR time in MW 1 for the instrumental condition ($M = 4.73$, $SD = 4.79$) was statistically significantly different (specifically lower) than that of the music with words condition ($M = 13.61$, $SD = 9.18$), $t(11) = -2.284$, $p = 0.044$, two-tailed test. This variable is highlighted with yellow and denoted with an asterisk in Table 1. Also, the overall time difference between conditions is very pronounced in Micro World 1.

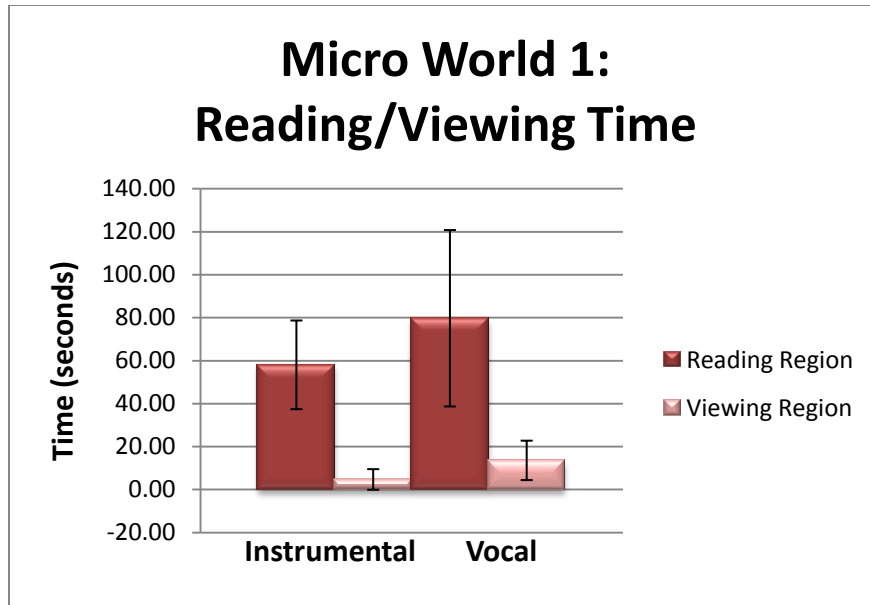


Figure 2 – Micro World 1 reading/viewing time for instrumental and vocal conditions by reading region and viewing region

In the graph below, the reading times for both conditions level off such that both reading times and viewing times are nearly the same for both conditions for Micro World 2.

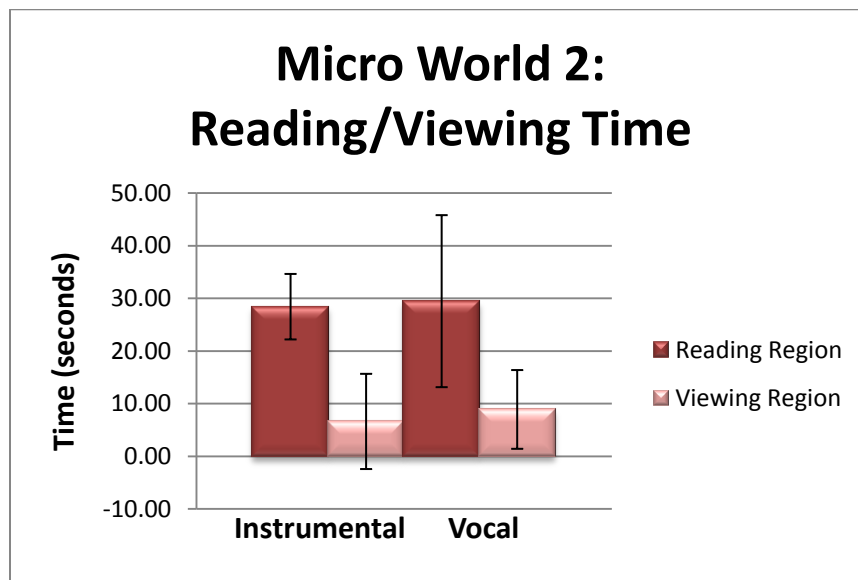


Figure 3 – Micro World 2 reading/viewing time for instrumental and vocal conditions by reading region and viewing region

The graph below demonstrates the inversion in the trend. The instrumental condition is now exhibiting noticeably longer reading times than the vocal condition for both reading regions and viewing regions.

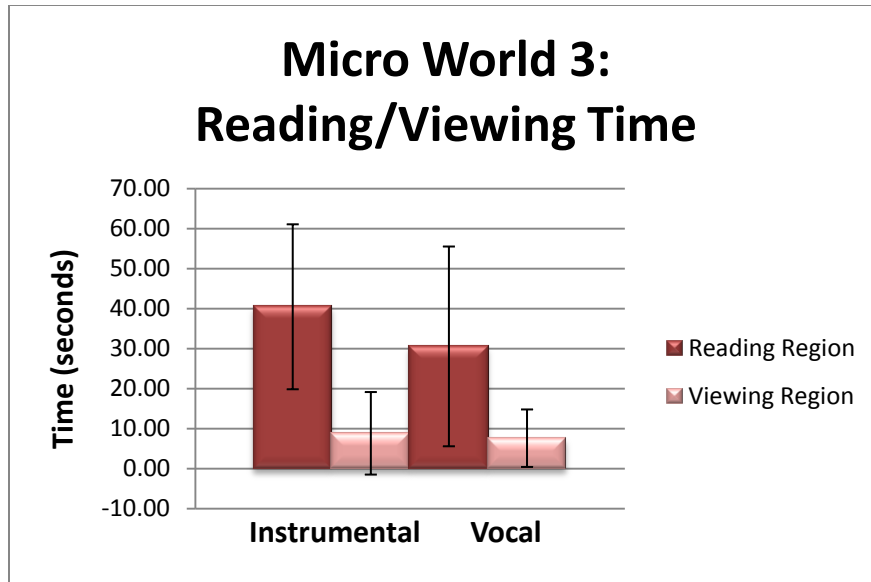


Figure 4 – Micro World 3 reading/viewing time for instrumental and vocal conditions by reading region and viewing region

Number of Fixations

The table below displays the number of fixations by condition, microworld, and reading/viewing regions. None of the resulting p-values from the t-tests are statistically significant, and there are no notable trends in the data.

Table 2 – Analysis of fixation percentages by region and microworld

Mean Percentage of Fixations	Instrumental	Vocal	p =
Total (of 144)	59.38%	60.81%	0.899
Total RR (of 121)	64.67%	62.46%	0.884
Total VR (of 23)	31.52%	52.17%	0.268
MW 1 Total (of 77)	48.57%	59.37%	0.249
MW 1 RR (of 63)	54.60%	58.73%	0.683
MW 1 VR (of 14)	21.43%	49.11%	0.108
MW 2 Total (of 32)	63.28%	68.36%	0.789
MW 2 RR (of 27)	68.52%	69.91%	0.952
MW 2 VR (of 5)	35.00%	60.00%	0.360
MW 3 Total (of 35)	79.29%	55.10%	0.161
MW 3 RR (of 31)	83.87%	55.76%	0.159
MW 3 VR (of 4)	43.75%	50.00%	0.813

In the graph below it can be seen that the number of total fixations between the instrumental and vocal conditions was similar for both reading regions and viewing regions.

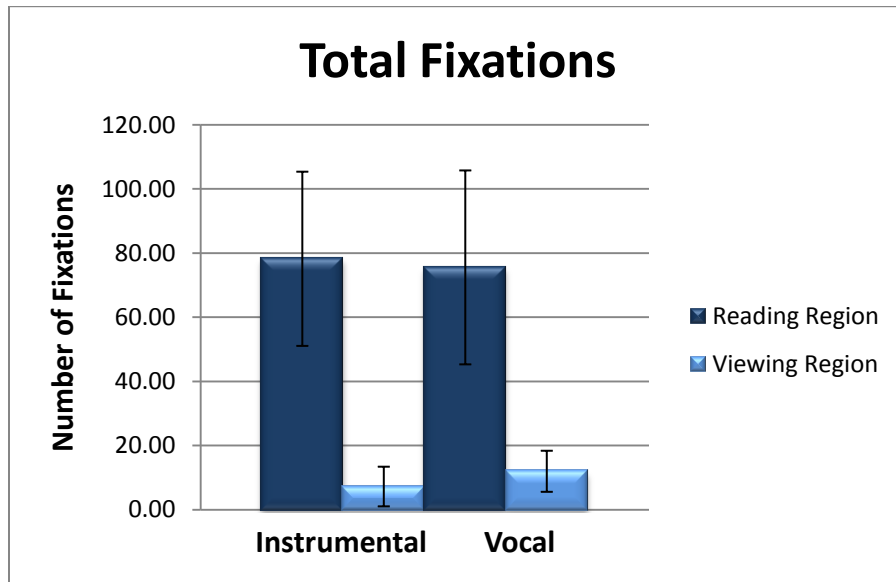


Figure 5 – Total fixations for instrumental and vocal conditions by reading region and viewing region

The graph below for Micro World 1 shows no noticeable difference between number of fixations in Micro World 1 between the instrumental and vocal conditions for reading and viewing times.

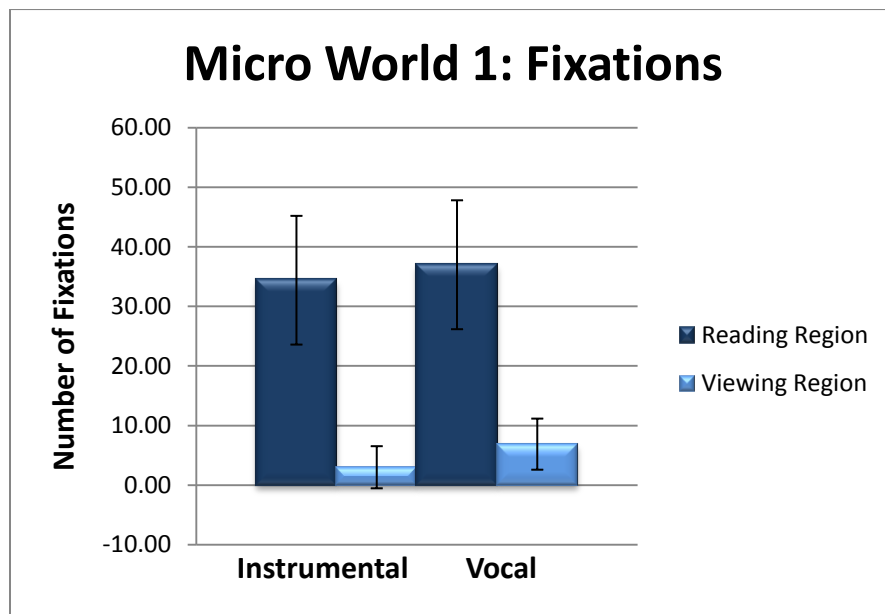


Figure 6 – Micro World 1 fixations for instrumental and vocal conditions by reading region and viewing region

Again, in the graph below for Micro World 2, the numbers are similar between conditions.

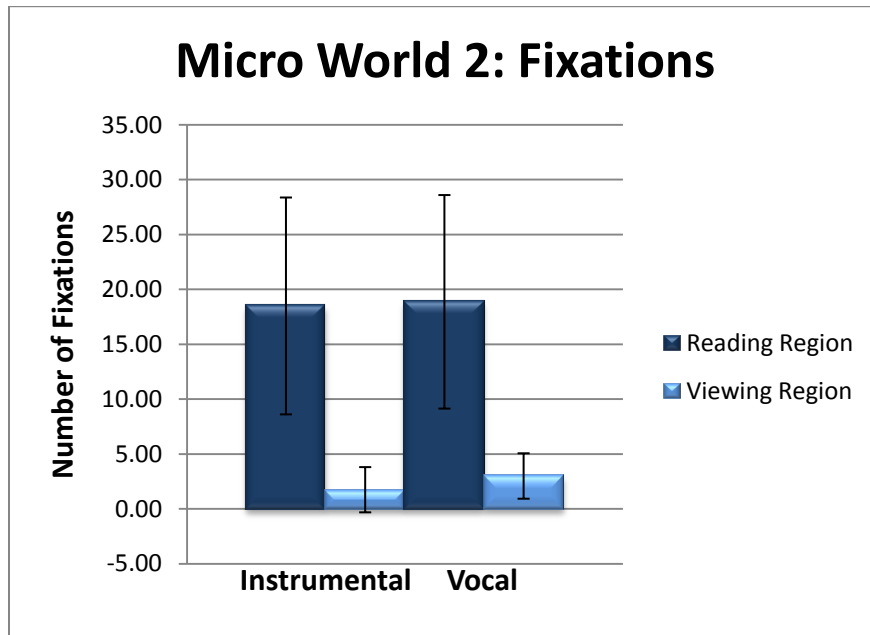


Figure 7 – Micro World 2 fixations for instrumental and vocal conditions by reading region and viewing region

In the graph below, the number of fixations for reading regions in Micro World 3 is slightly higher for the instrumental condition than the vocal condition, however the difference is not large enough to have obtained statistical significance.

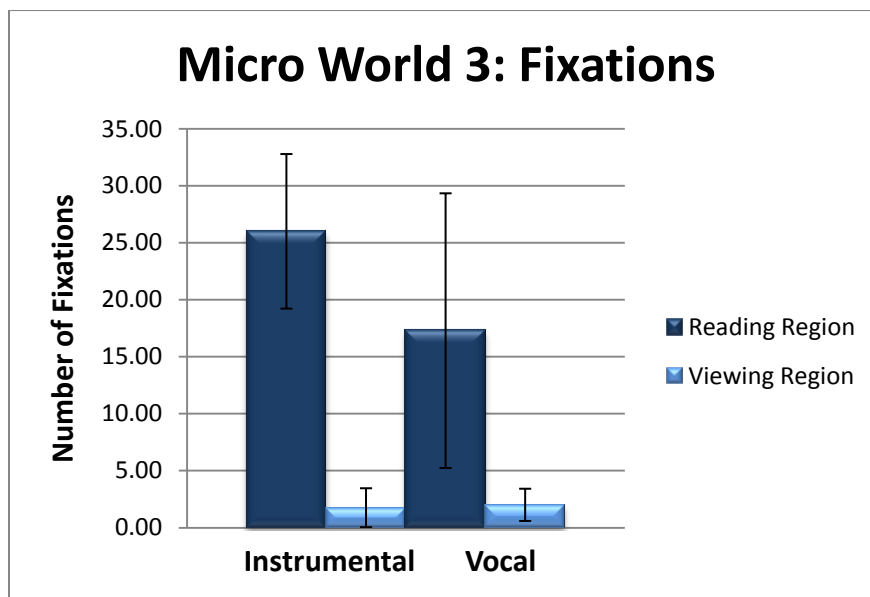


Figure 8 – Micro World 3 fixations for instrumental and vocal conditions by reading region and viewing region

Discussion

From these data, it seems additional participants in each condition might yield group differences in terms of both the reading and viewing times and for the number of fixations. Despite a fairly consistent trend in the overall times and for Micro Worlds 1 and 2 in which the music with words condition took longer on reading/viewing tasks, the means were not large enough to reach statistical significance due to the low number of participants. We had originally planned to collect more data but the large number of snow days in Central Massachusetts during our data collection period of January and February 2010 greatly affected our data collection. The trend in the data shows that there may be a difference between the two conditions for time on task, with the music with words condition taking longer, and that this effect may have obtained statistical significance if there were a larger subject sample tested.

Another factor that we could control for in future research is the school grade of the participants; we could keep this consistent so as to not skew results with potentially superior reading skills of older children compared to younger ones. This study included students in grades 5-8 since this is when plate tectonics is taught, but it may be helpful to control for this or use this variable as a covariate in the data (if the sample size permitted such analyses). Also, running more participants would make it easier to ensure that the student does not have substantial prior knowledge on the topic of interest. The less prior knowledge a participant has, the easier it is to clearly observe well-defined post-test gains. Finally, we should, in future, consider using different post-test questions from those used in the pre-test because it appears as though the subjects were not motivated to answer the questions a second time. Then perhaps our post-test data could be analyzed and triangulated with the other data in order to ascertain if the two learning conditions yielded different levels of comprehension, and whether those in one condition or the other were better able to address the transfer question. Further research with more participants could more easily allow us to determine whether differences in reading/viewing times or fixations between conditions is in fact evidence of deeper processing or more distraction since higher processing should be also associated with better comprehension scores (Craik & Lochkart, 1972).

Implications for Music and Language

The ongoing debate regarding music and language's overlapping qualities is interesting to consider here. Some theories maintain that music is a language in and of itself and that people process sounds as having meanings. This makes sense when we consider the implicit meanings of certain sounds and noises, such as a baby's cry or an animal's growl. Both of these sounds serve as prompts for urgent response and action, thus there must be a direct semantic relationship between the sound and the invoked response. Additionally there are certain musical qualities of spoken language that can be observed. These qualities are often helpful, and sometimes necessary, to processing the meaning of words.

In this study participants listened to music while reading pieces of text with goal of gaining new knowledge. When listening to music with words, a sensible hypothesis would be that the language in the music directly interferes with the language in the text and hinders reading ability, while in the instrumental condition there is no such interference. Hypothetically speaking if further research under more ideal conditions (more participants, more covariate variables, etc.) still does not yield significant results, then the theory of music as language may be true. In other words, the reason for the lack of difference between experimental conditions might be due to the fact that even instrumental music, with its lack of oral language, also interferes semantically with the words in the reading due to the semantic relationship of the sounds alone.

Similarly, random noise can be distracting when working, which is why many people seek a work location away from other people and stray noise. Sudden, unexpected noises communicate meaning to the listener, insinuating that their attention is required elsewhere. This is why people often listen to white noise generators while working. Having a constant, semantically dull noise playing can drown out any other noisy distractions in one's surroundings. Therefore music of any kind, instrumental or otherwise, may all have the same effect on reading; considering it is a semantically rich sound, even instrumental music can convey stories and emotions that can distract a reader's attention.

References

- Aheadi, A., Dixon, P., & Glover, S. (2010). A limiting feature of the Mozart effect: listening enhances mental rotation abilities in non-musicians but not musicians. *Psychology of Music, 38*(1), 107 -117.
- Craik, F.I.M., and Lockhart, R. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*, 671-684.
- Day, R.-F., Lin, C.-H., Huang, W.-H., & Chuang, S.-H. (2009). Effects of music tempo and task difficulty on multi-attribute decision-making: An eye-tracking approach. *Computers in Human Behavior, 25*(1), 130-143.
- Fox, J. G. (1972). Music: An aid to productivity. *Applied ergonomics, 3*(4), p. 202.
- Furnham, A., Trew, S., & Sneade, I. (1999). The distracting effects of vocal and instrumental music on the cognitive test performance of introverts and extraverts. *Personality and Individual Differences, 27*(2), 381-392.
- Furnham, A., & Strbac, L. (2002). Music is as distracting as noise: the differential distraction of background music and noise on the cognitive test performance of introverts and extraverts. *Ergonomics, 45*(3), 203-217.
- Gobert, J. (2000). A typology of models for plate tectonics: Inferential power and barriers to understanding. *International Journal of Science Education, 22*(9), 937-977.
- Gobert, J. & Clement, J. (1999). Effects of student-generated diagrams versus student-generated summaries on conceptual understanding of causal and dynamic knowledge in plate tectonics. *Journal of Research in Science Teaching, 36*(1), 39-53.
- Gobert, J.D., & Pallant, A., (2004). Fostering students' epistemologies of models via authentic model-based tasks. *Journal of Science Education and Technology. Vol 13*(1), 7-22.
- Gobert, J.; Heffernan, N.; Ruiz, C.; Kim, R. (2007). *AMI: ASSISTments Meets Inquiry*. Proposal NSF-DRL# 0733286 funded by the National Science Foundation.
- Gobert, J.; Heffernan, N.; Koedinger, K.; Beck, J. (2009). *ASSISTments Meets Science Learning (AMSL)*. Proposal (R305A090170) funded by the U.S. Dept. of Education.
- Hegarty, M., & Just, M. A. (1993). Constructing Mental Models of Machines from Text and Diagrams. *Journal of Memory and Language, 32*(6), 717-742.

- Holsanova, J., Holmberg, N. and Holmqvist, K. (2009), Reading information graphics: The role of spatial contiguity and dual attentional guidance. *Applied Cognitive Psychology*, 23, 1215–1226.
- Just, M. A., & Carpenter, P. A. (1980). A theory of reading: From eye fixations to comprehension. *Psychological Review*, 87(4), 329-354.
- Kolar, D. W., Funder, D. C., & Colvin, C. R. (1996). Comparing the Accuracy of Personality Judgments by the Self and Knowledgeable Others. *Journal of Personality*, 64(2), 311-337.
- Ophir, E., Nass, C., & Wagner, A. D. (2009). Cognitive control in media multitaskers. *Proceedings of the National Academy of Sciences of the United States of America*, Vol 106(37), 15583-15587.
- Rauscher, F., Shaw, G., Ky, K. (1993). Music and spatial task performance. *Nature*, 365, 611.
- Razzaq, L., Feng, M., Nuzzo-Jones, G., Heffernan, N.T., Koedinger, K. R., Junker, B., Ritter, S., Knight, A., Aniszczyk, C., Choksey, S., Livak, T., Mercado, E., Turner, T.E., Upalekar, R., Walonoski, J.A., Macasek, M.A., and Rasmussen, K.P. (2005). The Assistent Project: Blending Assessment and Assisting. In C.K. Looi, G. McCalla, B. Bredeweg, and J. Breuker (Eds.) *Proceedings of the 12th Artificial Intelligence In Education*, Amsterdam: ISO Press. p. 555-562.

Appendix A: Microworlds

Screen shot of Microworld 1

The Layers of Earth

Earth is composed of four layers: the crust, the mantle, the outer core and the inner core.

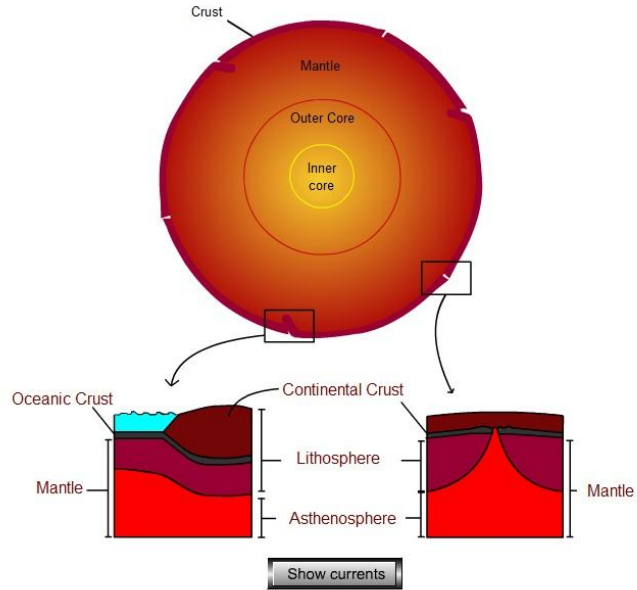
The crust is the thin outermost layer of Earth. There are two types of crust: oceanic crust lies underneath the oceans and continental crust lies underneath continents.

The mantle is below the crust. The mantle is 2900 km (1802 miles) thick. The uppermost part of the mantle is solid. This solid part of the mantle, together with the crust, makes up the lithosphere. The asthenosphere is a soft, flowing and rocky layer of the mantle sitting just below the lithosphere.

The outer core is thought to be a dense, hot liquid layer about 2190 km (1361 miles) thick. It is made of liquid iron and nickel.

The inner core is thought to be a dense, high-pressure solid about 2680 km (1665 miles) thick. It is made of solid iron and nickel.

The currents illustrated in the animation show the circular flow of matter. These are called convection currents. They occur when heat comes from the core and causes the asthenosphere to circulate. The dense matter deep in Earth is heated, making it less dense so it rises up through the layer. As it cools down, it becomes denser again, and sinks back down into Earth.



Screen shot of Microworld 2

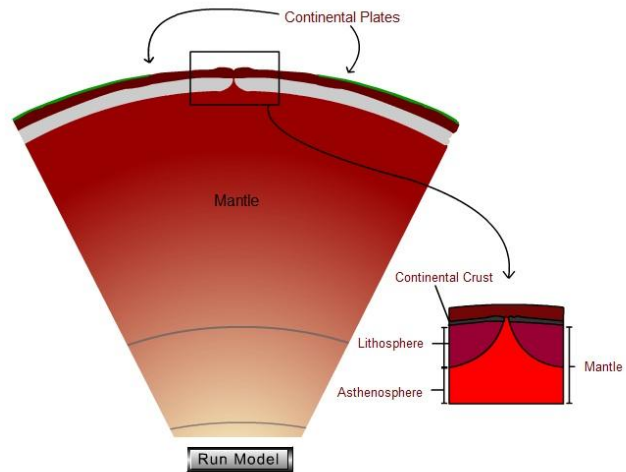
Continental-Continental Plate Convergence

When two plates with continents on their leading edges meet, neither one is able to sink into the mantle because they are both equally dense.

In other words, both plates are made up of the same amount of land. Instead of sinking, the two continents continue to push on each other and crush against the boundary.

As the plates collide, the continents are crumpled and lifted, producing the highest mountain ranges in the world.

In areas around the world where we see mountains, the plates are constantly pushing and straining against one another. These mountains get higher and higher at a rate of $\frac{1}{4}$ inch per year.



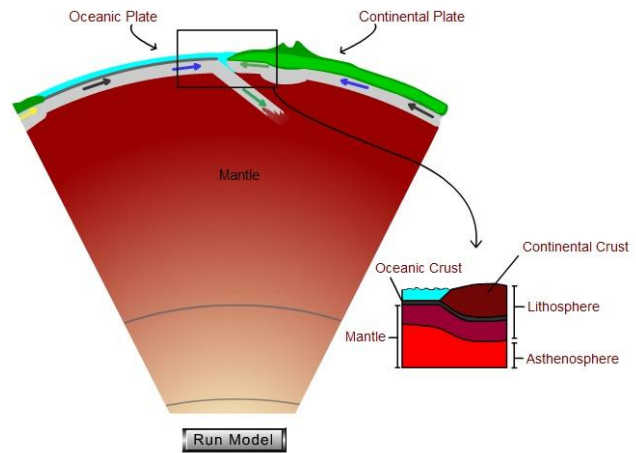
Screen shot of Microworld 3

Oceanic-Continental Plate Convergence

When an oceanic plate meets a plate with a continent on its leading edge, the continental plate rides over the oceanic plate because the continental plate is lighter, or less dense. This process of one plate sliding over another is called subduction.

When a subducted oceanic plate melts, it sinks into the asthenosphere which causes molten rock to rise through the continental plate. This creates volcanic mountain ranges. These volcanoes can be found along the edge of the continent.

The movement of the two plates against each other also causes stress to build in these areas. When the energy is released from these stressed areas, an earthquake occurs.

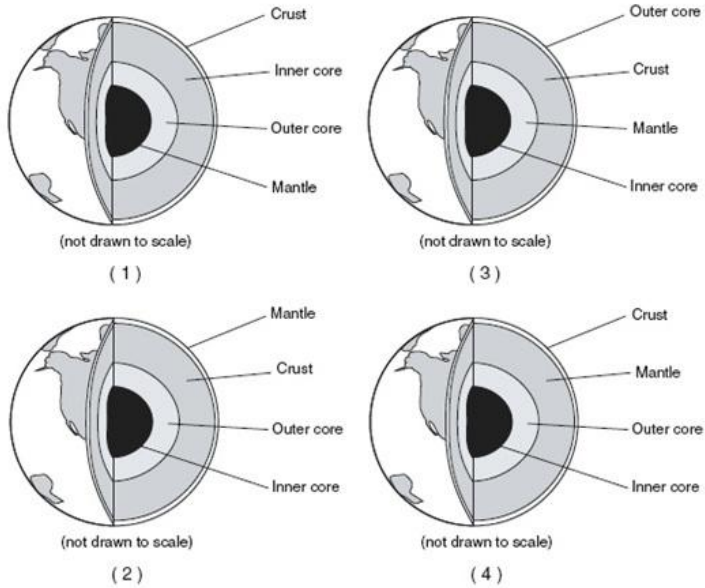


Appendix B: Multiple Choice Questions on Pre- and Post-test

Multiple choice questions on Pre-test and Post-test:

Assistment #158714 "158714 - Plate Tectonics PRE Test. POST is: 158713 "

A) In which diagram are the layers of Earth correctly labeled?



- 1 2 3 4

B)

Of the following, which of Earth layers has the greatest density?

- crust mantle inner core outer core

C) The crust and upper mantle make up Earth's _____.

- lithosphere asthenosphere core continents

D)

The cycle of heating, rising, cooling and sinking is called a _____.

- subduction zone convergent boundary convection current conduction current

E)

The movement of Earth's crust along plate boundaries produces _____.

- fronts tides hurricanes earthquakes

F) Active volcanoes are most likely to form at _____.

- transform boundaries the center of continents convergent continental-continental boundaries convergent ocean-continental boundaries

G) Plates of the lithosphere float on the _____.

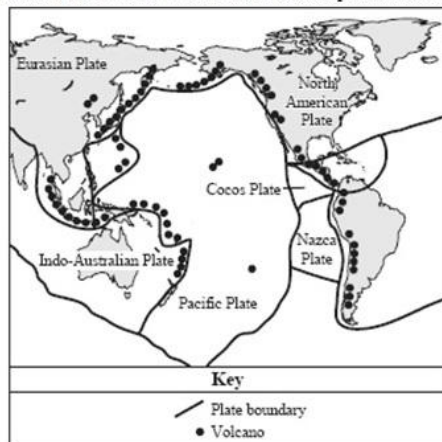
- crust asthenosphere core atmosphere

H)

The heat from deep in Earth's interior is transferred to its crust by which of the following?

- conduction in the ocean convection in the mantle radiation from the solid core evaporation at mid-ocean ridges

I) On the map below, dark circles represent the positions of volcanoes in the "Ring of Fire" in and around the Pacific Ocean. Dark lines represent tectonic plate boundaries of Earth's crust.



According to the map, where do volcanoes form?

- Volcanoes form in the middle of a tectonic plate. Volcanoes form below the surface of tectonic plates. Volcanoes form where tectonic plates meet other plates. Volcanoes form where earthquakes are least likely to occur.

Appendix C: Open Response Questions on Post-test

Open response questions, including transfer question (M), on Post-test:

J) Pretend that you are writing an explanation for a friend who did not do this activity: describe in as much detail as you can, the layers of Earth and how convection currents form.

K)

Pretend that you are writing an explanation for a friend who did not do this activity: describe in as much detail as you can, the process of how continental-continental plate convergence occurs.

L)

Pretend that you are writing an explanation for a friend who did not do this activity: describe in as much detail as you can, the process of how oceanic-continental plate convergence occurs.

M)

Using what you have learned (or already knew), pretend that you are writing an explanation for a friend who did not do this activity. Write an explanation for a friend who did not do this activity: describe in as much detail as you can, how the sea-floor gets bigger over time.

Appendix D: Scoring of Eye-tracking Data

Reading and viewing regions defined within Microworld 1

The Layers of Earth

RR1 Earth is composed of four layers: the crust, the mantle, the outer core and the inner core.

RR2 The crust is the thin outermost layer of Earth. There are two types of crust: oceanic crust lies underneath the oceans and continental crust lies underneath continents.

RR3 The mantle is below the crust. The mantle is 2900 km (1802 miles) thick. The uppermost part of the mantle is solid. This solid part of the mantle, together with the crust, makes up the lithosphere. The asthenosphere is a soft, flowing and rocky layer of the mantle sitting just below the lithosphere.

RR4 The outer core is thought to be a dense, hot liquid layer about 2190 km (1361 miles) thick. It is made of liquid iron and nickel.

RR5 The inner core is thought to be a dense, high-pressure solid about 2680 km (1665 miles) thick. It is made of solid iron and nickel.

RR6 The currents illustrated in the animation show the circular flow of matter. These are called convection currents. They occur when heat comes from the core and causes the asthenosphere to circulate. The dense matter deep in Earth is heated, making it less dense so it rises up through the layer. As it cools down, it becomes denser again, and sinks back down into Earth.

Reading and viewing regions defined within Microworld 2

Continental-Continental Plate Convergence

RR1 When two plates with continents on their leading edges meet, neither one is able to sink into the mantle because they are both equally dense.

RR2 In other words, both plates are made up of the same amount of land. Instead of sinking, the two continents continue to push on each other and crush against the boundary.

RR3 As the plates collide, the continents are crumpled and lifted, producing the highest mountain ranges in the world.

RR4 In areas around the world where we see mountains, the plates are constantly pushing and straining against one another. These mountains get higher and higher at a rate of 1/4 inch per year.

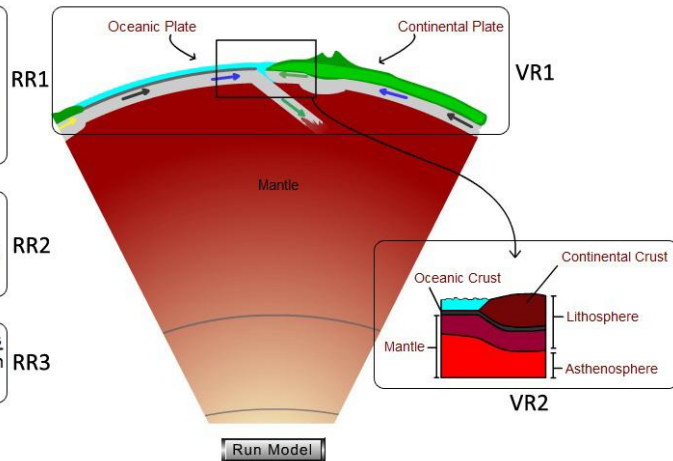
Reading and viewing regions defined within Microworld 3

Oceanic-Continental Plate Convergence

When an oceanic plate meets a plate with a continent on its leading edge, the continental plate rides over the oceanic plate because the continental plate is lighter, or less dense. This process of one plate sliding over another is called subduction.

When a subducted oceanic plate melts, it sinks into the asthenosphere which causes molten rock to rise through the continental plate. This creates volcanic mountain ranges. These volcanoes can be found along the edge of the continent.

The movement of the two plates against each other also causes stress to build in these areas. When the energy is released from these stressed areas, an earthquake occurs.



Screen shot of eye-tracking video illustrating fixations (red circles) and saccades (red lines)

uppermost part of the mantle is solid. This solid part of the mantle, together with the crust, makes up the lithosphere. The asthenosphere is a soft, flowing and rocky layer of the mantle sitting just below the lithosphere.

The outer core is thought to be a dense, hot liquid layer about 2190 km (1361 miles) thick. It is made of liquid iron and nickel.

The inner core is thought to be a dense, high-pressure solid about 2680 km (1665 miles) thick. It is made of solid iron and nickel.