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Table of Contents

Analyzing Responses in Adaptive Sequencing .......................................................... 3-9
Brigitte Eder, Faculty Mentor: Phil Kellman, Ph.D.

Biases of the Google Effect and Social Memory ................................................... 10-17
Caitlin M. Black, Faculty Mentor: Matthew Lieberman, Ph.D.

Perceptual Learning: Teaching with Computers .................................................... 18-26
Dustin Goldbarg, Faculty Mentor: Phil Kellman, Ph.D. and Everett Mettler, Ph.D.

Analogical Reasoning: Measuring Mnemonic Effects of Interference .................. 27-33
Ebi Rowshanshad, Faculty Mentor: Keith Holyoak, Ph.D.

The Effects of Game-Based Orienting Tasks on Memory Recall in Introductory Physics ....... 34-40
Elizabeth Shek, Faculty Mentor: Jesse Rissman, Ph.D.

Causal Relations of Instructional Mechanisms in Algebra Learning .................. 41-48
Fanny Hoang, Faculty Mentor: Patricia Cheng, Ph.D.

Program Depicting Illusory Objects in Spatiotemporal Boundary Formation .......... 49-55
Joanne Kang, Faculty Mentor: Phil Kellman, Ph.D.

The Neural Mechanisms of Episodic Source Memory ....................................... 56-62
Kaori Ito, Faculty Mentor: Jesse Rissman, Ph.D.

Eye Blink as a Phenotype for D2-Like Receptor Availability in Rodents ............... 63-71
Liseth Magana, Faculty Mentor: David Jentsch, Ph.D.

Can Daydreaming Help Improve Recall? .............................................................. 72-78
Natalie Redberg, Faculty Mentor: Robert Bjork, Ph.D.

Testing Spacing Against Fluency ........................................................................... 79-84
Robert Wilkinson, Faculty Mentor: Phil Kellman, Ph.D.

Perceptual Learning ............................................................................................... 85-91
Ruth Kebede, Faculty Mentor: Phil Kellman, Ph.D.
Analogical Reasoning .............................................................................................................. 92-98
Stephanie Sabatine, Faculty Mentor: Keith Holyoak, Ph.D.

Predicting Point Light Action During Binocular Rivalry ................................................. 99-106
Ye Eun Chun, Faculty Mentor: Hongjing Lu, Ph.D.
Analyzing Responses in Adaptive Sequencing

Brigitte Eder

Introduction

In the efforts to improve memory and learning, several types of scheduling and learner-customized procedures, or adaptive learning techniques, have been researched and implemented. While spacing out the presentation of materials over time has shown to be more effective than repeated presentations without any delays, it is still unclear which type of spacing schedule (equal or expanding) is more effective for learning over delays (Karpicke & Bauernschmidt, 2011). Expanding spacing has shown to be more effective than equal spacing for short term learning gains (Lander & Bjork, 1978). Past research in the field of adaptive learning, based off estimations of model parameters, has driven a new type of adaptive learning called Adaptive Response Time Based Sequencing (ARTS) which instead uses response time and accuracy as a measure of learning strength (Everett, Massey, & Kellman, 2011).

Geography and Adaptive Learning

The ARTS system was implemented in a geography study conducted at the University California, Los Angeles with undergraduate psychology students. The task was to match a highlighted country on a map of Africa to the country name from a list. Students were placed into three conditions: adaptive, fixed-equal, and fixed-expanding. In the adaptive condition, the equation for the ARTS system was used to adjust item presentation according to response time and accuracy (Everett, Massey, & Kellman, 2011). Subjects in the fixed-equal condition experienced equal presentations of 5 items in between each spacing, while the fixed-expanding condition experienced expanding intervals of 1, 5, and 9, items between presentations. All
subjects completed a pre-test, followed by training (in which one of three conditions was used) and an immediate post-test. They then returned one week later to complete a delayed post-test.

*Figure 1* shows the results from this geography experiment. There was increased performance in the adaptive condition on the delayed post-test, but no significant difference in the immediate post-test.

![Figure 1](image)

*Figure 1* Average scores for Geography Experiment

*Chemistry and Adaptive Sequencing*

After seeing successful results for adaptive sequencing for the geography experiment, we wanted to expand out to other, possibly more complex areas of learning, such as chemistry. Running chemistry experiments on college students can provide an added complication of various degrees of prior knowledge. While none of the subjects had taken chemistry while in college, all of them had taken some form of it in high school. In the African geography study, the amount of prior knowledge the subjects had was consistently much lower.

In order to attempt to replicate the geography study, this chemistry experiment used only element naming (24 elements in total) and did not include more complicated formulas such as
ions or acids. Subjects were placed into three conditions, just as in the geography study (adaptive, fixed-equal, and fixed-expanding). For all three conditions, subjects completed a pre-test, training phase, immediate post-test and a one week delayed post-test. The parameters used for the adaptive sequencing model (ARTS) were the same as the ones used for the geography experiment. Subjects were either presented with an element symbol and then asked to recall the name of the element or they were presented with the element name and asked to recall the element symbol. For both types of question they received feedback for correct and incorrect answers. For correct answers they were told how quickly it took them to reach that answer and for incorrect answers they were given the correct answer to the question.

The results for this experiment, shown in Figure 2, do not mimic the results from the geography experiment as we had hoped. As shown in the figure, the adaptive sequencing condition for chemistry did not show any significant improvement over the fixed-equal or fixed-expanding conditions in the either the immediate or delayed post-tests. In fact, the fixed conditions are show slight advantages for the immediate post-test. However, there is no measurable difference between the three conditions for the delayed post-test. While the pre-test scores from the chemistry experiment are also higher than those in the geography experiment, the differences from pre-test to immediate post-test and pre-test to delayed post-test still do not show any significant benefit to using adaptive sequencing over. These changes are shown in Figure 3.
Data Analysis

Due to these inconsistent results, we decided to look at data analyses by item. We did an individual analysis for the average scores each element across the three different conditions to see if there were significant differences in which conditions performed better for specific elements. The element/condition analysis is shown in Figure 4. We found a large variety across all the elements and were able to select certain elements for which the adaptive condition scored much higher than either of the fixed conditions.
Additionally, we looked at the types of errors that subjects were making when they were incorrectly inputting the name of the element after being prompted with the element symbol. We discovered five types of incorrect answers: misspellings, guesses, confusions (other elements), timeouts, and give-ups. Timeouts occurred when the subjects let the program time out without typing any answer, whereas give-ups occurred when the subjects hit “Enter” without typing anything or simply typed the question (element symbol) into the answer box. We then compared the percentages of incorrect error type for each element to the analysis of elements by condition and found some interesting correlations. For two elements in which the adaptive condition scored higher than either fixed condition (Manganese and Selenium), the percentage of misspellings (shown in Figure 5) were also fairly high (18% for Manganese and 11% for Selenium). We then compared these elements to two elements whose fixed-expanding results were higher than

Figure 4 Condition scores by item
adaptive, Silver and Barium. The percentage of misspellings for these two elements (shown in Figure 6) were much lower (4% for Silver and 4% for Barium).

![Figure 5 Percentages of incorrect answer types for Manganese and Selenium](image)

![Figure 6 Percentages of incorrect answer types for Silver and Barium](image)

We then decided to do further item analysis to compare the adaptive delays for items in which the adaptive condition did not do well and items in which it did perform better than the fixed conditions. The delays for Manganese and Sliver are shown in Figure 7.
The individual delays for Manganese and Silver show a much higher number of subjects who are still getting the answer incorrect at the second presentation for Manganese (seven) than those who are getting it wrong at the second presentation for Silver (three).

**Conclusions**

From these item analyses we can conclude several things. Adaptive sequencing works well for items that have high percentages of confusions and guesses but not for those with high numbers of misspellings. There is a possibility that a fixed-expanding schedule is better for items with high percentages of misspellings. This could be due to the fact that the program has no way of knowing when a participant is nearly correct (misspelling) compared to completely wrong. So in the fixed-expanding condition, the subjects still get the advantage of a spaced delay after a misspelling, while they will get an immediate presentation in the adaptive condition in this case. There is also a possibility that the results for the adaptive conditions are bimodal. When people do not have a problem with misspelling, the adaptive condition works well. However, when people misspell, the adaptive sequencing does not work and the average results are then pulled
down. We can conclude though, that the fixed-expanding and adaptive conditions are both better than the fixed-equal conditions for delayed learning retention.

Future Questions

If one of the problems for adaptive sequencing is the idea that misspellings are lumped into the same “incorrect” category as guesses and give-ups, then a solution might be the better detection of near hits. This would likely result in a formula change for the ARTS parameters. Other possibilities for further analysis are taking the pre-test scores into account and splitting up subjects into two different conditions, high prior knowledge and low prior knowledge, to see if the adaptive condition affects them differently. If adaptive sequencing truly works better for some items more than others, a hybrid system using fixed-expanding conditions for some items and adaptive sequencing for others might also make sense. It would also be interesting to see what happens when more complicated chemistry facts are introduced such as ion naming and acid naming and taking a look at the item analyses for these more complicated questions.
References


Biases of the Google Effect and Social Memory

Caitlin M. Black

According to the “Google effect” proposed by Sparrow, Liu, & Wegner (2011), constant access to information via the internet is slowly biasing our memory systems into focusing on the location of information rather than the information itself. The “Google effect,” as it has recently become known, is the growing dependence on technological sources to act as an external memory device. Sparrow et al. first demonstrated that when testing concepts of knowledge, thoughts about technological resources are primed. During a modified Stroop test in which participants were asked to name the color of words that were either technologically related, such as Google, Yahoo, Bing, etc. or non-technological terms, participants showed longer reaction times in naming the color of the technologically related terms after being asked conceptual knowledge questions. This effect illustrated that the technologically related terms were primed by conceptual knowledge questions. Furthermore, this study showed that when participants expected to have access to information for a memory recall test, but were not provided access to the information, participants performed poorer than participants who were told that they would not have access to the information during the memory recall test. In the third experiment, Sparrow et al. expanded on their previous findings and tested whether memory for the location of the information would be better if the information was believed to have been saved on the computer. Indeed, participants remembered the location (the computer folders that the information was supposedly saved in) of the “saved” information better than the actual information presented. However, participants were equally likely to not remember the information or the location as they were to remember only the location. Overall, participants
showed better recall for the presented information when they believed that the information had been erased.

Though the Google effect is a relatively new topic of exploration, psychologists have been studying similar topics of interest. The effect of a cheat-sheet on memory was studied by Dorsel & Cundiff in 1979; their study explored the dependency hypothesis in relation to the use of cheat-sheets as a crutch for performance. Participants in this study were separated into one of four conditions: No Cheat-Sheet, Cheat-Sheet/Unaware Unavailability, Cheat-Sheet/Aware Unavailability, and Cheat-Sheet/Aware Availability. All participants were given a pre-test to test their initial knowledge on the information they would later be tested on. Participants were then given an information paragraph and were instructed to follow the rules of their individual condition. Those in the No Cheat-Sheet condition were allowed to underline as a way of taking notes on the piece of paper that contained the information paragraph, but were not allowed to use these notes on the post-test. Subjects in the Cheat-Sheet/Unaware Unavailability group were allowed to take notes on a small sheet of paper with the expectancy that this note-sheet would be available during the post-test. The Cheat-Sheet/Aware Unavailability group was told that they would be able to take notes on a note-sheet, but would not be able to use these notes during the post-test. Finally, the Cheat-Sheet/Aware Availability group was told that they would be allowed to take notes on a small sheet of paper and would also be allowed to use these notes during the post-test. After allowing each group to read and study the information for ten minutes, each group was given a post-test (the same test given during the pre-test) under the conditions of their respective groups. Although the Cheat-Sheet/Unaware Unavailability group expected to use their cheat-sheet during the test, their cheat-sheet was taken away and these participants were told to complete the post-test as best they could without the cheat-sheet. The results showed that the
participants in the Cheat-Sheet/Unaware Unavailability group performed significantly poorer than the other three conditions, and there were no other significant differences between the remaining three groups.

The results from the Dorsel & Cundiff study (1979), in combination with modern day research, show that the Google effect is not limited to technology based resources, but is also present in other forms of information. This concept is important, as its properties further expand upon the current characteristics of the Google effect. Although limited research has been conducted in this field of memory, there are different aspects of the Google effect that can be explored.

To determine whether either the presentation format or the social-relevance of a paragraph can significantly affect memory, I propose the following experiment. I will first conduct a pilot study to match two socially relevant information paragraphs to two non-socially relevant paragraphs, based on reaction time (ms), for a total of four different information paragraphs used to elicit two different memory systems: social and cognitive. Sixteen short information paragraphs of both similar length and amount of information will be created and presented to the pilot study subjects; 8 of these 16 information paragraphs will contain socially relevant information while the remaining eight will contain non-socially relevant information. The presentation order of the information paragraphs will be counterbalanced across all subjects in order to account for primacy and recency effects that might bias participant reaction times. Participants will be asked to answer a series of true/false and multiple choice questions related to the information presented to them earlier in the experiment to test their accuracy and reaction time for each question. True or false and multiple choice questions were used for the ease of quantifying reaction times. Each participant will have approximately ten seconds to answer the
question presented and their reaction time and accuracy (number of questions correct) will be recorded. The resulting data from the pilot study will be compiled and compared based on reaction time. Average reaction times will be used to match two socially relevant information paragraphs to two non-socially relevant information paragraphs; this aims to counterbalance for difficulty of understanding among the four paragraphs, as these four paragraphs will be used in the main experiment.

The main experiment will build off of the pilot study by utilizing the resulting matched socially relevant and non-socially relevant information paragraphs in the pilot study to test not only differences in memory accuracy for socially relevant versus non-socially relevant information, but also expand on whether or not information presented on what appears to be an internet-accessible webpage (compared to what seems to be an internet-inaccessible word document) adversely affects memory, similar to the Google effect. There will be a total of four groups: Socially relevant information/Webpage format, Non-socially relevant information/Webpage format, Socially relevant information/Un-saved document, and Non-socially relevant information/un-saved document. This will allow testing of memory for format type (webpage vs. word document) without allowing the participant to realize what is being tested. A different group of participants from the pilot study will enter the study having read instructions stating that they are going to read four separate paragraphs and judge the paragraphs based on writing style, how interesting the paragraph is, and how much they can relate to the paragraph. The participants will then be presented with the four different paragraphs, counterbalanced across the subject pool to reduce potential primacy and recency effects. After the presentation of the four separate conditions, participants will be asked a series of true/false and multiple choice questions about the information paragraphs – similar to the pilot study.
Accuracy as well as reaction time will be assessed as a quantitative measure of remembered information.

I suspect that socially relevant information paragraphs will have faster reaction times and greater accuracy, based on the real-world necessity for accessing social information quickly and accurately in order to avoid embarrassing social situations. It seems more socially acceptable to pause before answering cognitive questions such as “When was the last time you ate sushi?” as opposed to socially relevant questions such as “How do you know Alexandra again?” Furthermore, I expect that simply formatting information to look like a webpage will bias a participant’s perception of the information’s accessibility and result in poorer memory than for information presented as an un-saved word document. By testing whether presentation of information as a webpage results in poorer memory, I am exploring whether or not our memory system is predisposed to shortcuts similar to the Google effect. If this unconscious memory shortcut actually occurs, the accuracy for information presented as a webpage will be lower than that of the un-saved word document presentation format. Finally, analyzing both the webpage format and un-saved word document format combines both the approach of Sparrow et al. with the approach of Dorsel and Cundiff (1979). The webpage format represents information that can be easily accessed on the internet, whereas the un-saved word document parallels the condition in which the cheat-sheet was taken away during the post-test. Overall, the proposed experiment will provide insight into the nature of memory biases related to the internet, as well as memory biases of the social memory system in relation to the cognitive memory system.
References


The issue of spaced versus massed learning is one that has been researched quite heavily in the past few decades, but the specific domains and conditions that are optimized by the spacing effect are still not concretely known or understood. In Pashler, Zarow and Triplett’s research conducted in 2003, they explored the benefit of spaced practice and determined if this benefit outweighs the negative effect that producing errors during learning can have. In 1968, B.F. Skinner proposed an idea of “error minimization” which asserted that the best way to learn material is to do it by making as few errors as possible. He thought that making an error would hurt the overall learning as this error could loom in the learner’s brain and be used to later incorrectly answer the same question. To avoid making errors during studying, practice should be massed. If there is a very short delay between instances that a certain item is practiced, the probability of an error being made is much lower than if the delay is long. However, according to the spacing effect, study bouts should be spread apart by long delays which inevitably leads to more errors during study. What this means is that we cannot employ these two ideas in the same study regimen. But which one leads to better overall and long term retention of information? Although, most of the time, learners believe massed practice is more effective, distributed practice is the superior learning strategy in terms of long lasting retention.

One reason why distributed practice is better is because it leads to greater encoding variability. What this means is that with spaced presentations of information, there is a wider variety of contexts in which the information is studied. This helps memory because more retrieval pathways are created that connect to the information. These pathways can be triggered through contextual cues. Thus, the more cues that lead to the information, the more likely
someone is to being able to remember the information. In the case of massed practice, on the other hand, the information is presented in the same context every time so there is no benefit of encoding variability. Another reason why distributed practice leads to better memory is that it leads to more attentive learning. When you study something repeatedly as in massed practice, you become habituated to the material. In other words, the depth of processing that occurs when you first see a new piece of information diminishes with repeated presentations. When learners become completely habituated to the information, studying becomes ineffective as they begin to simply passively or mindlessly go through the material. With distributed practice, there is a considerable amount of time that passes between each presentation. This helps to keep the material seem novel which will lead to deeper encoding and more attentive study.

It has been shown (Austin, 1921) that when a test is given immediately after practice, a massed practice strategy leads to performance that is as good and in some cases better than does spaced practice. Massed practice leads to rote learning which could explain this anomaly. Rote learning involves the memorization of material through repetition, so someone who has taken part in a massed learning strategy would be better at retrieving the information they just learned than someone who has practiced with spacing. Perhaps this is why the majority of people perceive massed practice to be more enjoyable and effective than spaced practice (Baddeley, Longman, 1978). When students cram the night before a test, they get through all of the material in a short amount of time and can even perform well on the test. However, those who space their practice will still have a better overall understanding of the material and will be able to remember the material for much longer than the rote learners.

Pashler, Zarow and Triplett conducted two related experiments to investigate how spacing between two initial tests would effect performance on a final test. The first experiment
involved subjects learning 66 words from the Eskimo language: Siberian Inupiaq. On the first day, the subjects went through 200 trials, seeing each of the Eskimo words, in the form of Eskimo-English word pairs, three times. The first exposure was a study trial, showing both the Eskimo word and the English word that it translated to. The second and third times each word was presented were test trials in which the Eskimo word would be shown and the subject had to type in the correct English translation. If the typed answer was wrong, the correct answer would be presented. The lag between the first exposure (study trial) and the second exposure (first test trial) was two intervening items. However, the lag between the second exposure and the third exposure (second test trial) was randomly assigned to either 1, 2, 4, 8, 16, or 32 intervening items. On the following day, subjects were tested, without feedback, on all the Eskimo words that had previously been studied. The data were analyzed to see if the variable lag between the second and third exposures would affect performance on the delayed test given on the second day. The results they found were quite telling. They found that the longer the lag after the second exposure, the worse the performance was on the third exposure. However, with increasing lag, the performance on the delayed test actually increased. The data was also analyzed to look at the performance on the delayed test depending on whether the subject gave the correct response on the second exposure (first test) or not. The findings show that with longer lags, subjects did better on the delayed test even when incorrect answers were given during the first test. What this tells us is that the benefits of spaced practice outweigh the proposed costs of error production during training. Additionally, this could shed light on why the majority of people mistakenly believe massed practice is more effective than spaced practice. With massed practice, people see immediate results. They study all the material subsequently and can answer the same questions repeatedly and fairly easily. But they do not retain the knowledge over a long period of time. In
fact, these findings show that they cannot even retain it until the next day. Spaced practice may seem harder to people in the short term, but has proven to be more effective in long term retention. The second experiment that Pashler, Zarow and Triplett conducted was very similar except for a few modifications. The first was that they used obscure English words instead of Eskimo words. Instead of word pairs, the words were paired with their definition. Another change was that they added lags of 64 and 96 intervening items. Lastly, the delayed test was changed from being given the next day to being given a week later. Similar trends were shown in the results from this experiment. Performance on the delayed test was better for items that had long lags than items with short lags. But something to note is that there was a slight decrease in performance on items with a lag of 96 intervening items. This suggests that the optimum lag is probably somewhere between 32 and 96 items.

The aim of the current study conducted by Everett Mettler is to improve adaptive learning technology by investigating how we can optimize spaced practice for each individual. The computer program that was used was an African geography learning module made up of a picture of Africa along with a list of country names. One at a time, a country would be highlighted within the picture of Africa and the participant would click on the corresponding country name from the list. First was a pretest in which participants would receive no feedback on their answers. Directly after that was the training phase. Participants would receive feedback after each of their answers and after every ten trials would be shown a bar graph of their performance. After the training phase participants took a post-test, again receiving no feedback. Finally, a week later, participants would come back to the lab to take a delayed post-test. The conditions differed in the order that the items were presented in the training phase. Some participants received item presentation in fixed intervals while others’ item presentation was
adaptive based on their performance. Responses from participants who were in the adaptive
condition in a prior experiment were used to construct the fixed interval schedules for
participants in the current experiment. This is referred to as the yoked condition. It is believed
that each individual has their own optimal learning schedule so it was predicted that individuals
in the adaptive condition would perform better than those with fixed item scheduling.

The data were analyzed in much the same way that Pashler, Zarow and Triplett’s were,
but the results greatly differed. In fact, there was more-or-less an opposite trend. Although not
statistically significant, the data in Figure 1 show higher performance on the delayed post-test in
the fixed interval conditions than the adaptive condition. What makes this finding perplexing is
that, also shown in Figure 1, those in the adaptive condition performed better during the training
phase. This follows what Pashler, Zarow and Triplett’s results found but conflicts with Skinner’s
theory of error minimization during training.

There is no simple answer as to why the acquired results appeared in this fashion, but
there are some important things to glean from the data. For example, the theory of error
minimization does not tell the whole story. In addition to avoiding errors during training, it is
also just as important that the training is difficult. There needs to be some thinking involved
during information retrieval in order to strengthen the memory. It is possible that the intervals
constructed for individuals in the adaptive condition were not long enough to produce long term
retention. That is why we see higher accuracy for the adaptive condition during training: errors
were minimized, but the difficulty of the produced schedules was too mild.

Perhaps we obtained these puzzling results because of differences found between
participants in this experiment and participants from the prior experiment in which the yoked
conditions were generated from. As shown in Figure 2, participants in the previous experiment
outperformed participants in the current experiment. There is no definitive answer as to why these differences arose. It is possible that there was a differential in motivation between the participants, but there is no evidence of this. In any case, a future experimental design should take this into account, possibly by generating yoked condition schedules based on participants from the same study rather than a previous one. This would decrease participant differences between yoke source and yoke target. Additionally, adding a within subject factor could increase the robustness of the design. Perhaps having a condition where the participants receive both adaptive and fixed items could lead to some interesting results.
Figure 1. Average accuracy by phase of experiment.
Figure 2. Number of participants who scored better than their yoke source.
References


Analogical Reasoning: Measuring Mnemonic Effects of Interference

Ebi Rowshanshad

The overarching goal of the current study was to understand more about the mechanisms involved during analogical reasoning (i.e., the cognitive process where inferences are generated between featurally dissimilar domains based upon similar, underlying relational structures). Previous studies have shown that introducing distracting information in the solving of geometric analogies (akin to Raven’s Matrices) produces decrements that have common and dissociable components with increasing the number of relational computations needed to solve the problem (Kroger et al., 2002). In fact, interference, defined as anything included in a problem that is not goal-relevant, impacts solving geometric analogies; In addition similar decrements in performance can be found across tasks which tap into cognitive processes such as attention and memory. In memory, a procedure called the retrieval practice paradigm has provided much insight for the workings of interference in retrieval dynamics (Storm & Levy, 2012). In this paradigm, participants are shown category-exemplar pairs (e.g., fruit : apple, fruit : orange, tree : evergreen, tree : maple). After studying these pairs, participants are then given retrieval practice for some of the words in some of the categories (i.e., in this example, they might see fruit : a_ _ _ _ , but NOT fruit : o_ _ _ _ _ ; and more importantly, they would not get any practice for the “tree” category). Results over many replications have demonstrated that recall for the words that were practiced (i.e., fruit : a_ _ _ _ ) was the best. This is not surprising given the extra practice. The interesting result comes from comparing words in categories that were practiced, but were not practiced themselves (i.e., fruit : o_ _ _ _ _), and words from categories that were not practiced at all (i.e., tree : e_ _ _ _ _ _ _ _ , or tree : m_ _ _ _ ). Results showed that memory for words from categories that were practiced, but were not practiced
themselves is significantly worse than for words that weren’t even practiced at all. Theories explaining this phenomenon refer to interference between category exemplars during the retrieval practice phase that leads to a suppression of non-practice exemplars when other exemplars in their category are practiced.

With regards to analogical reasoning, most models of reasoning take into account that there is interplay of long term memory (LTM) and short-term memory (STM) which is used when solving analogies. When making comparisons among domains, reasoners must retrieve information from their memory store to even begin to make comparisons. Once information is retrieved from LTM, specific types of information must be kept in STM long enough to see if these match across domains relative to a particular goal (i.e., making the relational bridge between two domains for successful analogical inference). However, current theories do not take into account what happens to information about each domain that is irrelevant when solving an analogy. For example, if a subject were to attempt to solve an analogy between a cell and a feudal kingdom, there would be plenty of underlying relational structures that could be compared (e.g., the wall around the kingdom is similar to the cell wall, or the castle situated in the center of the kingdom is akin to the cell's nucleus). Most theories of analogy use what's called the copy-with-substitution-and generation (CWSG) principle, when making inferences between two domains. Basically, this would take information from one domain (e.g., the castle wall), make a list of object-role relations (e.g., protects the castle from invaders, has drawbridges that control import and export of goods, etc.). Then they would make an isomorphic (i.e., one-to-one) connection between the domains and using other constraints, match the castle wall with the cell wall. Once the castle wall has been copied and substituted for the cell wall, the object-relations will be attached to the cell wall and minor changes can be made (i.e., the cell wall protects the
cell from harmful virus, it has protein channels that control the influx of ions, etc.). What these models are lacking, however, is characterizing what happens to irrelevant information in the processing of analogies and more specifically, what happens to information that would actually interfere with the ability to make the connection between one's mental model of a castle system and one's understanding of how a cell works.

The current study aimed to demonstrate that providing interference during an analogy would have implications for how information was processed during that analogy, specific to one's mental representation of the units representing each domain. To test this, we performed two studies, where we presented participants with an analogy trial, followed by a memory probe that tested their memory for information presented within the analogy. In the first experiment, participants solved two types of analogy trials: one where there was no interference and another where there was one piece of interfering information. Each interfering piece of information was interfering relative to solving the analogy (i.e., at a higher-order level when comparing the two domains presented). Three types of memory probes following each analogy trial were possible: a match (i.e., the identical pair of characters seen in the previous analogy, to which participants should respond "yes" to having seen that previously), an irrelevant mismatch (i.e., where a pair of characters was changed on a dimension that did not interfere with the solving of the analogy), or an interfering mismatch (i.e., where a pair of characters was changed on a dimension that previously interfered with solving the analogy). It should be noted that although match memory probes followed each type of analogy trial, by definition, an interfering memory probe could not have followed an analogy trial containing no interference. When comparing results for the analogy trials, performance was significantly worse when they included interfering information, replicating previous studies by Cho et al., 2007; 2009. What we added to the story was that
memory performance following analogy trials was significantly worse following analogy trials with interference than those without it. In other words, if there was interfering information in the previous analogy trial, people were less likely to discriminate between a match memory probe and one changed based on that interfering information.

A second study was conducted to expand on the results of the first experiment, and to test one specific limitation: memory performance may have differed not because the information was based on an interfering dimension, but because the memory trial came after an analogy task that was harder to solve. To control for this, a second experiment was run in which all trials had interference. Thus, any differences in memory performance for the irrelevant and interfering mismatch could not be due to the task demands on the previous analogy trial. Otherwise, experiment two would be identical to experiment one in its procedure. Our results from experiment two shows that memory for items based on interfering information was significantly worse than memory for items that were irrelevant, but were in line with solving the analogy. This can also be seen in the previous example with regards to cell and feudal kingdom analogy, irrelevant information would be akin to knowing about the castle and the nucleus when you were trying to make a comparison based on the cell and castle walls. Although, the nucleus and the castle are not relevant to your current comparison, the fact that they, too, are analogous would not interfere with your overall analogical comparison. However, the interfering information would be akin to thinking about the roads in the kingdom and comparing them to the ribosome in the cell. Although they seem to match, there are striking differences, such as that the roads are stationary and provide the means for carriages to travel on them, the ribosome directly transport information themselves. Therefore, this information would seem to be a strike against the analogy, and would interfere with your decision to say that these two domains were
analogous.

Although the results from experiment two were striking, another alternative explanation exists. Basically, the way we operationalized interfering information was taking a pair of characters in the analogy, and changing one of them based on the interfering dimension. The result of this change would necessarily lead to making this new pair analogically comparable to the other pair in the analogy. Perhaps, the difference in poor memory for interfering memory probes could be attributed to the fact that these were now in line with the analogical schema, and that the increase in false alarms had nothing to do with suppressing information about the previous mental representation, but rather was a bias induced by making this pair more schematically compatible with the previous analogy. To test this, we are currently designing a third experiment that will directly test whether the schematic alignment hypothesis or the interference suppression hypothesis is more accurate in predicting people’s recognition performance. Specifically, by adding in another memory probe based on the interfering information, but changing two of the characters (e.g., if the original characters were black and white, the change would make them white and black, respectively). This would result in a difference in memory from the original representation, but would still not be schematically congruent within the analogy (i.e., if the color was interfering before, it will still interfere), therefore making it easier for the participant to successfully reject this memory probe as something they had previous seen. If, however, the interference suppression hypothesis is correct, then information about the interfering dimension - in this example, color - will be weakened no matter how many transformations are performed, and more importantly regardless of whether it is schematically alignable within the previous analogy. Therefore, this hypothesis
would make the prediction that memory should be just as worse for this memory probe given the reasoner suppressed the interfering information related to this dimension.
References:


The Effects of Game-Based Orienting Tasks on Memory Recall in Introductory Physics

Elizabeth Shek

Even with our current unemployment rate of 13 million Americans, nearly half a million jobs are going unfilled. What these jobs have in common is a need in educational background in science, technology, engineering and mathematics – collectively known as STEM. In a recent study by the Lemelson-MIT Invention Index, 60 percent of young adults named at least one factor that made them reluctant from pursuing further education or work in the STEM fields (Engler, 2012). There is clearly something about our education system that is turning students away from the STEM fields. Whether explicit lectures are not attention grabbing enough or whether students are finding the sciences to be too difficult and unappealing, we need to change the way we cater to our students K-12 to enforce engagement and promote learning in these fields.

Research scientist in Education and professor, Dr. Val Shute argues that the education curriculum does not sufficiently assess or prepare students for the twenty-first century technological world. Furthermore Shute writes that traditional classroom assessments not only fail to influence learning, but also lose their validity in today’s system (Shute & Venture, in press). In a recent report, every second high school drop out admitted that the reason for their dropping out was that classes were simply not interesting (Shute & Venture, in press). We need to find more interactive and engaging ways to get our kids more involved in their education, help them learn and better remember information and inspire them to challenge themselves and continue to higher education.

Recent studies have shown that game play may have positive effects on the brain. Games are shown to improve visuo-spatial capacity, decision making and object tracking in healthy
individuals (Bavelier, Green, Han, Renshaw, Merzenich & Gentile, 2011). Schools are changing to implement games as models for learning, creating a novel environment that allows students to develop competence in STEM learning, cultivate 21st century skills (systems thinking, collaboration etc.) and teach hard to grasp concepts in fun, interactive ways. This research proposal intends to target students from a primary middle school age where STEM learning is first introduced and test how learners remember physics concepts through an interactive medium (a game).

Passively lecturing a young middle school crowd may not be sufficiently attention grabbing. On the other hand, embedding hard to teach concepts into a visually stimulating game may dramatically increase student attention and engagement. In this research, a game will be used as an orienting “task to perform on the stimulus material” (Hyde & Jenkins, 1969). The stimulus material will be a list of fundamental physics concepts. Research shows that the most successful orienting task is one that employs a deeper level of processing (Craik & Lockhart, 1972). The level of processing induced by the orienting task determines the outcome of retrieval. As coined by Craik and Lockhart, levels of processing stages are referred to as "depth of processing" where greater "depth" implies a greater degree of semantic or cognitive analysis and thus better memory.

In past design, orienting tasks have been separated into conditions according to shallow or deep level of processing and subjects were typically tested on word recall. An example of a previously used “deep” condition is judging if a word is part of a category (Craik & Tulving, 1975) or judging its pleasantness (Hyde & Jenkins, 1969). In this design, the game will be assumed as “deep” level of processing since it will utilize a higher degree of cognitive analysis through problem solving and game challenges. Meanwhile the control lecture-based condition
will be assumed to have a lower level of processing since students are “passively receiving information from the instructor” (Prince, 2004). Hyde and Jenkin’s (1969), varied depth of processing and intention to learn and found highest recall in the deep level of processing condition (judging pleasantness) when combined with an orienting task and instruction to learn the words (intentional + task).

The orienting task in this design will be playing a visually stimulating game. Incidental instructions will ask the student to interpret the pop-up physics laws to guide the game and complete the challenges, while the intentional condition will ask the students to try to memorize the physics laws as they play the game for a memory test later. In the recall only control condition, students will be asked to memorize the physics concepts as they hear them during a lecture for a later quiz (control - intentional learning). According to Craik and Lockhart (1972), “with an appropriate orienting task and an inappropriate intentional strategy, learning under incidental conditions could be superior to that under intentional conditions” (p. 677).

The purpose of this research is to prove that passively listening to lecture stimulates a lower level of processing, and that better memory of hard to grasp concepts is achieved through an interactive game based medium. Based on the results of Hyde and Jenkin’s and of Craik and Lockhart, I hypothesize that the groups encoding physics concepts through a visual game will both retain significantly more information than the control group that receives an explicit lecture. Furthermore, I hypothesize an insignificant difference in retrieval between the incidental and intentional group in the game-play condition since both will be employing a deep level of processing to engage in the game. These results would be consistent with Mendler’s (1967) results that showed similar level of recall for the incidental learning group with “deep” LOP (categorization of words) and the intentional learning group who performed the same orienting
task (Craik & Lockhart, 1969).

**Method**

**Participants**

Participants will be middle school students (grades 6-8) in a Los Angeles private school. Participants will be randomly assigned to one of the three conditions (game + incidental learning, game + intentional learning and lecture) for a total of two weeks.

**Design**

A between subjects design will be used to observe the number of physics concepts recalled in a free recall post-test. The independent variable being manipulated is the intent of learning (incidental or intentional). The dependent variable is the number of physics concepts recalled in a free recall post test.

**Procedure**

A game called Aero will be utilized in this project. Aero will be a visually stimulating game of an Albatross flying above the sea. Arrow keys will be used to move the bird up and down through obstacles. A series of targets will be in the air that the bird can fly through. The targets will be challenges that the learner must figure out by utilizing the pop-up messages/hints that will start off each challenge. For example, if the challenge concept is “gravity”. The pop up message will read a definition of gravity and ask the learner to keep the bird flying straight using the up and down arrows, hinting that when the gravity and lift vectors are of equal magnitude, the bird will fly straight. The Albatross will have vectors on each side of him showing magnitude of gravity, lift, thrust etc. In order for the bird to fly straight, the student will have to watch the vectors as he or she manipulates them using the arrow keys. After all the challenges are completed and all the concepts are learned, the game ends. Each student will get a tutorial of
how to use the arrow keys to become familiar with the game before it starts.

Students will be divided into three groups in a random fashion. Groups one and two will play Aero with either instructions to “play the game using the pop-up messages as guides” or to “play the game and try to memorize each pop-up message for a memory test later”. The two groups will be known as the incidental learning condition and the intentional learning condition, respectively. The third recall only control group will receive a lecture on the physics concepts with instructions that they “will be asked to recall the concepts later”. After the two weeks, the three groups will be asked to recall as many physics concepts as they can in one class period.

*Expected results*

I expect to see the highest percent recall for students in the game-task intentional condition. I predict an insignificant difference in recall for students in the game-task intentional versus incidental condition. Furthermore, I predict the lowest percent recall in the lecture based intentional condition. I expect my results to look somewhat like the figure below.

![Expected Results](image)

*Discussion*

If my expected findings prove to be correct, we will have further evidence that the traditional lecture regimes are growing out of date and not engaging students enough. This effect would be consistent with past research on traditional lecture learning that found significantly
improved performance for students in classes with substantial use of interactive-engagement methods (Prince, 2004). Low level of recall in the intentional lecture condition will show a more shallow level of processing than in the two game based conditions. With this research we can change the way students learn novel material and ultimately increase excitement in the much needed STEM fields.

A shortcoming in this study is that it doesn’t necessarily check for understanding of the material. We are assuming that the student is learning to play the game by memorizing the physics laws and applying them but it is possible that the student is applying a trial and error technique. Additionally, students (especially at a younger age) can get distracted by the visual stimulation of the game, enough that they do not pay attention to the physics concepts and fail to remember anything at all.

The above is an implication for future research. We can continue testing for game task memory retrieval and manipulate levels of visual stimulation to create a game that is neither boring for students nor distracting. We can also continue testing for transference in learning from game-based design. If students can remember physics concepts in relation to the Albatross in Aero, can they transfer this knowledge to other physics related scenarios? Game based learning has huge potentials for the future of our education. If memory recall increases in a simple game, then we can test and develop many more games that target different subjects and recreate the curriculum of education to cater to the needs of the students in the 21st century.
References


Causal Relations of Instructional Mechanisms in Algebra Learning

Fanny Hoang

Abstract

Effects of traditional and contrasting instructional procedures in algebra learning over time were examined in this experiment. College students presented with a contrast conceptual method of algebra solving instructions performed better over time. Students presented with a traditional method of algebra solving instructions saw a decrease in performance over time. There was increase in performance with the contrast condition with self-explanation, but a decrease with the traditional condition with self-explanation. Though the sample size is small for the experiment, the common trend for all conditions is that the traditional group did better initially, but over time, performed dropped. The contrast group did better over time, suggesting there was better learning and transfer of concepts.
Causal Relations of Instructional Mechanisms in Algebra Learning

Mathematics is a subject taught in school that is not only important for making real world calculations, but also important in toning general problem solving techniques. Higher-level mathematics such as algebra is more complex to solve and there are many different instructional methods teachers can use to teach students in school. The type of instruction and how it is presented is important, as previous research has found that different designs of instructions: instructions based on procedural instructions, principles, and examples, have different factors that either help or hurt learning performance as a function of instruction type (Eiriksdottir and Catrambone, 2011).

Eiriksdottir and Catrambone (2011) describe and distinguish the different types of instructional designs with each type representing different levels of information type and abstraction. Procedural instructions describe the step-by-step process in carrying out the task; principles give rules of the task domain and the task itself; examples guide how to carry out a task with or without explanations (Eiriksdottir and Catrambone, 2011). In this experiment, we focus on comparing procedural instructions to instructions based on principles and concept. Examples are used as well as self-explanation in some of the conditions. Performance over time is examined with a focus on performance from the immediate posttest to the delay posttest. We want to address the transfer problem in mathematical instruction and hope to find instructional methods that will best lead to better learning and transfer of conceptual material. Overall, we see a trend of increasing performance with principles and conceptual instructions and an initial increase in performance with self-explanation.
Method

Participants

College students of UCLA were recruited through the UCLA SONA online system and received course credit for their participation. This was a two-part study in which the first part of the experiment was performed on the computer and the second part was perform on paper with a delay time that ranged from 5 to 26 days. Subjects totaled to 110 participants, but 90 subjects’ data were analyzed after outliers and perfect pretest scores were discounted for.

Materials and Procedure

For Part 1 of the experiment, students were given an algebra pretest that consisted of multiple-choice questions and solving for x problems; it was scored out of 18 points. After completing the pretest, subjects were assigned a condition and on a computer, presented with instructions on how to solve algebra problems, specifically with factoring and solving for a variable. Subjects then completed a number of practice problems where the last four problems were used as an immediate posttest; they were then given a short questionnaire to fill out about the first part of the experiment. After a time delay, participants returned for Part 2 of the experiment where they took a 12-question posttest and completed a post-experiment questionnaire.

There were five conditions and subjects were given a different condition randomly. Two conditions were traditional conditions (T and TS) based on the traditional procedural instructions where step-by-step instructions were presented to subjects prior to having them solve practice problems. The instructions gave an example and could be viewed again for reference in sequential windows. The TS condition had a self-explanation addition where between questions, subjects were asked to evaluate what they just learned and explain it in words. Two other
conditions (CS and CE) were contrast conditions where subjects were asked to solve problems first before given an explanation of how to solve the problems. They were then asked to compare the problems they previously attempted to solve. In the CE condition, subjects were asked to rate the explanations, whereas, in the CS condition, subjects were asked to evaluate and self-explain the problem solving concept. A last condition, TK, had subjects watch two videos on YouTube from the Khan Academy, which provided step-by-step instructions and examples on how to solve algebra problems. The subjects were then given a practice problem set after watching both videos.

There were 19 subjects in the CS condition, 18 in the CE condition, 20 in the TS condition, 16 in the T condition, and 17 in the TK condition. 38 subjects fell into the short delay group, which was seven days or less. 52 subjects fell into the long delay group, eight days or more.

Results

The data was collected and a two-way ANOVA with one factor being the five conditions and another factor being delay period, short and long delay, was performed. With 90 participants, there was already a between-subject difference in pretest scores across conditions. For posttest scores, the means were taken with the CE condition scoring the highest score overall with an immediate posttest mean of .7222 and delayed posttest mean of .6772. Differences between delayed and immediate posttest means were taken. For the CS short delay group, there was a 0.01 increase in mean from the immediate to delay posttest and a 0.034 increase for the long delay group. For the CE condition, there was a 0.14 decrease in mean from short to long delay in the short delay group and a 0.016 increase in the long delay group. The CE condition had the highest immediate posttest mean of .8571 for the short delay group. The TS condition
saw a decrease in mean from immediate to delay posttest with a 0.0357 drop for the short delay and 0.195 drop for the long delay. The T condition also decreased with 0.1428 for the short delay group and 0.0911 for the long delay group. The TK group had an increase in mean for the short delay group at an increase of 0.125 and a decrease of 0.1489 for the long delay group.

Discussion

The basic trend for all conditions follows that the contrast group improved in performance as time went by. Though for the CE condition, the mean dropped for the short delay group from the immediate to delayed posttest, overall, for both groups there was still an increase in performance. Though there is no significance in performance, we do see an increasing trend. For the traditional conditions, performance decreased more drastically over time and all traditional conditions subjects did poorer with the delayed posttest. The T condition saw the largest decrease from immediate to delayed posttest in the short delay group.

Though the study is working with a small sample size, an apparent trend is already forming in that the trend for the traditional group is a decrease in performance over time. This may be attributed to the idea that learning traditionally, or by procedural instructions is based on rote memorization. While this may be good for performance initially because subjects are able to solve problems by following the same steps to solve a problem, this does not help for transferring of principles and concepts. A previous study by Wiedenbeck (1989) and Pirolli (1991) concluded the same idea that it was mostly rote memorization with using procedural instructions and examples, and there is actually no abstraction or learning of the task principle (Pirolli, 1991; Wiedenbeck, 1989). Another thing with being given traditional instructions is that people generally want to exert the least amount of effort required to solve something (Szlichcinski, 1979) so while instructions are meant to help subjects, it could be very well that
subjects neglect thoroughly reading and comprehending instructions, especially with the participants being students who have previously taken an algebra class in middle or high school prior to college. In this case, it is not surprising to see the traditional conditions performing worse as time goes by because it is likely that there is no abstraction occurring; rather, subjects are merely using memorization to get through solving basic and similar algebra problems. This poses problems as the problem solving concepts are not really being learned and subjects will be unable to solve transfer problems, problems that pose to be more difficult but can be solved similarly.

There is an apparent trend in the contrast group, as it sees improvement over time in both the short and long delay groups from the immediate to delayed posttest. This suggests that subjects may have internalized the principles of algebra problem solving better and that some transferring of concepts has occurred. This conceptual transfer may be attributed to the usage of principles in the contrast instruction conditions. By not providing step-by-step procedural instructions eliminates the ability to rely on memorization to solve problems. Participants in this contrast group may possibly be engaging in higher order implicit thinking with having to think for themselves in how to go about solving problems. Participants in this condition are asked presented problem comparisons between similar problems and even though there may be failure of understanding mathematical procedures initially, they are presented with the correct way of solving problems. The usage of principles is helpful in transfer as understanding principles will lead to better understanding of the task domain and having a better understanding of the task system can lead to better learning when it comes to transfer and problem solving (Eiriksdottir and Catrambone, 2011). So while traditional procedural instructions may be lead to good
performance initially, instructional techniques that incorporate principles and forcing subjects to think on their own may prove to be better in the long run for transferring.

A previous study by Chi, Bassok, Lewis, Reimann, and Glaser (1989) found that there was more self-explanation in well-performing students and the self-explanation involved making notes about the task’s principles and relationships between variables in the problem. Self-explanation makes learners active and engages them in metacognition, which improves learning and transfer (Chi et al, 1989). What is interesting is that with the traditional condition that asked participants to give self-explanation, there was not an increase observed in the TS condition over time in performance. Instead, the TS condition saw a large drop in performance, especially in the long delay group. This contradicts previous research, but the contrast condition CS with the self-evaluation does see an increase in performance over time. Good learning and transfer then requires learners to be engaged in effortful cognitive activities and to be actively thinking when problem solving. With more research and more data to add to this study, the relations between different types of instructional mechanisms can be further examined.
References


Program Depicting Illusory Objects in Spatiotemporal Boundary Formation (SBF)

Joanne Kang

This program shows a rotating shape in the center of a field of dots. This program was created in order to show that even though no shape is actually drawn (it is actually just a bunch of dots that are changing color), people still perceive an actual shape rotating in front of their eyes. This project stems from Dr. Kellman and other researchers' previous research in illusory objects in Spatiotemporal Boundary Formation (SBF). This code is created to run on MATLAB and Octave.

```
try
Get the information about the user's screen.
screens = Screen('Screens');
screenNumber = max(screens);
Colors used for this project: Black is the color of the background,
white is the color of the dots that are not in the polygon (the square),
and darkRed is the color of the dots that are within the polygon
black = [0 0 0];
white = [255 255 255];
darkRed = [255/2 0 0];
Opening the window: This command opens the window on you computer screen for the experiment.
[win, winRect] = Screen('OpenWindow', screenNumber, black);
```
Make the image look nice. This command makes the dots on the screen appear smoother.

```matlab
Screen('BlendFunction', win, GL_SRC_ALPHA, GL_ONE_MINUS_SRC_ALPHA);
```

Seed the random number generator

```matlab
tau = clock;
rand('state',sum(100*tau));
```

Get the width and heights and center values for the screen:

These values are needed to place the object in the polygon of the screen

```matlab
[width height] = RectSize(winRect);
[cx cy] = RectCenter(winRect);
```

Shape scaling matrix: this matrix will be used to scale the size of the polygon

```matlab
scaleShape = [1.05 0 0 0; 0 1.05 0 0; 0 0 1.05 0; 0 0 0 1.05];
```

Retrieve the starting point of the shape. Next, scale the shape so that the dots disappear properly

```matlab
startingPosition = [0 -50; 100 -50; 100 50; 0 50];
startingPosition = scaleShape * startingPosition;
startingPosition(:, 2) = startingPosition(:, 2) + cy;
currentPosition = startingPosition;
```

The number of pixels of the square (numPixels * 2)
numPixels=50;

This matrix defines the x and y coordinates of the polygon. The cx and cy coordinates center the polygon. Also note that since the y-axis is inverted, the upper portion of the object (cy-numPixels) has a smaller coordinate value than the bottom coordinates (cy+numPixels).
startingPosition = [cx-numPixels cy-numPixels; cx+numPixels cy-numPixels; cx+numPixels cy+numPixels; cx-numPixels cy+numPixels];

Define a new matrix that takes the value of the staring position of the polygon. Also, define the degree of rotation of the polygon. In every frame, the polygon will rotate by 3 degrees.

currentPosition = startingPosition;

deg=3;

Rotation matrix to be multiplied with the position of the shape to achieve rotations.
RotationMatrix = [cosd(deg) sind(deg); -sind(deg) cosd(deg)];

Specifications of the dot size of the dots in the grid (10px), the number of dots in the grid (600), and the color of the dots in grid (darkRed)
dotSize = [10];
numDots = 600;
dotColor = repmat(darkRed,numDots,1);
These variables store the dimension of the field of dots. In this case, the field of dots will be 500 by 500 pixels.

```matlab
x_dimension = 500;
```

```matlab
y_dimension = 500;
```

The "Dots" matrix stores all of the dots that will appear in the 500x500 grid. 

MakeUniformPlayground is an external function that is called by the program in order to create the field of dots shown in this program.

```matlab
Dots = MakeUniformPlayground(x_dimension, y_dimension, numDots);
```

Dx and dy gets the distances between the x and y coordinates of the matrix center and the center of the screen. This is important because these values will be added to the Dots matrix to center the dots in the field.

```matlab
dx = (cx - (x_dimension/2));
dy = (cy - (y_dimension/2));
```

Add the centering distances to the entire first row (x_coordinates) and to the second row (y_coordinates) in order to shift the field of dots to the center of the screen and not to the top left corner.

```matlab
Dots(1,:) = Dots(1,:) + dx;
```

```matlab
Dots(2,:) = Dots(2,:) + dy;
```
Animate the shape in the center of the field of dots. It should look like there is a red square in the middle of the screen rotating.

Animation will occur until the user presses a key on the keyboard.

while 1

[IN ON] is a matrix that gets all of the coordinates of the dots that are in or on the shape. This is an important feature because it gets all of the coordinates of the dots that need to change colors from white to darkRed.

[IN ON] is a predefined command.

[IN ON] = inpolygon(Dots(1,:), Dots(2,:), currentPosition(:,1), currentPosition(:,2));

Determine dot colors based on if the dots are in the shape or not.

The dots are white if they aren't in the shape. They are darkRed if they are in or on the shape.

Note that only one dotColor matrix is being updated. This is important because the DrawDots command can only handle one matrix with all of the colors of the dots in it.

dotColor = repmat(white,numDots,1);
dotColor(IN,:) = repmat(darkRed,sum(IN),1);
dotColor(ON,:) = repmat(darkRed,sum(ON),1);

Draws the dots on the screen based on the previous Dots matrix.

Screen('DrawDots', win, Dots, dotSize, dotColor', [0 0], [1]);
"Flip" the screen to update the picture on the screen. This makes it look like there is animation happening

Screen('Flip', win);

Update position of square:

Subtract the center coordinates from every point in order to apply rotation matrix

currentPosition = currentPosition - [cx cy; cx cy; cx cy; cx cy];

Apply rotation to the shape. Every time this while loop is entered, the shape is rotated by three degrees more than the previous time.

currentPosition = currentPosition * RotationMatrix;

After the rotation has been applied, add the center coordinates to make the polygon appear like it is rotating in the center of the screen

currentPosition = currentPosition + [cx cy; cx cy; cx cy; cx cy];

This if statement checks to see if the user presses a key on the keyboard.
If they do, the animation ends.

if KbCheck
  break;
end
The program waits for another key press to close the screen
KbWait;
KbReleaseWait;

Close the screen
Screen('CloseAll');

This try-catch duo catches errors (if there is one) and reports them in the main window after the program has closed.
This can be really helpful for debugging the code later on.
catch
Screen('CloseAll');
psychrethrow(psychlasterror);
end
Screen('CloseAll');
The Neural Mechanisms of Episodic Source Memory

Kaori Ito

Introduction

Episodic memory is essential to remembering past personal events, including what we ate for breakfast and who our childhood friends are. Because of its importance in daily functioning, episodic memory is at the forefront of research in cognitive science. In the research project I am currently taking part in as a research assistant, episodic memory was unsurprisingly one of the areas of focus. The main goal of our study was to find the role of the rostral prefrontal cortex (rPFC), and we integrated memory, reasoning, and perception tasks to test whether the rPFC is implicated in task-switching and monitoring. However, in the present paper, I will direct my focus on the memory component of the reasoning, perception, and memory (RPM) study and discuss the neural mechanisms of episodic source memory as found in fMRI studies.

Summary of components of source memory & its relevance to RPM

Recognition in episodic memory is composed of item memory and source memory. Item memory is the sense that items are familiar, whereas source memory is the recollection of the contextual details in earlier encounters. In item memory, a person may know that they have encountered a situation before, but not know where. This is also called the “know” paradigm. An example would be having a déjà vu—having the strange sensation that the same situation has been encountered before, but not being able to recall when it had happened. In source memory, a person should be able to recall the situation and details of an encounter that they had previously, the “remember” paradigm. However, source memory is a more general concept than a memory’s context. It includes bounded information on perceptual information, spatial details, temporal details, semantic information, emotional information, and records of the cognitive operations.
engaged. Furthermore, source memory has high differentiation, which means that more than one feature is combined to form a memory that is separate from another (Mitchell & Johnson, 2009). Source memory is further broken up into two controlled operations: retrieval cue specification and recollection monitoring. Retrieval cue specification is when characteristics of potential sources to a retrieval cue are evaluated. In the example given in the 2002 study by Dobbins et al, cue specification would be conjuring up a friend’s characteristics (e.g., whether she is a bookworm or shopaholic) to remember whether she was at the library or at the mall. Efficient episodic memory retrieval is determined by the ability to consider the most relevant characteristics of the memory cue (Dobbins et al, 2002). Recollection monitoring is the process of checking the correspondence of the retrieved memory to the cue. This cognitive process is important for determining relevancy because irrelevant information to the cue may be recollected in a recognition test.

In the RPM study, participants were given a list of words to memorize on the first day of the study. Subjects were instructed to imagine the word in either a “self” context or an “other” context. For example, if the word “rake” was presented with the “self” cue, I would picture myself raking my back yard. Conversely, if the word “flowers” was presented with the “other” cue, I would picture my sister (or anyone else) planting a flower. On the second day of the study, participants were put under the fMRI scanner, and they were given a recollection test on the words they had been presented on the previous day. On a screen with four words, one or none of the words would appear, for which the subjects had to choose between the following options: 1, the word that was encoded was associated with the “self” context; 2, the word was associated with the “other” context; 3, one of the words is familiar, though the context is forgotten; and 4, all four words are novel. The first two options reflect source memory; the third option in which
the word is recognized, but the context in which it was encoded is forgotten—a reflection of item memory.

Regions involved in source memory encoding and retrieval

The prefrontal cortex (PFC), posterior parietal cortex (PPC), and the medial temporal lobe (MTL) are all regions that have been heavily implicated in episodic memory. I will discuss the implications of these areas in episodic memory in the proceeding portion of the paper.

The prefrontal cortex (PFC)

According to Shimamura, the prefrontal cortex is thought to be used in top-down processing to “select, maintain and update relevant event features, which comprise the multitude of conceptual, emotional, and sensory features that make up an episodic event” (2011). Lesions in this area are thought to disrupt feature binding and other processes used for revival and evaluating source information (Mitchell & Johnson, 2009; Shimamura, 1995). Many fMRI studies have found that left lateral PFC shows more activity during source memory judgments, relative to familiarity. This finding has been found across different types of source information, including location, size, and cognitive operation performed. Right lateral PFC shows greater activity when it comes to heuristic judgments (which are thought to be used more for item recognition and familiarity). The left PFC has also been found to be in active for systematic monitoring of specific information, according to the source monitoring framework. The production-monitoring hypothesis, on the other hand, proposes that the right PFC is in charge of all types of monitoring, while the left PFC is engaged in production of memory retrieval (Mitchell & Johnson, 2009). In terms of remembering, “old-new” studies (in which participants are given the task of recognizing old items that they have previously encountered when they are presented again with new items) implicates that dorsolateral PFC was involved in updating and
manipulating retrieved features in complex and goal-oriented retrievals (Mitchell & Johnson, 2009; Shimamura, 2011). The ventrolateral PFC is found to be more active during maintenance of item features, semantic access, and initiating retrieval (Shimamura, 2011). These findings are supported in the 2002 Dobbins study, in which they found that anterior LLP is engaged in controlled semantic analysis tasks and phonological maintenance, and the frontopolar and/or posterior dorsolateral regions are involved in recollective monitoring.

Posterior Parietal Cortex (PCC)

The PPC (inferior and lateral areas) is also a brain area that has been found to be involved in source memory across multiple studies. Some studies have found that the PPC is more active for responses in which greater specificity is evaluated—the PPC was more active for Remember responses than Know responses in a study of long-term memory (Wheeler & Buckner, 2004). The PPC is currently considered one of the most active regions during successful retrieval of episodic memory, regardless of the stimuli type used (Shimamura, 2011). It is implicated in source memory, as it shows greater activity during source recognition tasks than item recognition tasks (Dobbins et al, 2002). The PPC shows more activity for correct “old” recognitions than for correct rejections. Furthermore, when incorrect recognition trials are assessed, PPC was found to be more active for false alarms, in which participants incorrectly responded that a new item was “old”, than for correct rejections. Even more interestingly, PPC activity is greater in high-confident correct rejections than low-confident correct rejections. This implies that PPC is reflective of one’s subjective feelings of remembering (Shimamura, 2011). The PPC, similar to the PFC, is functionally segregated: the ventral PPC (vPPC) has been observed to be involved in episodic retrieval and source recollection and is a marker for later retrieval success, while the dorsal PPC (dPPC) appears to be associated with nonspecific attentional processes and is more
involved when judgments require more effort (e.g., when a person has a harder time coming up with the source) (Shimamura, 2011; Wheeler & Buckner, 2004).

The Medial Temporal Lobes (MTL)

The medial temporal lobe regions are in charge of binding various features stored in separate regions of the brain into one memory. The MTL is necessary to facilitate initial retrieval and reactivation of memories, by accessing the events that are bound together (Daselaar et al., 2006; Mitchell & Johnson, 2009; Shimamura, 2011). The MTL is composed of the hippocampal formation, perirhinal and parahippocampal cortices. The amygdala is also a part of the MTL, which explains the role of MTL in modulating emotional memory. Because of its function in memory, the hippocampus has been a topic of many memory studies. In these studies, the hippocampus, specifically, has been proposed to be engaged in binding features across time and space into episodic memories during encoding and remembering. The perirhinal cortex is typically more active for incorrect source items, which contributes to the idea that it supports item memory. The parahippocampal cortex, unlike the perirhinal cortex, produces more similar activations with the hippocampus. The parahippocampal cortex has been suggested to be more active for contextual information (Diana et al, 2007; Mitchell & Johnson, 2009). Currently, there are some problems with the methods for mapping MTL functions, including the assumption that incorrect source judgments reflects familiarity. Thus, it is useful to make inferences about the MTL region’s functional role in episodic memory, but better specificity in the basis of these findings is still needed (Mitchell & Johnson, 2009).

Conclusion

Episodic memory is an essential cognitive process, not only for daily functioning, but also for our society to function (say, for eyewitness testimony). The research findings in
cognitive science have a fairly good grasp on what areas are implicated for episodic source memory encoding and retrieval (again, the MTL, the PCC, and PFC). However, there is still plenty of room for a further, more concrete understanding of local functions within each of the regions implicated in source memory. Future research, including the RPM study, will work towards illuminating the workings and mechanisms of memory.
References:


Eye Blink as a Phenotype for D2-Like receptor Availability in Rodents

Liseth Magana

Abstract

D2-like receptor density could possibly predict predisposition to drug use in humans before addiction begins. Eye blink is related to inhibitory control disorders such as drug addiction. Eye blink was measured for phenotype consistency, and was found to be consistent in a cohort of rats across days. There is a link between inhibitory control and inhibitory control disorders like addiction. There is also a link between inhibitory control and D2-like receptor density in humans and in animal models. Together these findings suggest that D2-like receptor density could be a common molecular mechanism bridging observed inhibitory control dysfunctions with addiction.

Keywords: Eye blink, striatal D2-receptors, inhibitory control, addiction
It is observed that inhibitory control disorders such as substance abuse affect only some of the population. In an effort to determine why certain individuals are more likely to develop substance abuse, different studies in both human and animal models have implicated a dopaminergic, biochemical pathway (Groman et al., 2011).

Chronic exposure to drugs is thought to produce a reduction in the striatal D2-like receptors availability. Specifically, substance dependent individuals show low D2-like receptor levels (Volkow et al., 1993,2001; Lee et al., 2009). Similarly, animal PET studies showed that chronic exposure to drugs can produce reductions in the striatal D2-like receptors availability (Groman et al., 2012). There is also evidence that preexisting lower D2-like receptor levels in animal models may lead to inhibitory control disorders (Groman et al., 2011).

Reversal learning tasks are used to measure inhibitory control. In these tasks subjects first learn to direct their behavior to a rewarding stimulus and in the reversal task they must update their behavior to the new stimulus. This change from established pattern reflects behavioral flexibility. These tasks are linked to D2-like receptors. For example, during the reversal phase of a reversal learning task, monkeys with increased D2-like receptor availability showed a decrease in number of trials required to reach criterion. While monkeys with low D2-like receptor availability showed the opposite effect. Therefore, preexisting low D2-like receptor availability in animal models may lead to drug abuse by altering inhibitory control processes (Groman et al., 2011).

It follows that D2 dependent dopamine transmission maybe a common neural pathway to inhibitory control, and given that inhibitory control is related to addictive disorders, these suggest that D2 receptors may be a common molecular mechanism bridging inhibitory control dysfunction with addiction (Groman et al., 2011).
However, because PET scans are expensive, time consuming, and difficult to implement, a noninvasive phenotype that indexes the functionality of D2-like receptors is needed.

Eye blink is dependent upon dopaminergic signaling (Elsworth et al., 1991). Elsworth and colleagues showed causal evidence linking the dopamine pathway to eye blink in vervet monkeys. They used both D1 and D2 agonists and antagonists, dihydrexidine and SCH 23390 respectively, to show a significant change in eye blink. In unpublished data collected in our lab, spontaneous eye blink rates in rodents were found to correlate with neuroimaging assessments of D2-like receptors and not D1-receptors. Specifically, subjects with lower D2-like receptor availability had lower eye blink rates than subjects with higher D2-like receptor availability.

This significant effect linking D2-like receptor availability and eye blink rate indicates that eye blink can serve as a way to measure D2-like receptor availability, and as a result test for inhibitory control, and therefore inhibitory control disorders. Moreover, it may suggest that D2-like receptor agonists could benefit individuals whose primary symptom is inhibitory control, a behavioral deficit common in drug addiction (Groman et al., 2011).

Since human inhibitory control disorders such as substance abuse are linked to inhibitory control, and there is also evidence that inhibitory control is linked to D2-like receptor availability in animal subjects, it is important to provide causal evidence implicating a D2-like receptor change to a change in eye blink rate. By selectively manipulating the D2-like dopaminergic system with haloperidol, a D2-antagonist, we hope to cause an up regulation of available D2-like receptors. We expect this to match onto an increase in eye blink. As a first step in determining a causal relationship between D2-like receptor availability and eye blink rate, we measured the reliability of spontaneous eye blinks in a healthy cohort of 6 male rats across three days.
A consistent measure here would indicate a reliable phenotype that is independent of behavioral differences and dependent on a common biological substrate.

Methods

Participants

Six healthy male rats were used in the current study.

Materials and procedure

A transparent and movement limiting cage was constructed in order to record the rats eye blinks. The cage was not much wider than the rat but allowed for free vertical movement. Prior to recording, all rats were habituated to the cage. They were placed in the cage for one hour a day, for three days. After habituation, subjects were recorded for 40 minutes using two high definition cameras that were placed 180 degrees from each other. Each camera corresponded to left and right views of the rat.

The videos were played back simultaneously on two computer monitors and videos were scored using a program developed in house. This program allowed users to document the occurrence of an eye blink and the periods of time when subjects were visible. Eye blink was defined as a spontaneous eye closing making the pupil temporarily nonvisible. The rater began by scoring trial videos of healthy rats until reaching a statistical reliability as compared to a cohort of previous raters. Eye blink rate was calculated by determining the number of blinks that occurred per visible minute.

All data was analyzed using SPSS software (version 15).

Results

The number of eye blinks per visible minute in the healthy cohort of rats was analyzed
for statistical significance. Eye blink measurement of each rat across all scoring days was reliable. As indicated by a Cronbach’s α of .771 (Figure 1).

In other words, the number of eye blinks of each rat on different days did not vary by a statistically significant amount. Indicating that eye blink rate is a reliable phenotype.

Summarizing, there was a consistent measurement for each rat, for each day of scoring videos. The average eye blink reported was two to three eye blinks each minute, and scores were consistent throughout subjects. This indicates that number of eye blinks in rats could be a reliable tool to measure D2-like receptor availability. This also suggests the need for a causal experiment that tests if eye blink in rats is in fact a phenotype for D2-like receptor availability.

Discussion

Previous work indicates D2 dependent dopamine transmission maybe a common neural pathway to inhibitory control which is also related to human addictive disorders. In an effort to understand if D2 receptors may be a common molecular mechanism bridging inhibitory control dysfunction with addiction we have begun to test the reliability of the eye blink phenotype. As previously mentioned, further defining this phenotype between eye blink and D2-like receptor density is important because of the demonstrated link between impulse control, its related inhibitory control disorders, and D2 availability.

Here, we have demonstrated that a cohort of 6 rats showed a consistent number of eye blinks across days. This indicates that eye blink is based on a common biological substrate, and is likely not due to other environmental effects. Based on previous work we suspect that the common biological substrate is D2-like receptor availability. By administering a dopamine antagonist, haloperidol, we hope to cause an up-regulation of D2-receptor availability. We then
expect the number of eye blinks before and after this direct manipulation to increase respectively.

If we measure eye blink after the antagonist is given, and eye blink rates are increased, we may be able to show a direct causal relationship between D2-like receptor availability and eye blink rates.

The present results raise many questions promoting future research. We will investigate the idea that there is a common molecular mechanism linked to change in D2-like receptors. We will achieve this by administering haloperidol, an antipsychotic and D2 receptor specific antagonist. We predict that blocking D2-like receptor availability will increase the D2-like receptor availability that should lead to a causal influence, increasing eye blink.

Having completed the first step in one rat cohort provides evidence that this way of measuring the phenotype can be reliable and suggests that it is important to move forward in further describing the D2-like receptor mechanism and its link to inhibitory control. Results from future causal research have the ability to directly affect the lives of many people suffering from inhibitory control disorders such as drug addiction. It is possible that D2 density could predict drug taking behavior and characterize predisposition before addiction ensues. By identifying higher risk individuals we could intervene at an earlier age, before drug addiction.
Figure 1. The relationship between eye blinks on day two (EBR_Day2) and on day three (EBR_Day3) show a positive correlation.
References


Can Daydreaming Help Improve Recall?

Natalie Redberg

Abstract

This experiment was designed to test the effect of daydreaming on learning. Daydreaming is “mind wandering that involves off-task thought” (Smallwood & Schooler, 2006). Previous studies have shown that daydreaming after learning causes forgetting of the information learned before the daydream, with the amount of forgetting varying as a function of how “far” the mind wanders (Delaney et al., 2010). Studies on list-method directed forgetting have shown that when participants are presented with two lists and cued to forget List 1, they have worse recall of List 1 than participants without the forgetting cue. They also show better recall for the list that they are supposed to remember (Pastötter et al., 2012). This effect is thought to be due to the release of List 1 from proactive interference due to remembering List 2. Thus, the current study replaces the forgetting cue with a cue to daydream during a learning task. The cue given to the participants after the presentation of a first set of information will be manipulated. Participants will either be instructed to daydream or to do a set of given math problems. Then they will be presented with a second set of information to be learned. It is predicted that results will show that participants in the daydreaming condition perform better on the second set of presented information (to-be-remembered) and worse on the first set of presented information (to-be-forgotten) than the participants in the control condition.
Can Daydreaming Help Improve Recall?

Daydreaming is a state of “mind wandering that involves off-task thought” (Smallwood & Schooler, 2006). Traditionally, daydreaming has been considered counterproductive to learning and remembering. Previous research has suggested that daydreaming can have an amnesic effect on memory from before the daydream. For example, in a study by Delaney et al. (2010), university students who had recently been on a vacation (either foreign or domestic) were told to study two lists of words, which appeared one by one on a screen. Between the presentations of the two lists, participants were told three different sets of instructions determined by random assignment. In the control condition, they were told to complete a multiplication task as quickly as possible. In the first daydreaming condition, participants were told to imagine a domestic vacation that they had been on and to describe it in detail. In another daydreaming condition, they were instructed to imagine and describe an international vacation that they had been on. List 1 was remembered best by the participants in the control condition, followed by the domestic vacation daydream condition. Participants who daydreamed about an international vacation recalled List 1 the least. Delaney and Sahakyan attribute this cost to context change. (2005) The more different the context is from the current situation, the more forgetting will occur. They suggested that daydreaming provides an internal context change, which causes substantial forgetting of information that was encoded in a non-daydreaming context. The mismatch between encoding context and retrieval context causes the reduction in recall.

Delaney’s research demonstrates and explains the “cost” part of the list-method directed forgetting paradigm. The context change causes forgetting of what was just learned. Pastötter et al. (2012) explain the “benefit” of enhanced remembering of List 2 in terms of release from
proactive interference by List 1. They suggest that a forget cue causes “reset-of-encoding” (Pastötter and Bäuml, 2010) as the forgetting gets rid of the memory load of List 1 and resets encoding for List 2. This releases List 2 from the effects of proactive interference.

The purpose of the current study is to find out if daydreaming can be used as a sort of directed forgetting cue to improve recall of information learned post-daydreaming. Based on the results of Delay et al. (2010), I hypothesize that daydreaming will work to reset encoding for post-daydream information and cause forgetting of pre-daydream information.

**Method**

**Participants**

Participants will be undergraduate students from psychology classes at the University of California - Los Angeles. They will complete the experiment voluntarily for course credit. Participants will be randomly assigned to one of the two conditions, either the daydreaming condition or the math problems condition. There will be an even number of participants assigned to each condition.

**Design**

A between-subjects design will be used to observe the difference between the testing scores of the two conditions for both the pre-task related questions and post-task related questions. The independent variable is the task presented between the two sections of information being learned – either daydreaming or math problems. The dependent variables are the number of questions answered correctly for both the pre-task and post-task related questions.

**Materials**

The information presented to participants will be the same for all trials. It will be an approximately four minute long section from an audiobook recording of Nelson Mandela’s
autobiography “Long Walk to Freedom” playing on a computer with a blank screen. This section will be split into two approximately two minute halves, in between which the participants will be given the cue for either the daydreaming task or the math problems task. For the daydreaming task condition, a prompt will appear on the computer screen after the first section of the recording. It will instruct them to imagine the last vacation they went on, to draw a picture of it, and to write about it in detail. For the math problems task, the participant will be given twenty different two-digit multiplication problems to complete as quickly as possible. When the participants complete the assigned task, they will hear the second half of the recording. They will then be given a test on the computer with open-answer questions about the recording they just heard. Twelve of the questions will be on information from before the task and another twelve will be on information from after the task. Two of the questions will be overall summary questions. The questions will be given in a block randomized order. At the end, participants will be given a survey to see whether or not they knew what the experiment was about.

Procedure

Participants will be run individually so that the audio could be played out loud instead of through headphones. All participants will fill out an informed consent form prior to the experiment. The task for both conditions will be to listen to the first half of a section of the audiobook, do a task (daydreaming or math), then listen to the second half of the audiobook, and take a test on what they just listened to. The instructions for both conditions will be given on a computer screen. If participants have any questions, an experimenter will answer them prior to the experiment or during the task. Each half of the audiobook recording will be approximately two minutes long, and the participants will be given ten minutes for both the daydreaming task and the math problems task. At the end of the experiment, the participants will be given a survey
to see if they have prior knowledge on what the study is about, and then the experimenter will
debrief them on the experiment. The participants will then receive their course credit.

Results

I predict that for participants in the daydreaming condition, the scores on pre-test
questions will be on average lower than the scores of participants in the math condition. In
addition, I predict scores on the post-task questions for the participants in the daydreaming
condition will be higher than the scores of participants in the math condition. My hypothesis is
that the results will look somewhat like Figure 1.

![Figure 8](image)

Discussion

The purpose of the study is to determine the effect of daydreaming on learning and
whether or not it could be useful. I am particularly interested in seeing if the “benefit” of the list-
method directed paradigm will be present in the daydreaming condition. If it is, this could have
implications for using daydreaming as a constructive learning tool in classroom settings. If the
results look like what I predicted, it is possible that daydreaming could serve to “reset” encoding for information being learned after the daydream. The reason for this could be that people “empty out” their brains of what came prior to the daydreams, thus causing less mind-wandering after the purposeful daydreaming task. If this is so, daydreaming could be a useful tool in classroom settings. If students are instructed to daydream prior to listening to a lecture, they may be less likely to let their minds wander while they are supposed to be learning information.

After this study, it could be interesting to examine several different factors. It could be useful to vary the qualities of the information presented pre- and post-task. For example, the information in this study is related (both pre- and post-task information is about Nelson Mandela), so there could be an effect that participants recall pre-task information better because they are somewhat reliant on it when they recall post-task information since the information is related. Retrieval of post-task information could be giving them a benefit of remembering more pre-task information. Perhaps the difference in the daydreaming condition between pre- and post-task could be greater if the information was unrelated.
References


Testing Spacing against Fluency

Robert Wilkinson

In working in the Human Perception Lab, specifically in research on the spacing effect, I was immediately interested in the concept of an adaptive algorithm for learning, whether it be in the realm of spacing or elsewhere, as background research shows perceptual learning’s implications in areas as marketable as advertising (Appleton-Knapp, 2005). As earlier studies in the lab showed success for the adaptive algorithm for spacing using geography map memorization and chemistry element name and symbol memorization, I was interested in the discussion of these perceptual learning applications, especially for classrooms and standardized math testing, as previous research explicitly notes the relevance of spacing in the classroom (Dempster, 1988). When recalling my own history with standardized testing, I thought more on the fluency effects of seeing material learned in classrooms in a new format— from the style of word problem/number problem to even the font and presentation (sheet vs. booklet). This is rooted in the increased processing which results from more unusually displayed/formatted materials (Greifeneder et al., 2010). When thinking about what is missing in applying classroom knowledge to the real world, I keep coming back to the necessity to build a basis of examples beyond just word problems, but to actually use fluency changes to create a comfort level with the material to the point where the content is greatly abstracted. While in practice this may come down to showing different teaching modules, exam types, and practice problems, the isolated lab method of examining the effects would be best as a continuation of the past memory studies, adapted from the adaptive spacing memory modules, but updated to test fluency effects. Essentially, my interest would be in a design of testing adaptive spacing against adaptive fluency to determine if the effects are additive or if one is indeed superior.
Method

Design

The study would use a one-way between-subjects design to examine the compared effects of fluency, spacing, and the combination of the two in fixed and adaptive cases. The independent variable will be learning technique, with six levels - fluency, adaptive fluency, spacing, adaptive spacing, combination, and adaptive combination. These levels are operationally defined as going through a complete computer module of the stated learning method. The dependent variable will be the participants before and after scores on pre and post tests up to one week later as in the previous geography and chemistry modules as well as the possibility of noting later standardized test scores for follow up.

Materials and Procedure

Participants would be given a computer based multiple choice math pretest, where an algebra problem would be displayed on screen with four choices to select from. After the pretest, there will be a learning phase where the participant sees one of the six levels of teaching method. The fixed spacing case will show problems at fixed intervals in a 5-5-5 fixed equal or 1-5-9 fixed expanding schedule, and the adaptive case modifying the spaced schedule based on correct/incorrect responses. For the fixed fluency condition, problems would cycle sequentially, without an expanding schedule, but on each rotation after a correct answer, the problem would be redisplayed in increasing dissimilar forms. For example, the first rotation would have a new font type and size, the second would space the information and multiple choice answers differently on the page, and finally the problem would be re represented as a word problem. In the adaptive fluency case, missed problems would result in the presentation being reverted to the original or cleanest form, similar to the spacing case pushing the missed problem up in the
queue. Finally the combination fixed case would add the presentation changes to the appropriate spacing position, for example a correct answer would move the question to be re asked five trials away and with new font. The adaptive combination case would space out problems dynamically and re present them, as well as scale back when they are answered incorrectly.

Discussion

In testing adaptive spacing, the design would use the previously established modules which monitor response time to indicate learning to push a question back or forward in the queue of questions depending on if it was answered correctly or incorrectly to predict optimal spacing. This manipulation has been shown to push memory to “bend without breaking,” effectively hitting the temporal sweet spot where enough time has passed to make an effortful recall, but before the information has been forgotten. However, for fluency and adaptive fluency cases, the response time model would need to be adjusted, given the delays associated with encountering a slightly or very different problem format.

To test fluency, a correctly answered question would be presented again in a different format, ie. an algebra problem shown numerically versus being presented as a word problem, or even shown with different font sizes, colors, and on different parts of the screen. This manipulation goes in line with desirable difficulty effects, in which a new or harder format will create more effort in processing, giving more neural connections for recall (Baddeley, 1978). I feel this manipulation could be even more practical than the adaptive spacing because of the many formats children might see problems presented in. While spacing trials might indeed have a stronger effect in promoting memory, training students in many different presentations seems more suited to prepare them for standardized tests, in which the format (including using a booklet, bubbling in, and strict timing) is relatively new or shocking, coming from local
classroom style/informal testing (Dempster, 1988). While the spacing effect is simpler to implement by moving a correct question back by a discrete number of units, fluency changes could be more subjective. For example, after one correct answer, the font and color might change, after the second correct response, the page presentation might be rearranged. Eventually the problem would be in an entirely different number into word format, hopefully showing a gradual transferability of problem structure knowledge.

In the combination trial, a correctly answered question would be moved back in the queue of new questions, and would be presented differently.

I would hypothesize that the combined condition would provide the greatest increase in learning for later tests because both more neural connections are being made from the fluency effects on presentation, and because the spacing effect is taking place (Greifeneder, 2010). Following the “bending but not breaking” memory idea, this combination allows for small jumps in separate directions, ideally if the spacing increment isn’t significant to create a memory trace, then some change in the presentation might pick up some slack. If the subject isn’t completely overloaded with input, which given the fairly standard display would seem unlikely, the combination condition shows promise in adding some desirable difficulty to either the spacing or presentation realm. Essentially, only one of these effects would need to improve a memory trace in order to improve later recall.

Overall, I think the use of algorithms for learning is full of opportunity, as most of the modern models for educations are relics of the industrial revolution. The textbook/analog model of rote memorization more akin to the fixed equal (5-5-5) schedule has been seen as inferior to even the fixed expanding schedule for many types of information (Baddeley, 1978). Research in adaptive perceptual learning algorithms shows the trend of optimization leading away from the
old method of fixed memorization. In the digital age with such an emerging knowledge of brain and memory functionality, it only seems natural for educational models to make the most of such innovations.
References


Perceptual Learning

Ruth Kebede

Throughout our lives, one thing that we can never escape is learning, whether consciously or unconsciously. From the age of 5, children are brought into schools to “learn” and the conventional ways in which people are taught have been primarily accepted all around. This involves explicitly showing students different concepts procedurally in the hope that students will fully understand. These are the methods that underlie elementary, middle, high school, and colleges everywhere. Though these ways have worked well, what if there was another type of teaching that could supplement and help people better understand concepts? Essentially, what if there was a new way to learn, a more efficient or maybe even a just easier way to learn? Would school, as we know it, change? To take it further, could this possibly help people learn to improve diagnoses of patients, and could it even cross domains throughout life? The notion is Perceptual Learning. To think back, perceptual learning was one of the only ways babies could learn in their first year of life. Without the ability to explicitly learn from others, babies have the job of pulling-in relevant information from their surrounding to learn (Kellman & Garrigan, 2009). Could these methods translate to now? All these are questions that are important when considering perceptual learning as a way to teach

What is perceptual learning?

Researchers everywhere have long studied the process of learning. In research, there has been an emphasis with humans in “encoding items in memory (declarative learning) and learning sequences and actions (procedural learning)” (Kellman & Garrigan, 2009). Unfortunately, there has not been much of an uproar in using perceptual learning (PL) to teach despite its implications. Perceptual learning is “an increase in the ability to extract information from the
environment, as a result of experience and practice with stimulation coming from it” (Kellman & Garrigan, 2009). Basically, PL is not based on explicit teaching methods but the belief is that, through experience, the brain will pick up the necessary concepts to understand the task at hand.

Relevant to perceptual learning is the concept of experts in different domains. In the example of Chess experts, there is essentially no way to explicitly teach someone up to an expert level but rather repeated exposure to the game is what causes these experts to find relations perceptually that help them get to the next mastery level which could take years. To go further, the differences between middle level players and experts do not involve explicit knowledge but it appears to be perceptual learning effects, which are “exceptional abilities to encode rapidly and accurately positive and relations on the board” (Kellman & Garrigan, 2009). This is what essentially underlies the concept of perceptual learning. It aims to create these connections at a relatively faster rate than average by producing learning modules specific to domains (Kellman & Garrigan, 2009).

In order to test and efficiently use perceptual learning, laboratories have created perceptual learning module’s (PLM), each directed towards the concepts specific to the domain being studied. These modules are essentially developed to test the perceptual learning abilities of humans. For example, with a chess PLM, there might be many different board set-ups repeatedly shown, and the subject may be asked what the best move would be without being explicitly taught on what is best and what is not before hand. There are definitely problems in developing these PLM’s across the different domains. One is that there is no concrete way of knowing what the best techniques are to make modules for a specific domain. For example, a module for math differs from the way a module for chess would be made. Modules may also need to differ depending on the participant, a master at chess might need a different module compared to a
novice in order to benefit greatly. Regardless of the problems that arise, studies using PLM’s have created amazing results across the many domains of study.

*Perceptual learning in high school & middle school*

A great example of this is with high school and middle school student studies. A math PLM, called *Multi-Rep* PLM was developed to “help middle and high school students develop pattern recognition and structure mapping with representations of linear functions, in graphs, equations, and word problems.” (Kellman, Massey, Son, 2010). The PLM consisted of mapping questions that had either a target equation, word problem, or graph. The students were then to choose, based on the original target, which other representation out of the three representations was the same. For example, a student would have a target graph and the three options could be 3 different equations, with the correct answer being the equation to the target graph. This study lasted two consecutive days in class periods; the first day consisted of the pretest, and PLM or, for the control, a practice packet. During the second day, the students finished their PLM or packet and did the posttest. It is important to note the posttest consisted of translation questions that “required the students to generate a correct equation, graph, or word problem” (Kellman et al., 2010). Results showed that students that did the PLM did considerably better on the posttest than the control group that only had packets.

The points to take from this study is that the students in the PLM condition did not explicitly do any type of equation solving, word problem solving, or receive any procedural or declarative instruction (the common method of teaching for high school and middle school students), yet they were able to do much better than the control students that did have most of the above things (Kellman et al., 2010). Thus showing that the PLM students were able to map important information and make necessary discriminations by merely doing the questions in the
PLM. They did not need anybody to show them these discriminations because they were perceptually learning through the repetition. This shows that there are certain concepts that cannot be explained in the current way of teaching in grade school; some things can only happen perceptually.

The power of perceptual learning in k-12 can drastically alter the results of students, and help them better learn these concepts in a comparatively shorter amount of time. There are many more studies that show that perceptual learning can even create longer lasting understanding, essentially there could be no need to recap as much in the end of chapters of subjects. The implications that PLM studies have on schools go far beyond the above mentions concepts; which makes this area of research even more worthwhile to education. This can be translated to the workforce as well.

_Perceptual learning in workforce/higher education_

Just as the major distinction between a middle level and expert level chess player are perceptual learning effects, the major distinction between novice and experts in piloting skills is the same. A couple studies done by Philip Kellman and Mary Kaiser (1994), used two PLM’s. PLM1 focused on visual navigations whereas PLM2 focused on instrument relationships and cross-check. For PLM1-visual navigation, the conditions consisted of a group of experienced pilots, and three groups of inexperienced. Out of the inexperienced subjects, one group was explicitly taught the necessary instructions to do well, such as the fact that highways and rivers are good points of reference, and the others were implicitly taught using the PLM’s. The task at hand was to view visual displays of real scenes and make judgments on their locations. The second study used PLM2-instrument relationship which consisted of a display of the aircraft instrument panel and subjects were tested on their ability to speedily know what would happen if
certain button were pressed. The subjects consisted of 10 naïve, and 4 experienced pilots. (Kellman & Kaiser, 1994)

Results show that in both studies for non-pilots and pilot’s, response time was considerably reduced. Also, for non-pilots, accuracy improved drastically. The greatest finding in both is that “naïve subjects after training performed as accurately and reliably faster than pilots before training” (Kellman & Kaiser, 1994). These studies only consisted of two training days and the fact that naïve subjects were able to get to the same level as the pilots before going through the modules shows that perceptual learning has the ability to speed learning. This also suggest that these modules could possibly make people experts at a relatively faster rate than the conventional ways of pilot training. The naïve subjects were able to make the necessary connections to do well without explicit instruction. Also, pilots improved on accuracy for the PLM1-visual navigation. These results are of significant importance because pilots recurrently make mistakes on visual navigation (i.e. landing in the wrong airport, getting lost). Unfortunately, “it is not difficult to turn up 100 reports in which visual navigation errors seriously compromised safety” (Kellman & Kaiser, 1994). Essentially, modules in this field could create greater safety, and enhance the learning of the naïve and experience pilots.

Review

These are only one a couple examples of possible workforce/education PLM implications but there are many more for several other domains. Such domains are dermatology, making it easier and quicker for medical school students to learn relevant concepts, which can produce highly educated doctors with more accurate diagnoses. Also, currently in the production stage is an EKG PLM, with the hope to produce a higher rate of accurate diagnoses and reduce the chance of misdiagnoses in heart related problems. Furthermore, in education, topics such as
chemistry are currently being studied producing the same above mentioned results.

The possible implications of perceptual learning are vast and outnumber even what is currently known. Correctly implemented, this could revamp the education system, as we know it. If perceptual learning were to be developed as the new conventional way of teaching, there is no knowing how much of an impact it could have on education, the work force, and essentially society. Research in this field is not only extremely useful, but it tells us more about the abilities of the brain in regards to learning.
References


Analogical Reasoning

Stephanie Sabatine

The Reasoning Lab at the University of California, Los Angeles is directed by Dr. Keith Holyoak and Dr. Patricia Cheng and is home to a variety of research focused on thinking and reasoning. Much of this research explores analogical reasoning, which was the main focus of my research and thus this paper. I was privileged to work as a research assistant for Michael Vendetti under Dr. Holyoak for Fall 2012, my first quarter working in a research lab on campus, and it has been a very interesting and fulfilling experience.

As a Computer Science and Cognitive Science major, I have always been interested in the mechanics of human cognition, and the Reasoning Lab has been a great opportunity for me to explore some of its remaining mysteries. One of the main projects I have assisted with this quarter is a series of experiments testing analogical induced forgetting. Additionally, our research team held weekly meetings to disseminate information and review useful and interesting papers that have recently been published in research journals, and a subset of us met for an additional weekly meeting to learn about MRI technology and its use in Cognitive Science research. This including receiving a through introduction to the FMRIB Software Library for use with experiment data.

Analogical is a type of role-based relational reasoning. It involves many different processes, including retrieving preexisting “source” knowledge to apply to the target problem, comparing the structures of the problems, and generating new inferences (Holyoak, 2012; Holyoak & Koh, 1987). The preexisting knowledge about the source is used to infer information about the target, under the assumption that the source is similar enough to the target for this inference to be valid or reasonable. Much of the contemporary research has focused on how one
makes a decision about which source analogue to use, and how to quantify its similarity to the target.

In 1987, Holyoak and Koh found that participants in the study used both structural and “surface” similarities to determine a useful source analogue, even though surface similarities were unhelpful in actually applying the source to solve the target problem. The goal of one of their studies was to expand on past findings to provide clear evidence of analogical transfer in the absence of demand characteristics. The experiment used two groups of students, an “analogy group” that had been previously exposed to the source situation by their course textbook and a control group that had not. Subjects in the analogy group was significantly more likely to solve the target problem based on the source than the control group, indicating high rates of spontaneous transfer from the source analogue to the target problem.

Holyoak and Koh found that changing either surface or structural would usually lead to significant impairment in a subject’s ability to generate the “correct” source model (i.e. spontaneous transfer of the source analogy) given a target. This supports a summation theory that takes both surface and structural properties equally into account (Holyoak & Koh, 1987). However, Holyoak (2012) asserts that it is not solely perceptual features that are important for relational reasoning, but “commonalities (and sometimes differences) in the roles [the elements] play.”

Around the same time as the Holyoak and Koh study, Gentner proposed the structure-mapping theory to represent the interpretation of an analogy. This theory states that a stronger analogy has a higher proportion of mapped (alignable) to unmapped properties between the two relations, and weak analogies have a low proportion. Deciding which properties map is based on
the “systemacity principle,” which determines how properties are systematically interrelated (Bejar et al., 1991).

Shortly thereafter, Holyoak and Thagard developed their own model of the analogical mapping process, a computer simulation called the Analogical Constraint Mapping Engine (ACME). In addition to a constraint for structural consistency similar to Gentner’s, this model also imposed other constraints as “pressures” that encourage more probable mappings. The model was successful in mapping a variety of analogies, including explanatory and problem-solving analogies, and mimicked human performance fairly accurately (Bejar et al., 1991).

One specific project I was involved with worked to expand previous findings regarding mapping-induced forgetting. Studies by Markman and Gentner had previously found that, as suggested by the structure-mapping theory, alignable differences between pairs in a similarity comparison were “better memory probes” than nonalignable differences (Markman & Gentner, 1997). They concluded that this suggests that, during the analogy process, alignable differences are encoded and remembered while nonalignable differences are ignored.

The research run by Michael Vendetti takes a closer look at such findings and explores alternate explanations for the results. Like Markman and Gentner’s study, it looks at the effects that the mapping of analogous properties in two scenes has on memory retrieval, and it seeks to determine how mental representations of analogies are stored and manipulated, and thus how they are remembered by the reasoner.

In one study, participants are assigned to either a “describe” or a “compare” group, where members of the latter are given two analogous scenes and asked to compare them, while the former is given random individual scenes and asked only to describe it, not compare it to another. A follow-up study adds a third group whose only instructions is to count items in
randomly-presented scenes. All participants are then presented with individual items taken from these scenes and asked whether they have seen the same item before. Preliminary results agree with Markman and Gentner’s findings that participants who made comparisons were recalled likely to remember alignable items than nonalignable items; however, data also shows that these participants were more biased towards the alignable items.

In addition to assisting with the experimental design and execution of the mapping-induced forgetting study and other similar endeavors, I began to acquaint myself with the FMRIB Software Library (FSL) with the intention of using it to clean and analyze MRI data taken for the start of another study, a variation of one of Vendetti’s previous projects, as other projects conclude at the start of the next quarter.

Working with MRI presented an accessible means of dealing more directly with the neurological level of the reasoning process, and many of the projects I was working on had a significant neurological component. I therefore began to research and become more aware of the brain structures and processes involved in the reasoning process, and how they relate to other neurological functions.

Most neuroimaging studies (and other physical evidence) point to the prefrontal cortex as being the primary area involved in high-level reasoning and decision making (Bunge et al., 2005). Additionally, the frontopolar subregion has been identified as being responsible for some of the most complicated problem-solving that involve integrating multiple relations. (Holyoak, 2012). Many neuroimaging studies use the visuospatial analogy test Raven’s Progression Matrix to measure relational integration and control complexity: there are one-relational and two-relational RPM problems, and the latter require significantly more reasoning power. One study used two-relational RPM problems to isolate the left frontopolar cortex as the most
sensitive area to relational complexity (Bunge et al., 2005). Analogical reasoning is also highly
dependent on a subject’s working memory and other executive functions, which are also
centralized in the prefrontal cortex (Holyoak, 2012).

There have been conflicting opinions about whether the ability for analogical reasoning is
present from birth, or whether it is obtained as a child’s brain more fully develops. It has been
shown that there is a transition during development toward placing greater importance on
relational structure in mapping, called the “relational shift” (Holyoak, 2012). However, some
argue that this is due not to a physical development but to a child’s increasing knowledge about
relevant relations as he grows older. On the other hand, new evidence suggests that cognitive
changes due to malnutrition, for example, also affect analogical reasoning, suggesting that
physical brain development may be a factor, and the age at which children tend to experience the
“relational shift,” 13-14 years old, coincides with the age their prefrontal cortexes have become
substantially mature (Holyoak, 2012).

There is thus still much more to discover about analogical reasoning: in terms of the
information transfer and mathematics of the mental process, and in terms of the physical
biological bases of the processes in the brain. Though many of these areas have been extensively
researched, there still has yet to be one prevailing theory or a consensus within the scientific
community. Though we will hopefully approach that point and we seem to be making new
discoveries in the field every day, reasoning remains one of the most interesting and mysterious
topics in cognitive science.

My time in the Reasoning Lab has been very interesting and enlightening, and has
exposed me to many different areas of research within cognitive science, psychology, and
neuroscience that I was not before familiar with. I look forward to continuing my work in the
Reasoning Lab, especially on the upcoming MRI project and the completion of our current studies. I hope to further expand my knowledge base and to apply my new knowledge and experiences to different areas.
References


Predicting Point Light Action during Binocular Rivalry

Ye Eun Chun

Introduction

When we drive a car on the road, we have to use our all possible perceptions to drive safely. For example, we would use our motion perception and visual perception to see not only our own car but also other cars passing by and people walking on the street. To prevent all possible accidents, we continuously perceive moving objects nearby and also predict which way moving objects will move to in next few seconds. Since perception and prediction happen in a very short amount of time, they can be seen as occurring simultaneously. Do perception and prediction occur together or separately?

According to article “Predicting point-light actions in real-time”, visual perception was not simply reconstructed from visual input, but it was a predictive activity (Markus et al., 2007). This idea has been supported by the results from many previous studies of neuro-imaging. Brain areas, such as MT which processes real motion, were activated when static images with implied motion were presented (Kourtzi and Kanwisher, 2000). Other researchers also found that superior temporal sulcus (STS) coded biological motion when it was implied from static postures (Jellema and Perrett, 2003b). However there was not much evidence found about the timing of these predictive aspects, so a study of the prediction of human actions involving real-time simulation processes, was conducted (Markus et al., 2007).

In order to show animated human actions to subjects, they used the technique known as point-light animation of biological motion. With point-light animations, the human action is portrayed by small point lights placed on the head and the joints of the body (Randolph, 2007). The great advantage of using point-light actions is that observers can judge sex and the
emotional implication of a point-light defined walker when viewing the animation of the whole body. With this technique, experimenters motion-captured a number of human actions and made them as point-light action animations. During the experiment, subjects watched sequences of point-light actions, followed by an occluder and then a static test posture. After that subjects were asked to judge whether the test posture depicted a correct continuation of the action before the occluder. Occluder time and the movement gap, which is the time between the endpoint of the action and the static test posture, were varied; occluder time (100ms vs. 400ms vs. 700ms) and movement gap (100 ms vs. 400ms vs. 700ms). Error rates were lowest when occluder time and movement gap corresponded. These findings suggest that action prediction involves a real-time simulation process.

In our experiment, we assumed that observers would predict the correct action continuation when two conflicting test human figures shown to the observers after various occluder times. To show different images to each eye simultaneously we used binocular mirror system. During binocular rivalry two images compete for access to consciousness and low-level inhibitory interactions and high-level excitatory influences will promote perceptual grouping and selective attention (Frank, 2006). Therefore our assumption is that action prediction involving a real-time simulation process will work on visual perception during binocular conflict and make observers see the correct continuation human figure more clearly than the other.

Method

Participants

Nine UCLA undergraduate students participated in this experiment. Subjects were given a course credit for their participation.

Design
A 2x2 within-subjects design was used for this experiment. The first independent variable (IV1) was represented by two levels of occluder time; 200ms or 800ms. The second independent variable (IV2) was represented by two levels of matchness between stimuli in probe movie and test stimuli after occluder; Match vs. Mismatch. The dependent variable (DV) was the percentage of correct responses out of all responses.

Materials and Apparatus

We used point-light action method but instead of static dots placed on a human figure we assign 6 random dots appeared on a human figure so that potential speed effect can be eliminated in our experiment.

The experiment consisted of five parts: a learning session, a practice for block 1, actual experiment of block 1, a practice for block 2, and actual experiment of block 2.

Learning session consisted of 6 movie sequences (A pulls B and B resist; A pulls B, B resists, but B loses; Scramble for last seat, A loses and stands up; High-five; A sits, B pulls up A; A picks up stool, threatens to strike B) and they were repeated once again. Recognition test consisted of 24 trials that subjects judged whether each trial movie was old (shown in the previous presentation) or new (wasn’t shown in the previous presentation).

In each actual experiment block, 10 practice trials were given in the beginning. There were two blocks totally. Each block consisted of 48 trials. 200ms occluder time trials and 800ms occluder time trials were placed in an intermixed order. Also two different matchness conditions (Match vs. Mismatch) were equally distributed within each block. For each trial, it consisted of two tasks. One was to judge which human figure was more visible during two test stimuli were conflicting. The secondary task was to choose the facing direction of the green figure in a probe movie.
The correct figure in the 200ms occluder time condition had a movement gap of 200ms, while the incorrect figure in the 200ms occluder time condition had movement gap of 800ms. Vice versa for the 800ms occluder time condition, the correct figure in this case had a movement gap of 800ms while the incorrect figure had movement gap of 200ms. Correct figures were counterbalanced for both eyes (left or right) and two colors (red or blue).

The size of the frame was 350 pixels when screen resolution was 1208×1024 pixels and the refresh rate was 75Hz. The luminance level for figures in probe movie was 8 cd/m² and there was no luminance difference between correct test stimuli and disturbing stimuli.

Test Stimuli

\begin{center}
\begin{figure}[h]
\centering
\includegraphics[width=0.4\textwidth]{stimuli.png}
\caption{Test Stimuli}
\end{figure}
\end{center}

Procedure

During the experimental session, a participant sat in front of the computer. First the participant was informed the instruction of the experiment and then placed the face on the chin rest. The chin rest makes the distance from a subject’s face to screen fixed with 47cm. When the participant looked through the binocular mirror to see the monitor, the instructor turned off the light of the testing room so that the participant could fuse the two images on the participant’s
each eye easily. When the participant confirmed with clear vision through binocular mirror, then learning session began. In this session, 6 different motion sequences were played and repeated again. Right after this presentation, the participant was required to complete the recognition test which consisted of 24 trials by using arrow keys (left key for new movie, and right key for old movie). This recognition test repeats until the participant reached above 75% correct out of 24 trials to continue on prediction rivalry task. In the beginning of each actual prediction task block, 10 practice trials were given. Each 48 actual trials for each block so total 96 trials for two blocks were required to be completed. After all rivalry task completed, the participant was required to answer to 50 questions about the subjects’ autistic traits, and then the experiment finally ended.

Results

Figure 1 indicates the average accuracy rate. Looking at the pattern of results showed in Figure 1, it presents that average accuracy rate, in general, is higher when occluder time is 800ms than 200ms.

To test these effects, the data were analyzed by using a 2 x 2 (Occluder time [200ms, 800ms] x Matchness [Match, Mismatch]) within subject analysis of variance (ANOVA), which presented a significant main effect of Occluder time, such that accuracy rate was significantly higher when in Occluder time 800ms conditions ($M = 0.87$) than when in Occluder time 200ms conditions ($M = 0.79$), regardless of Matchness. On the other hand a significant main effect of Matchness was not revealed, such that accuracy rate was not much different between time Match ($M = 0.81$) and Mismatch ($M = 0.82$), regardless of matchness. Additionally, the interaction between occluder time and matchness was not found to be significant.
Figure 1. Effects of occluder time (200ms vs. 800ms) and matchness (Match vs. Mismatch) on accuracy of predicting human action.

Conclusion and Discussion

From the results, we only came up with one main effect of occluder time. The average accuracy for 800ms occluder time condition was significantly higher than 200ms occluder time condition but the difference between Matched and Mismatched was not significant. Even accuracy for 800ms was higher; there was not much difference between Matched and Mismatched conditions with 800ms. On the other hand, we found some significant amount of difference between Matched and Mismatched conditions with 200ms. Since Mismatched conditions worked as controlled base numbers for both occluder times, actual prediction was better when occluder time was 200ms. Therefore even though overall accuracy rate were higher in 800ms, we can’t derive the evidence of action prediction from 800ms occluder time case but we can derive it from 200ms occluder time.

This finding supports the idea that action prediction is not ruled by cortical processing. Since it takes about minimum 300ms until cortical processes are completed, so 200ms is too
short for processing action prediction done by cortical processes. Therefore action prediction is possibly related to bottom-up processes instead of top-down processes. As perception is occurring almost automatically and later we feel sensation, we might use our action prediction as like perception level and we plan later based on action prediction.
References


