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Support For bzip2's Ability to Aid in the Automated Diagnosis of Epilepsy

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Abstract

Epilepsy is a potentially life threatening condition that affects approximately 50 million people worldwide. Electroencephalography (EEG) is one of the most useful and prevalent diagnostic procedures currently available for epilepsy. EEG machines measure the electrical signals produced by a patient's brain and record data in the form of time series. There is supporting evidence that suggests the EEG data of patients with epilepsy might possess less complexity during seizures than interictal periods (between seizures). In this study we will demonstrate how an automated method built around bzip2 can be used to analyze the complexity of a time series. We will explain how our method, called bzip2 analysis, is employed and used to analyze the complexity of time series derived from linear patterns, single sine waves, complex sine waves, and complex sine waves with added noise. Our results will show that bzip2 analysis can produce measurements that are inversely related to a time series' complexity. Due to the results obtained in this study, it is possible that the measurements obtained using bzip2 analysis may provide information that can be used to detect seizures in EEG data and thereby aid in the automated diagnosis of epilepsy.

Keywords: epilepsy, Electroencephalography (EEG), bzip2, computer-aided diagnosis

1. Introduction

Epilepsy is a potentially life threatening condition that affects approximately 50 million people worldwide [4]. Patients with epilepsy experience chronic abnormal episodic bursts of electrical activity in certain neural networks that can cause a brief disturbance of cerebral function [1]. These disturbances can lead to seizures that, in some cases, cause patients to experience uncontrolled convulsions that may expose them to life threatening scenarios.

Electroencephalography (EEG) is one of the most useful and prevalent diagnostic procedures currently available for epilepsy [1]. EEG electrodes record the electrical signals produced by a patient's brain. The voltages produced by these electrical signals are recorded on graphs as functions of time. EEG data collected from patients that have suffered a single seizure may possess features that can help doctors decide if the patient has epilepsy, defined as a chronic propensity to have seizures.

Conventional analysis of EEG involves a visual screening of the EEG data by highly skilled physicians, who are in extremely high demand. Physicians inspect this record for events that provide evidence for the presence of pathologic epileptogenic networks. In a conventional 20-minute EEG, these events only occur 50 percent of the time. This practice can result in long wait times before a diagnosis is given, an increase in medical expenditures, and a consequent delay in necessary treatment [1]. Furthermore, if the patient has experienced a single seizure and their EEG demonstrates activity that is currently known to correlate with epilepsy they have only about a 50 to 60 percent chance of actually having another seizure [3]. Automated methods have the potential to aid the diagnosis of epilepsy by detecting features in EEG data that reliably correspond with epilepsy.

There is supporting evidence that suggests the EEG of patients with epilepsy might possess less complexity* during seizures than interictal periods (between seizures) [2]. Patients with epilepsy possess neural networks that generate seizures, called epileptogenic networks. During seizures the epileptogenic network causes abnormal neural firing rates in the brain [2]. Therefore, an automated method that can analyze the complexity of EEG data may be extremely valuable for diagnosing epilepsy.

In this study we will demonstrate how an automated method built around bzip2 can be used to measure the complexity of a time series. Since EEG data are time series, bzip2 may be able to analyze the complexity of a patient's EEG. This measurement could be incorporated into an automated tool that would analyze many features of a patient's EEG data and be able to aid in the diagnosis of epilepsy

2. Bzip2

Bzip2 is a high quality open source data compressor used to decrease the size of computer files. One type of file bzip2 is capable of compressing is computer files containing text. Bzip2 compresses a text file and produces a corresponding .bz2 file that is typically smaller in size. Bzip2 also contains mechanisms to decompress .bz2 files back to their original form. Bzip2 is extremely efficient. It can compress and decompress files approximately 2 and 6 times faster than other compression programs [5].

Bzip2 utilizes an ordered set of character recognition algorithms in order to compress text files. The primary character recognition algorithm bzip2 relies on is the

*EEG data higher in complexity is formed from a greater number of less synchronized electrical signal patterns compared with lower complexity EEG data.

Burrows-Wheeler Transform. The Burrows-Wheeler transform permutes the individual characters printed on the text file in a way that efficiently groups identical characters together. Several more character permutations as well as character substitutions are carried out before the .bz2 file is created from the original text file.

3. Methods

We examine the compressibility of time-series based on a series of functions ranging from simple to complex. We demonstrate that compressibility is inversely related to the original function's complexity.

3.1 Measuring Compressibility

In order to analyze the complexity of a function, f(x), start by printing the dependent value, f (1), to the first row of a text file. Compress the text file using bzip2. Measure the amount bzip2 was able to compress the text file by calculating the compressibility of the text file. Compressibility is defined as:

$$Compressibility\left(\frac{KB_{text\ file} - KB_{bz2\ file}}{KB_{text\ file}}\right) * 100$$

Next, write the dependent value, f (2), to the second row of the same text file. You will now have 2 elements in the text file: f (1) in the first row and f (2) in the second row. Once again compress the text file using bzip2 and calculate the compressibility. Repeat this process for every consecutive dependent value until an integer, n, that is acceptably large [(i.e. repeat process for: f (3), f (4)…f (n-1), f (n)]. We then plot the compressibility as a function of file length (Figure 1, for example).

We observed that the compressibility of the text file is inversely related to the complexity of the function that generated the text file. In other words, bzip2's ability to compress data derived from a function is inversely related to that function's complexity.

The method described in this section will be referred to as bzip2 analysis for the rest of this paper.

3.2 Producing Measurements for Specific Functions

We selected functions to analyze that range from simple to complex. In order of complexity, we examined the compressibility of a linear function, a sine function, the sum of 3 or 10 sine functions and an entirely random sequence.

In order to assess that bzip2 analysis can recognize complexity, a function derived from a simple linear patter (low complexity) was compared to a function derived from a sequence based on random numbers (high complexity). Both functions shared the same range of numbers and identical double fixed notation was used to print the dependent values of each function to their respective text files.

In order to assess whether bzip2 analysis can recognize the complexity of a single sine wave, functions derived from a single sine wave and a random sequence of numbers were compared. For comparative purposes both functions shared the same range of numbers and identical double fixed notation was used to print the dependent values of each function to their respective text files. This comparison was done ten times, with the single sine wave randomly shifting in phase for each comparison.

$$Single\ Sine\ Wave = \sin(x + R)$$

Where R is a random number generated between 1 and 10 for each comparison.

In order to assess whether bzip2 analysis can differentiate between complex sine waves, two complex sine wave functions possessing different levels of complexity were compared. In order to vary the degree of complexity between the two sine waves, the less complex sine wave was composed of the summation of three single sine waves and the more complex sine wave was composed of the summation of ten single sine waves. The formula used to create each single sine wave was:

$$Single\ Sine\ Wave = R1 \sin\left(\frac{x}{R2} + R3\right)$$

Where R1, R2, and R3 were random numbers generated between 1 and 10 for each comparison. The formula used to create the less complex sine wave was:

$$Less\ Complex\ Sine\ Wave = single\ sine\ wave\ 1 + single\ sine\ wave\ 2 + single\ sine\ wave\ 3$$

Both double fixed and binary notations were used to print the dependent values of both complex sine wave functions to their respective text files. The comparison was calculated ten times.

In order to assess whether bzip2 analysis will be able to differentiate between EEG data based on complexity, two complex sine waves with added noise were compared. The method we chose for adding noise was to add a random number to each dependent value of both complex sine waves. This random number was chosen from a normal distribution with values ranging from 1 to -1. For this comparison all dependent function values were printed in binary notation, and the comparison was done ten times.

4. Results

4.1 Analyzing the Complexity of a Function Derived From a Linear Pattern

The comparison of a linear pattern and a random sequence using bzip2 analysis is given in figure 2. Figure 2 illustrates that bzip2 analysis was successfully able to differentiate between a linear pattern and a sequence of random numbers. Bzip2 was able to compress the less complex linear pattern to a greater extent than the more complex random sequence. This supports the notion that bzip2 analysis is able to differentiate between functions of varying complexity.

4.2 Analyzing the Complexity of a Single Sine Wave

The average results for ten comparisons between a function derived from a single sine wave and a function derived from a random sequence are shown in figure 3. Figure 3 illustrates that bzip2 analysis was successfully able to differentiate between a single sine wave and a sequence of random numbers. Bzip2 was able to compress the less complex single sine wave to a greater extent than the more complex random sequence.

These results show that bzip2 analysis is recognizing a single sine wave as a complex pattern and not a random sequence of numbers. The ability of bzip2 analysis to recognize a single sine wave as a complex pattern is important because EEG data is comprised of the summation of many different single sine waves that vary in amplitude and frequency.

4.3 Analyzing the Complexity of Complex Sine Waves

The average results for 10 comparisons between two complex sine waves that vary in complexity are shown in figure 4. Figure 4 illustrates that bzip2 analysis was successfully able to differentiate between the two complex sine waves. Bzip2 was able to compress the less complex sine wave more than the more complex sine wave. However, as seen in Figure 4, the magnitude of difference between the compressibility of the less complex sine wave and the more complex sine wave is small. If binary notation is used instead of double fixed notation then the difference between the two complex sine waves is much larger and remains consistent in direction (figure 5).

These results show that bzip2 analysis is capable of differentiating between two complex sine waves based on their complexity. These results are important because EEG data is formed from functions that have the very similar properties as complex sine waves.

4.4 Analyzing the Complexity of Complex Sine Waves with Added Noise

The average results for 10 comparisons between two complex sine waves with added noise are shown in figure 6. Figure 6 illustrates that bzip2 analysis was able to differentiate between the two complex sine waves with added noise. Even with the limited noise added bzip2 was able to compress the more complex sine wave to a greater extent than the more complex sine wave.

Although EEG data is composed of complex sine waves, these complex sine waves are in constant fluctuation due to noise. The magnitude of the noise does not overpower the underlying complex sine wave but must be considered. The fact that bzip2 analysis can differentiate between two complex sine waves with added noise is a very strong indication that bzip2 analysis will be able to differentiate between EEG waves with varying complexity.

5. Conclusion

In this study we showed that bzip2 analysis is able to consistently produce measurements that are inversely related to a function's complexity.

The ability to efficiently and accurately diagnose epilepsy relies heavily on the ability to detect features of EEG data that are associated with epilepsy. There is evidence to suggest that one such feature might be that during seizures patients with epilepsy possess less complex EEG data than during interictal periods.

Our results suggest that bzip2 analysis may be able to differentiate between the varying complexities of an electrographic seizure and normal baseline recordings. Due to the results obtained in this study, it is possible that the compressibility, measured by bzip2 analysis, may provide information that can be used to detect seizures in EEG and thereby aid in the automated diagnosis of epilepsy.

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7. Figures

Figure 1

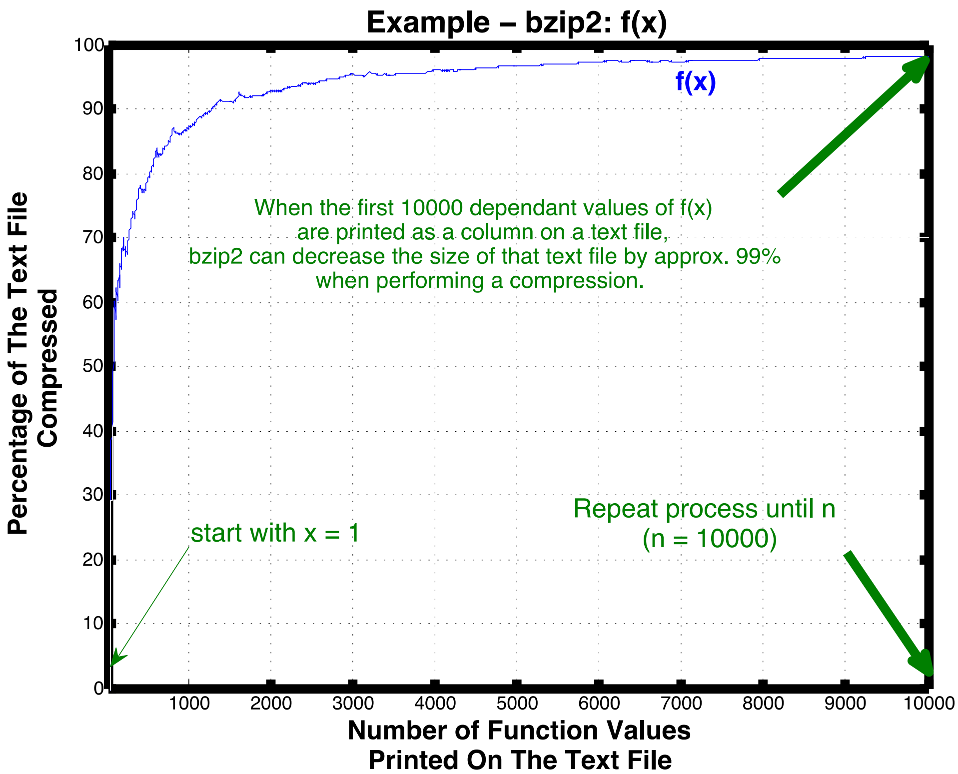


Figure 2

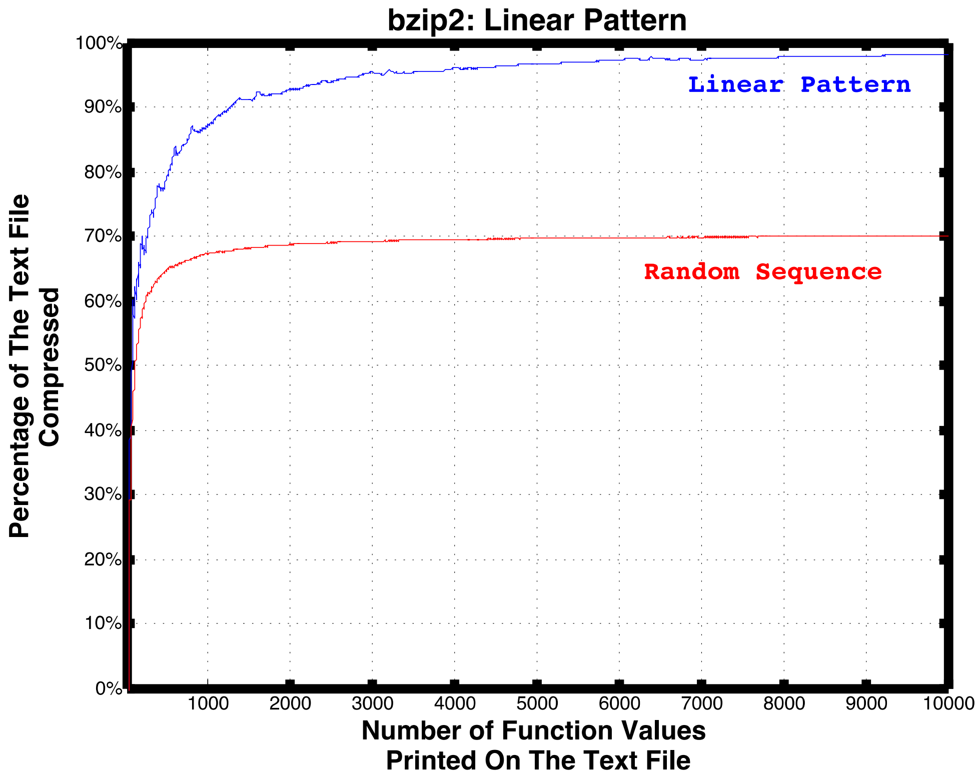

bzip2: Linear Pattern
Linear Pattern
Random Sequence
Percentage of The Text File Compressed
Number of Function Values Printed On The Text File
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000

Figure 3

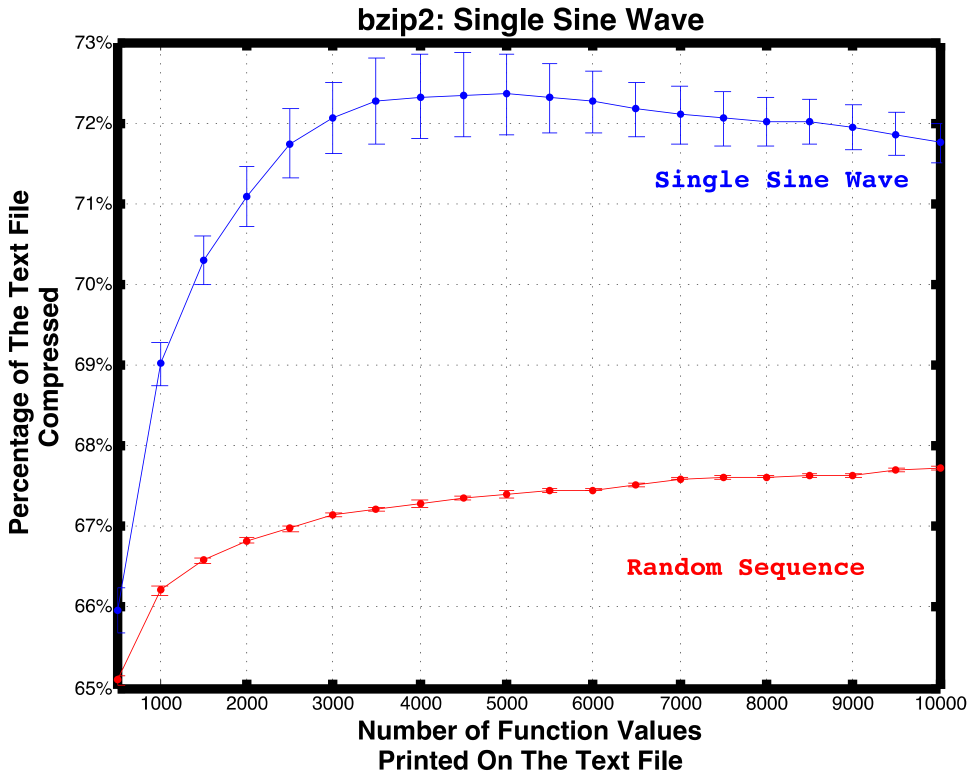
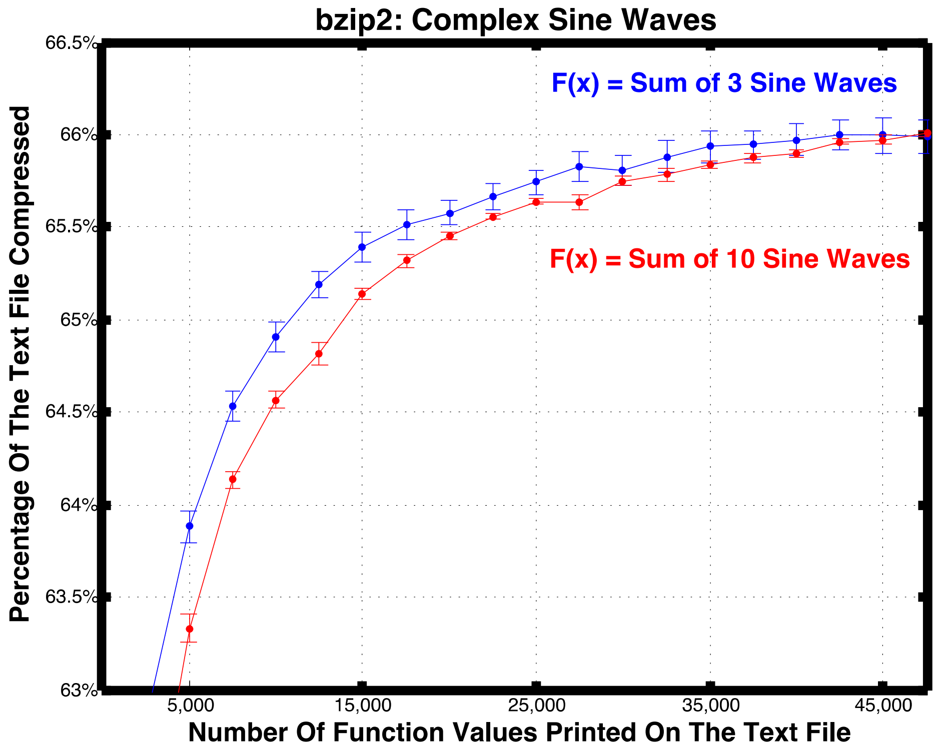
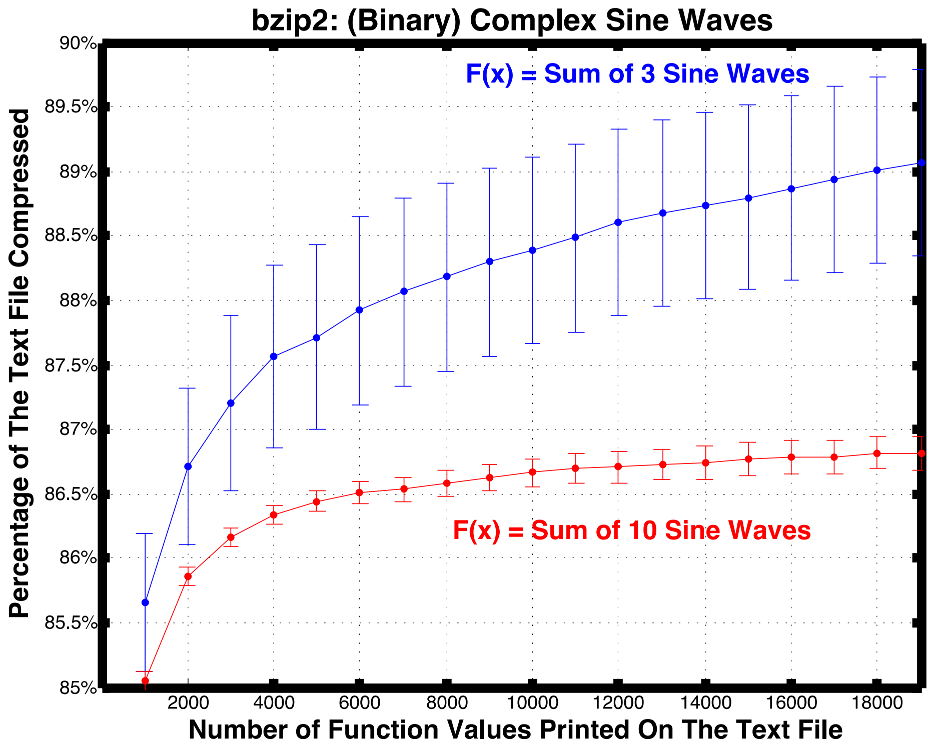

bzip2: Single Sine Wave
73%
72%
71%
70%
69%
68%
67%
66%
65%
1000
2000
3000
4000
5000
6000
7000
8000
9000
10000
Single Sine Wave
Random Sequence
Percentage of The Text File Compressed
Number of Function Values Printed On The Text File

Figure 4



bzip2: Complex Sine Waves
F(x) = Sum of 3 Sine Waves
F(x) = Sum of 10 Sine Waves
66.5%
66%
65.5%
65%
64.5%
64%
63.5%
63%
5,000
15,000
25,000
35,000
45,000
Percentage Of The Text File Compressed
Number Of Function Values Printed On The Text File

Figure 5



bzip2: (Binary) Complex Sine Waves
F(x) = Sum of 3 Sine Waves
F(x) = Sum of 10 Sine Waves
Percentage of The Text File Compressed
90%
89.5%
89%
88.5%
88%
87.5%
87%
86.5%
86%
85.5%
85%
2000
4000
6000
8000
10000
12000
14000
16000
18000
Number of Function Values Printed On The Text File

Figure 6

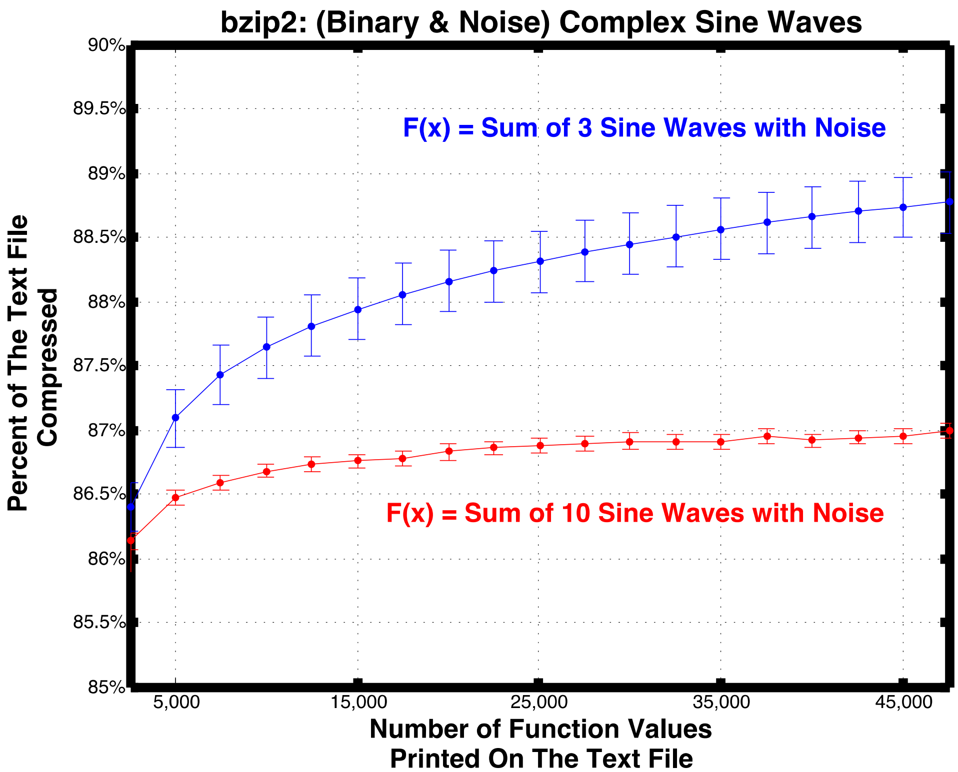

bzip2: (Binary & Noise) Complex Sine Waves
F(x) = Sum of 3 Sine Waves with Noise
F(x) = Sum of 10 Sine Waves with Noise
Percent of The Text File Compressed
90%
89.5%
89%
88.5%
88%
87.5%
87%
86.5%
86%
85.5%
85%
5,000
15,000
25,000
35,000
45,000
Number of Function Values Printed On The Text File

Figure Legends

Figure 1.

A graph showcasing bzip2's ability to compress information derived from the function f(x). This graph is meant to serve as a general example of what the results of this study look like.

Figure 2.

A graph comparing bzip2's ability to compress information derived from both a simple linear pattern and a random sequence.

Figure 3.

A graph comparing bzip2's ability to compress information derived from a single sine wave and a random sequence.

Figure 4.

A graph comparing bzip2's ability to compress information derived from two complex sine waves. The information derived from the complex sine waves was analyzed in double fixed notation

Figure 5.

A graph comparing bzip2's ability to compress information derived from two complex sine waves. The information derived from the complex sine waves was analyzed in binary notation.

Figure 6.

A graph comparing bzip2's ability to compress information derived from two complex sine waves with added noise. The information derived from the complex sine waves was analyzed in binary notation.

Rubber Hand Illusion is induced by Visual Stimulation, Proprioception Drift is not

Albert Chung

Introduction

The Rubber Hand Illusion was first formally demonstrated by Botvinick and Cohen in 1998. It is described as a "the feeling that a rubber hand belongs to one's body brought by stroking a visible rubber hand synchronously to the participant's own occluded hand."(Rohde, Luca, and Ernst 2011) In this study it was found that Rubber Hand Illusion induces significant displacement in a 'reach judgment task.' Also, a questionnaire which indirectly asked for the effects of ownership demonstrated further support that there were significant visual and tactile sensory integration induced by the Rubber Hand Illusion. Such result was reproduced in many other studies such as ones done by Armel (2003), Tsakiris (2005), and Constantini (2007). In a recent study by Rhode, Luca, and Ernst (2011), it was found that the mechanism for feeling of ownership and proprioceptive drift may be separate mechanisms.

In the current study, with the aims to investigate the difference in mechanisms of ownership and proprioception, we explored different possibilities of visual-tactile integration and visual-proprioception integration. The used methods were similar to the methods that were used in Rohde, Luca, and Ernst (2011) study with slight modifications. The modifications were intended to have a better control over the sensory stimulation received and to reproduce Rubber Hand Illusion as well as we could.

Method

Participants

A total of 94 subjects were recruited in this study. These subjects were students volunteers from University of California, Los Angeles and were recruited by SONA-system. These participants were given 1 credit on SONA for each participation session as compensation. 14 of these were excluded as they deviated from the standard population in their pre-test proprioception. This was an essential exclusion criterion because too much deviation from pre-test proprioception would mask any effects of proprioception drift in Rubber Hand Illusion.

Design

In the study we were interested in two main dependent variables: ownership and proprioception drift. These data were collected across four different conditions, each controlling for different combinations of stimuli. "Synchronous" condition received synchronous visual and tactile stimulation, "Asynchronous" condition received a delayed tactile stimulation after the visual stimulation, "Hand" condition received no tactile stimulation, and "No Hand" condition did not receive visual or tactile stimulation. This independent variable was measured as between subjects. Both ownership and proprioception was measured before and after the stimulus.

Material

A spray painted goggles, a black cloth, two brushes, a rubber hand, medical tape, cardboard and a handcrafted wooden box were used in this study. Also, Matlab installed Mac desktop with monitor size of ~20 inch was used. The handcrafted wooden box was composed of three wood boards, two of them parallel to each other and one of them connecting the two at the bottom. A Matlab program designed to collect and save data was installed the Mac desktop.

Procedure

Each participant was asked to read and sign the consent form before any procedure was done. They received a copy of the signed consent form and participant bill of rights. Also, each participant was asked to check if they satisfied any exclusion criteria depending on their health state.

Participants were seated in front of a Mac desktop monitor in a specific position marked with a tape and were asked to be blinded by putting on the spray painted goggles. The Matlab based program was executed at this point and was used during the remainder of the entire procedure. The goal of this phase was to blind participants from their own hand for 240 seconds until pre-stimulus proprioception could be measured. The timer counting down 240 seconds started and was displayed on the screen from the moment the participants were blindfolded. This displayed number was designed to jiggle at a random moment to be used as a distractor task throughout the experiment. While the timer counted down, the experimenter placed the handcrafted box in front of the participant and placed his or her left arm in a predetermined position. The left index finger was aligned in a particular spot for all subjects who were recorded in the Matlab based program. The index finger was fixed to stay there with use of a medical tape. The participant's right arm was positioned outside the box. Then a cardboard was placed on top of the handcrafted box, and was covered with the black cloth. The spray painted goggle was removed, and the participants were asked to look at the counting down seconds and mentally keep track of how many times the number jiggled for the remainder of 240 seconds.

After the 240 seconds, the subjects were asked to perform 4 practice trials and 40 proprioception measurement task trials. In this task, the participants were asked to move the mouse cursor which was fixed across Y axis to the location that best fit the description "wherever the left index finger feel like it is" and clicked. Matlab based program measured and recorded this location and automatically calculated the distance between the actual index finger location and the response location. At the end of 40 trials, the participants were blinded again by the spray painted goggles. Then, the experimenter placed a cardboard wall between the participant's real left arm, and where the visual stimulus (rubber hand) would be placed. Depending on the experimental condition that the participants were assigned, either the rubber hand was placed if they were in "Synchronous", "Asynchronous", or "Hand" conditions, and nothing was placed if they were in "No hand" condition. Participant's right arm was placed in the box symmetric to the rubber hand as it was reported that it amplifies the Rubber Hand Illusion.

The spray painted goggle was removed after this point, and the participants were asked to rate on the scale of -3 to 3 on how much the rubber hand felt like it was their own hand based only on visual stimulation if they were not assigned in the "No hand" condition. This was recorded as "pre-test ownership" score. Then, the participants received visual and tactile stimulation for 240 seconds. If they were assigned in the "Synchronous" condition, subjects observed brushes on the rubber hand while they received the same tactile stimulus on the same location of their real hand. In the "Asynchronous" condition, the tactile stimulus was spatially congruent, but was temporally delayed, creating an asynchronous stimulus. In the "Hand" condition, the subjects only received visual stimulation, and in the "No Hand" condition, they were given no task to do, but were asked to stare at a fixed point where the rubber hand would have been placed.

At the end of the illusion phase, the participants were blindfolded with the goggles, and the same setup as previous proprioception measurement was restored. The participants were asked to do the proprioception measurement task, this time without the practice trials. Then, a short questionnaire asking for how much the rubber hand felt like it was their hand after the illusion phase was asked this answer was recorded as "post-test ownership" score.

Results

The ownership scores were only collected in "Synchronous", "Asynchronous", and "Hand" conditions as "No hand" condition did not receive any visual stimulation by the rubber hand. The collected means for the pretest ownership scores for "Sync," "Async," "Hand" were 0.947, 1.28, and 0.789 respectively. However, because no condition dependent manipulation is done at this point, a pretest ownership score could be better presumed by collapsing data across all conditions. This results the ownership score of 1.00. After the condition specific manipulation, these ownership scores changed to 2.00, 0.28, and 0.95 for "Sync," "Async," and "Hand" conditions respectively.

The change in proprioceptive measure, delta bias, was found to be 4.517cm, 1.358cm, 3.058cm, and 1.295cm for "Sync," "Async," "Hand," and "No hand" groups respectively. For the analysis of the change in proprioception measure, one way ANOVA was performed, and was found significant ($F(3, 72) = 3.05$, $p = 0.034$). A further t-test revealed that proprioception drifts were only significant across "Sync" group and "Async" group ($t(36) = 2.74$, $p = 0.009$), and across "Sync" group and "No Hand" group ($t(36) = 2.77$, $p = 0.009$).

Discussion and Conclusion

While the results of the current study replicate most of the findings in the previous studies, it also showed a novel finding that the feeling of ownership is achieved mostly by visual stimulus, though it is either retained or lost after tactile stimulation depending on how synchronous the visual and tactile integrations are.

However, the drifts in proprioception were only significantly different between "Sync" group and "Async" and between "Sync" and "No hand" while not significantly different between "Hand" group and "Async" group and between "Hand" group and "No Hand" group. This suggests that even though the Rubber Hand Illusion, or the feeling of ownership, could be achieved by visual stimulus only, the proprioceptive drift is dependent on the visual tactile integration.

Future Directions

Because we used right hand symmetry as an advantage to induce Rubber Hand Illusion, we are curious whether this was the defining variable that resulted in visual only induced illusion. To look into this, we plan to run a separate group of subjects without the right hand symmetry. Also, if possible we will try to make a model for drift in proprioception.

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Neonate Thyroid Hormones Dynamics Stimulation

Benjamin Steeper

Highly successful techniques have been developed to treat congenital hypothyroidism (CH), which is among the most common diseases that can be screened for at birth. These treatments can be very specific depending on the patient. Ideally, treatment starts as soon as the disease is diagnosed; restoring thyroid hormone (TH) to normal levels quickly can negate most and sometimes all of the effects of the disease. To aid in the understanding of pharmacokinetics and pharmacodynamics of L-T4 treatment in neonates, a feedback control systems model was adjusted from the model used for adult and children TH dynamics in humans. The model remained incomplete and further research of initial conditions and parameters is needed to refine the model and get results. T3 and T4 curves are of the right shape but scaled incorrectly, and TSH lacks an acceptable estimate altogether.

Introduction

Congenital Hypothyroidism (CH) occurs in about one out of every 3000 individuals born worldwide and greatly decreases the production rate of thyroid hormone (TH) in these neonates. The most serious effect of this TH deficit is the inhibition of brain development, resulting in severe mental retardation. Similarly, it can result in insufficient muscle and bone growth. Despite these severe growth impairments, CH is one of the most curable diseases and is easily caught in the first four days of life, if the neonate is screened for TH deficit. Only a quarter of the countries worldwide are implementing screening techniques. Infants who lack T4 and have an excess of TSH should be treated with L-T4 as soon as possible to restore T4 to a closer to normal range; treatment is most effective if started within the first 2 weeks after birth[10].

CH develops as a result of natal abnormalities in the thyroid system ontogenesis. There are two types of CH, permanent and temporary. The permanent disease commonly results from complications during phase one and two of pregnancy and the transient case comes from complications that arise in the third phase. Thyroid dysgenesis accounts for the majority of the permanent cases of CH. Thyroid dysgenesis is the most prevalent cause of permanent CH and it encompasses three conditions: a missing thyroid gland (agenesis), an ectopic or abnormally located gland, and an underdeveloped or hypoplastic gland. The next most common cause of CH is thyroid dyshormogenesis in which the TH is improperly produced or metabolized. Two other causes of permanent CH are deficient TSH levels or action and unresponsiveness of the peripheral systems to TH. Transient CH most commonly arises in preterm infants because of their underdeveloped hypothalamus[3].

If CH begins to develop in a fetus and it cannot produce its own T4, the fetus capitalizes on its mother's T4 entering from the cord blood. Consequently, infants with CH can retain 30% of normal range T4 at birth. Additionally, T4 to T3 conversion in the brain ramps up in the fetus under these conditions to salvage neural development as much as possible. A neonate born under these conditions, if treated rapidly can be restored to near normal post-natal development[10]. As soon as an infant is diagnosed with CH, treatment with L-T4 should be started with an initial dose of 10-15μg/ kg/ day[10]. The procedure is to normalize T4 levels as quickly as possible. In normal babies, there is a natural TSH surge immediately after birth to restore T3 after having been suppressed in the third phase of pregnancy. L-T4 treatment is used to mimic and replace that surge and therefore promote regular postnatal growth. A higher initial dose of L-T4 can normalize the T4 faster, but over treatment has adverse effects as well. If serum T4 levels are too high, it can cause premature fusing of the cranial plates, disproportionate muscle growth rates and abnormal attention and temper in the individual[6].

Eisenberg et al (2006) developed a feedback control system model to simulate TH regulation in the hypothalamo-pituitary-thyroid axis of adult humans and used it to assess bioequivalence of levothyroxine (L-T4) in treatment of CH[5]. That model was improved (Eisenberg et al, 2008) to include sub models for the brain and was validated with pharmacokinetic data. They found optimal doses of L-T4 for various treatment administration methods in adult humans6. The model encompasses the dynamics of the pituitary, thyroid, and hypothalamus as their role in hormone production and the degradation and elimination of T3, T4, and TSH as the sink.

The project goal is to find the approximate neonate's T4, T3 kinetics parameters based on the developed thyroid model[6] and the literature data of T3, T4, and TSH values[1-3, 8, 10]. The established neonate's thyroid hormones regulation model thereafter can be used to find the proper L-T4 treatment of TH deficient babies, similar to what Eisenberg et al (2006) have done with adults.

Method

The goal of the simulation is to find kinetic parameters for neonate thyroid hormone regulation. The adult model was shown in Figure 1[5, 6]. The interested kinetic parameters were k_{02}, k_{12}, k_{13}, k_{21free}, k_{31free}, and V_{TSH}. Due to limited resources, there were no experimental human neonate data for model fitting. Instead, past literature data was used as the reference for the model data. T3 level, T4 level, free T3 level, free T4 level, TSH level, and the volume of neonate plasma in the first few days of life were the crucial data for the regulation model. And there were found in the literature.

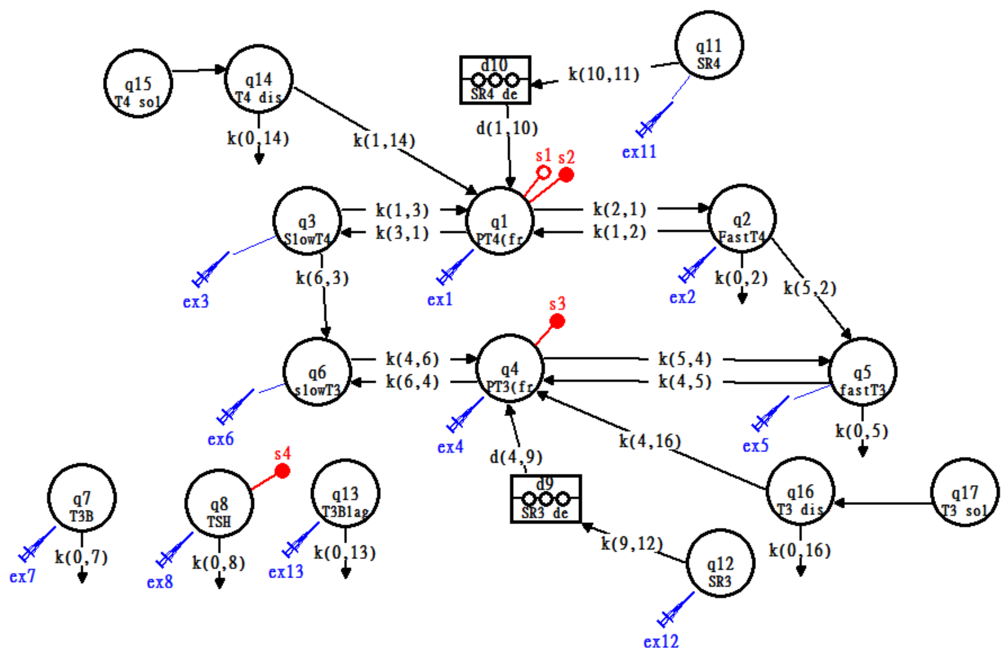

Figure 1 Neonate Thyroid Hormones regulation SAAMII Model. Red solid dots indicated data association with the output values. The output values needed to fit the data.

Table 1 The initial bolus input of compartment q1-q13

Compartment	Adult (1L)	Neonate (167mL)
q1 (plasma Total T4)	0.09655170 μmol	0.02469500 μmol
q2 (fast T4 conversation pool)[5]	0.127 μmol	0.03248279 μmol
q3 (slow T4 conversation pool)[5]	0.143 μmol	0.036575 μmol
q4 (plasma total T3)	0.00331 μmol	0.0001295 μmol
q5 (fast T3 conversation pool)[5]	0.00490 μmol	0.00012533 μmol
q6 (slow T3 conversation pool)[5]	0.028175 μmol	0.00068096 μmol
q7 (Brain T3) [5]	7.058 μU/hr	1.80522466 μU/hr
q8 (plasma TSH) [6]	1.084 μU/hr	1.00 μU/hr
q9 (Delay block) [5]	8 hours delay	8 hours delay
q10 (Delay block) [5]	8 hours delay	8 hours delay
q11 (Total T4 secretion) [5]	0.000769 μmol	0.00020367 μmol
q12 (Total T3 secretion) [5]	0.000170 μmol	0.000004108 μmol
q13 (lag function control of brain T3) [5]	7.057 μmol	1.80497 μmol
P_{lasma}	1L	167mL

The bolus input of compartment q1, q4, and q8 were the initial amount of plasma Total T4 (moles), plasma Total T3 (moles), and plasma TSH (μU/h) [2, 10] in the neonate (with volume=167.4mL). The values were listed in **Table 1**. The bolus inputs of compartments q1-q8, q11-q12 of neonate model were different from that of the adult model because the initial hormones levels of neonate and adult should be different due to physical differences, such as size and growth rate. Therefore, the bolus input of the adult model was adjusted to neonate's value by the ratio of initial Total T3 in neonates to that of adult (0.25577), and the ratio of initial Total T4 in neonates to that of adult (0.034169). The adult's initial bolus of q2, q3, and q11 was multiplied by 0.25577 to become neonate's initial bolus of q2, q3, and q11 because these compartments shared the Total T4 in the model. Similarly, the adult's initial bolus of q5, q6, and q12 was multiplied by 0.024169 to become neonate's initial bolus of q5, q6, and q12 because q5, q6, and q12 shared the Total T3 in the model. For q7, q8, and q13, the initial bolus was estimated by multiplying the adult's bolus values and 0.25577. Those values were listed in **Table 1**.

Other neonate's parameters remained unchanged and therefore they were same as those of adult model.

<u>Total T4, Total T3, free T4, and free T3 data</u>

There was a plethora of literatures about the neonate T4, T3, free T4, and free T3 concentration in different time range[1-3,8,10]. The longest neonate Total T4 and Total T3 concentration data (5 days period) were obtained from Delbert A. *et al*[3] and the longest neonate free T4 and free T3 concentration data (3 days period) were obtained from Erenberg A. *et al*[2]. GetData Graph Digitizer was used to extrapolate the graphs in the literatures and it was used to generate the data point. The units of the literature data were converted to proper units for the model's parameters using Microsoft Excel and the resulting graphs were shown in **Fig. 2a-2d**).

TSH Data

Similar to Total T4 and other data, TSH data was obtained within 2 days period[7]. The resulting graph was plotted in **Fig. 3**.

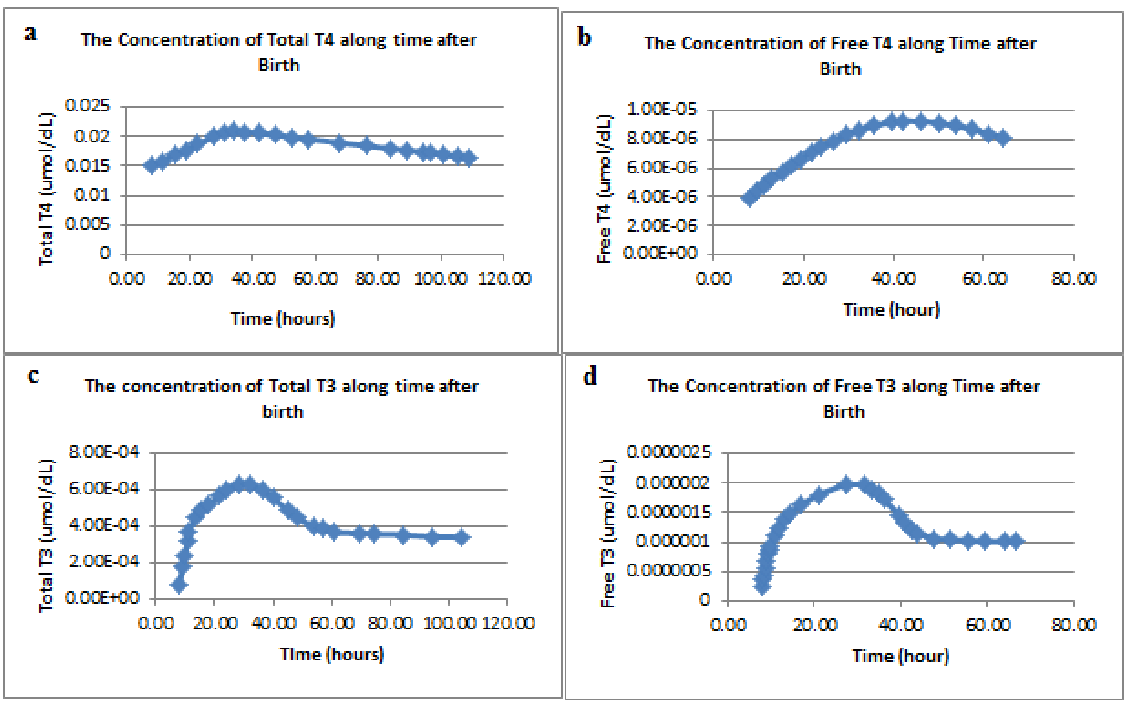

Figure 2 Concentration of Literatures Total T4 and Total T3[2, 3.] (a) The graph of the concentration of Total T4 along time. The graph was regenerated by GetData Digitizer and Microsoft Excel with unit micromole/d. **(b)** the graph of the concentration of free T4 along time. The graph was regenerated by GetData Digitizer and Microsoft Excel with unit micromole/d. **(c)** The graph of the concentration of Total T3 along time. The graph was regenerated by GetData Digitizer and Microsoft Excel with unit micromole/d. **(d)** The graph of the concentration of free T3 along time. The graph was regenerated by GetData Digitizer and Microsoft Excel with unit micromole/dL.

Neonate Plasma Volume

The average weight of full term (42 months) neonates was found[11]. No. 5-9 Infants[9] had the weight that was close to the average weight of full term neonates. The average volume of plasma was obtained by averaging these infants' plasma volume from the paper, which was 167.4 mL (See **Table 1**).

Simulation

SAAMII version 1.1.1 was used to run the simulation. The Total T4, Total T3, and TSH data were associated with compartments q1, q4, and q8 respectively (**Fig. 1**). k_{02}, k_{12}, k_{13}, k_{21free}, k_{31free}, and V_{TSH} were set to be "Adj" (adjustable) in the model and the rest of the parameters were fixed. The "Fit" function of SAAM II was used to

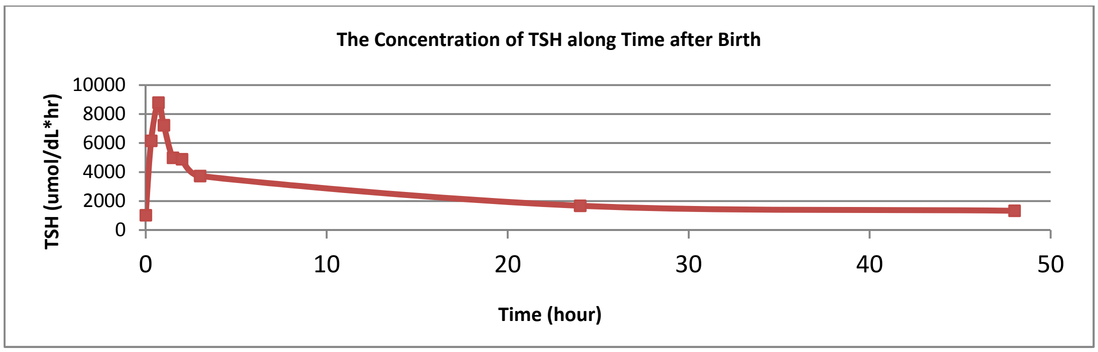

Figure 3 The graph of the concentration of TSH along time7. The graph was regenerated by GetData Digitizer and Microsoft Excel with unit U/dL*hr

Table 2 The resulting fitting parameters of neonate compared to children and adult

Parameter	neonate	%CV	children	%CV	adults	%CV	Units
k_{02}	1.00	4.29e9	0.0114	17	0.0189	25.7	h^{-1}
k_{12}	1.00	3.50e9	0.523	19.2	0.868	18.3	h^{-1}
k_{13}	5.00	9.28e9	0.0514	28.8	0.108	12.4	h^{-1}
k_{21free}	unbounded	-	2275	14.4	584	31.2	h^{-1}
k_{31free}	643.41	3.44e11	225	36	2043	16.6	h^{-1}
k_{TSH}	1.12559	48.2	2.5	-	3.5	-	dL

fit the data. Multiple simulations were run and the relatively best result (still, not fitted) was shown in **Fig. 4a-c** and **Table 2**.

Result

Kinetic parameters for neonates were estimated from the parameters of adults and children used in previous research. With these estimates the sets of neonate data were fit individually for TSH, T4, and T3 using the new neonate system model. **Fig. 4** shows the best fit for TSH with no dose input over the first forty hours of life. TSH rapidly approached zero and by twenty hours was negligible which is inconsistent with real data (**Fig. 4a**). Total T4 rose rapidly over the first 10 hours then dropped off (**Fig. 4b**). Similarly, Total T3 rose rapidly in the first 11 hours of life and then declined quickly for a period, after which it slowed to small decent (**Fig. 4c**). Both Total T4 and Total T3 mimicked their data curves well, but the magnitudes were too large.

Discussion

The simulation did not provide a correct fit for the data sets, indicating that there were errors or invalid assumptions in the model. From **Table 2**, the %CV of all the parameters was too large and k_{21free} was not found; the fitting parameters were unreliable. In **Fig. 4a-4c**, the fittings did not match with the data sets. The bad fitting might be caused by inaccurate assumption in parameters estimation.

There were some similarities between the fitted curves and the data points although they were not equivalent. In **Fig. 4a**, the fitting curve of TSH concentration decreased in the first hour, but it died quickly which did not match with the TSH data point. This was incorrect because the value of TSH should reach to steady level according to **Fig. 2e**. In **Fig. 4b**, the peak of the concentration of Total T4 was at t= 10 hours. There was a quick increase of Total T4 at t=5 hours. Such peak was caused by the delay block (q9) in which the secreted T4 reached to the compartment q1 after 8 hours of birth. In Figure 2a, the data set of Total T4 also had a peak value, but it was about 30 hours after birth, which was different to the fitted curve, i.e. After 8 hours. In **Fig. 3c**, the shape of the fitted curve was similar to the data set (**Fig. 2c**). But, the peak was different and the magnitude of the concentration was 100-fold in difference.

There should be further changes in the simulation to produce better approximated parameters. There were several possible causes of inadequate fitting and there were suggestions to improve the model. First of all, the initial boluses of neonate model were calculated using ratios (see **METHOD**). This approximation might not be correct, which potentially caused the bad fitting. In-depth research should be done or other approximation methods could be used to improve the reliability of the initial bolus value. Second, the delay block value of the neonates could be changed. A neonate is much smaller than an adult and has a faster metabolism, thus, it was reasonable to predict that the transport rate of Total T3 and Total T4 from q11/q12 to q1/q4 was faster because neonate had smaller volume. Thus, the value of delay could be shortened. Third, some important parameters were not changed in the neonate model, such as the neonates' kblag[4], T4ss (steady value of Total T4), T3ss (steady value of Total T3), plasma protein bindings parameters etc. There was insufficient time verifying those values for neonate's model and it should be done in the future. Lastly, alternative modeling method, such as using steady-state constraint to set the initial values, can be used to improve the model.

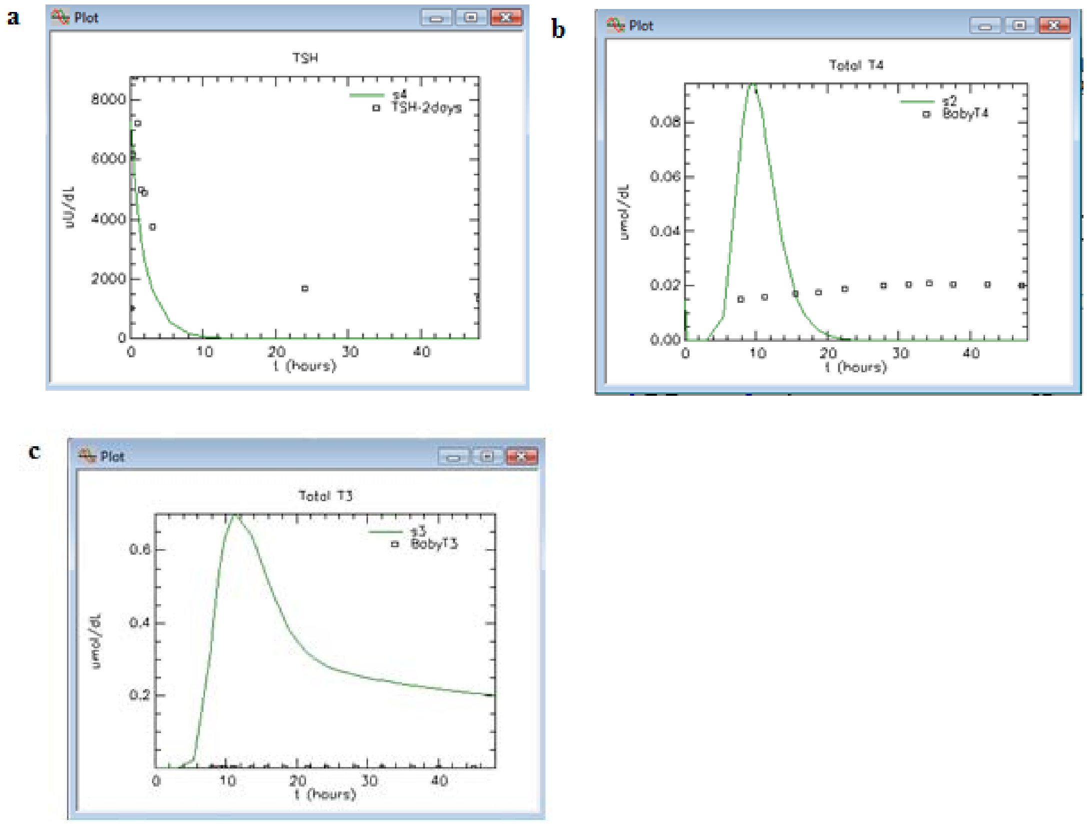

Figure 4 Simulation of concentration of TSH, Total T4, and Total T3 within 48 hours after birth. (**a**) TSH. (**b**) Total T4. (**c**) Total T3.

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The Relationship between Education and Causal Reasoning

Britney Zavada

Causal relations are at the foundation of mathematical concepts and are often not taken advantage of in the classroom setting. The Western and Eastern approaches take two greatly different perspectives on mathematics and the methods of instruction. It is well known that America has been at a large disadvantage in the world for having a low performance in mathematics. Even more startling is the amount of community college students that cannot graduate because they are unable to pass one math class that is required. The Eastern approach focuses on dwelling on a small set of challenging problems for students to understand the underlying concepts and the general theory that is behind the mathematics. The Western approach focuses on drilling students with many example problems and then testing their knowledge. In this form, students seem to spend time learning a procedure of steps in order to get the correct answer, rather than the reasons why they are performing these tasks. When both kinds of students are presented with a novel problem, those that understand the theory perform much better than those who simply got examples. Even in my college experience I have heard many students say that a test was unfair because the professor never showed a similar problem in lecture. They did not expect such a challenging and novel problem to be presented on the exam. I am sure that the professor gave the problem thinking that if a student understood the theory then he or she would have the tools available to solve the problem. Furthermore, when I am in a class and I hear that I will need to provide a proof and understand certain proofs, I find that difficult and foreign. Other than my high school geometry class, there is little emphasis on the concept and formality of proofs.

Overall, the literature is mostly void of articles that look at education and causal reasoning as an important application in mathematics. In the reasoning lab where I work, there are many topics being explored that have wide implications. Much of the work that has been done regarding causal reasoning regards Bayesian system and networks. One of the professors that runs the reasoning lab, Keith Holyoak, has conducted many of these important experiments (Holyoak et al, 2010). He looked at human induction and how certain factors restrain and act on possible inferences. He asserted that induction is a part of the human experience to make accurate and goal-relevant inferences that are sensitive to uncertainty. This is relevant to our experiment because when people make comparison they must discover the concepts with the goal of getting the solution. Holyoak utilized a computational theory with Bayesian inference to test his predictions. He focuses on the probability of causal predictions that would then be extrapolated to a target based on source knowledge. There have been numerous papers done regarding how people learn a theory of causality, a concept that is greatly related to our research. One paper looked at Bayesian modeling to explore the problem of innateness and how it pertains to abstract knowledge. In a way math is an abstraction especially as the concepts reflect instances that cannot be observed. Goodman et all explored the concept called the blessing of abstraction where a person can use inductive reasoning to understand an abstract concept and get the correct answers without being consciously aware of the underlying process. Once again this reflects the idea that people might be able to solve certain math problems without an understanding of the theory (Goodman et al, 2010). Lee and Holyoak in another paper dealing with causal models but instead with analogical inference. Here they showed that analogical inference did build upon a causal model, even cross-domain. This study dealt more with the mathematical concept of Bayesian causal nets and how it related to analogical reasoning (Lee & Holyoak, 2008). The present experiment builds off this already achieved knowledge to make its assertions. Although the system of inference can be modeled by Bayesian computation models, we were interested in seeing the results of such processes in the context of education and mathematics.

Last year I was a Research Assistant for Jessica Walker we explored this troubling statistic with college level students and the difficulties they have. The study was designed to take a more Eastern approach but add new features to the teaching method. The material was based on students relearning factoring and what the factors meant. There was a small set of problems that participants would run through and try to solve as best they could. If they got an item wrong then in a nested fashion they would continue going deeper into the concept underlying the current problem. The addition from this research was that participants had to make comparisons throughout the experiment. This made them identify the causal relationship between the problem and the theory. It was important however, that they discover this on their own. If the information were just given to them then it would have resembled the Western approach more. Last quarter it was very exciting to see that the result came out as predicted and was robust. Overall people that had the manipulation of causal reasoning performed better, especially on novel problems.

This quarter we wanted to see if these results would replicate when taken on the computer. First of all this would take away any bias that the experimenter could have and also, the results could have a higher impact. There is a great deal of sites such as Khan Academy, Udemy, and Mastering Physics that cater to helping students learn a certain subject. Websites and online quizzes that keep track of a student's progress, feedback, and quizzes have become very popular in the education system. If these results extrapolated to the computer, than this would give the possibility for an online quiz bank to be created to help students. The target audience would be community college students who have a certain level of difficulty with mathematics. Some of this work had been done toward the end of the quarter but there was not enough participants to see if the finding was robust. We continued running participants this quarter so that there were over 20 in each condition. Once again, we were excited to find that the results were significant showing that students not only performed better but did extremely better on those tasks involving a novel problem. These kinds of novel problems were called transfer problems. It was also interesting to note that people actually seemed to write more in the comparison and contrast questions. This could have possibly been because people were accustomed to typing large amounts, but more reluctant to write when using pencil and paper. It was also interesting that almost all the participants that were controls answered that the method of learning was similar to what they had seen in the classroom, whereas for the groups of participants that had the manipulation, this was said less frequently. Participants were aware that this was not the tradition teaching method. There was a ceiling effect for our study however, that was difficult to get around. Overall, UCLA students are very smart and especially when a student comes in with a background of college level mathematics, they generally perform very well. We tried to throw out participants that had a perfect score, but there were still many that only missed one or two. Factoring is an elementary concept so it would have been interesting to see how people would perform if a completely new concept was introduced. This would mean that participants could not use any prior knowledge. The results of the study though still show significant findings on the computer and can now be studied further. The paper is being subjected to journals now.

I learned a lot of important concepts and skills while running participants and working with Jessica as a research assistant. She always informed me of why we were conducting certain procedures and what was essential. I learned more about the experiment and why it was influential. Even when I have done research on the topic within education, there are very few articles that have made the connection between education and causal reasoning. Those few studies did not get significant results so this study is very crucial for the education and cognitive science literature. I learned more about data analysis and what was important to look at when observing the data. Our experiment was greatly focused on the transfer problems and not the example problems. This is where the important graphs were extracted. Also, since Jessica is going through the process now of getting her paper published I have actually learned a lot about that process. The paper has gone through many phases and has received input from many different esteemed professors and colleagues. I have noticed that the issue is not having enough to say, but rather not having enough room to say what you want. Every sentence that is included must be of a great amount of importance in order to be included, especially for a wide reaching journal. I am glad I gained the experience that I did with working with Jessica and I look forward to working with her more next quarter. Now that this experiment has concluded I will be working on coding another quiz for a different topic, number lines, for a younger age group. Hopefully these results and applications will be as important as the above-mentioned study.

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Learning and Forgetting Lab: Retrieval Induced Forgetting: Effects on Eyewitness Testimony and Mental Transportation

Brooke Hollyfield

I will admit that when I joined the Learning and Forgetting Lab, I did not understand why anyone would need to study forgetting. I understood why memory was such a fascinating topic to study, but forgetting seemed to be the opposite, like something you would want to avoid that was simply a consequence of remembering. However, after participating in this lab this quarter I now see how intriguing forgetting is in the dynamic memory system. For example, if you remembered where your car was parked every time you went to the grocery store, it would take hours to find your car each time you went shopping. Forgetting is adaptive in that it prevents the brain from becoming overloaded with excess information, and thus is essential to memory. Retrieval Induced Forgetting is a phenomenon in which retrieval of items can cause forgetting of related items due to competition during retrieval in memory (Anderson, R.A. Bjork, & E. L. Bjork, 1994).

I was interested in applications of different aspects of memory that could possibly involve retrieval induced forgetting. The first article explains how repeated questioning can possibly cause misinformation in eyewitness testimony, which his possibly related to retrieval induced forgetting. The second article explores situation in which retrieval induced forgetting may not impair memory of related information. The first article, " The dark side of testing memory: repeated retrieval can enhance eyewitness suggestibility," delves into the reliability issue of eyewitness testimony. I thought this was interesting in relation to retrieval induced forgetting because it seems slightly counterintuitive. Retrieval-induced forgetting seems to suggest that repeatedly recalling a piece of information suppresses other related items. In the case of eyewitness testimony, that might suggest that asking a witness to continually recall the event would continually decrease the memory of the details of the event not being actively recalled. We rely so much on eyewitness testimony in our legal system, and the fact that eyewitness testimony may be vulnerable to misinformation is unsettling. This idea that initial retrieval of events can cause a tendency to report misinformation is called retrieval-enhanced suggestibility. Chan and LaPaglia conducted an experiment to demonstrate this effect, in which they showed participants a video of an event and then subsequently gave them tests about the information in the video to reactivate the information. Participants were in two groups: a 1-test condition and a 5-test condition. They then gave the participants an initial test that repeatedly asked them questions about the event. Listening to an auditory narrative of the event, which included misleading information, consistent information, and control information, followed this. Then, they completed the final recall test (either one or five) that was identical to the initial recall test. They conducted their analysis on the number of correct information and misinformation reported in the initial and final tests. Interestingly, they found that as the number of initial tests increased, the probability of recalling misinformation increased. Participants in the no-test control condition recalled far less misinformation than either participant in the 1-test or 5-tests condition. This finding seems to be consistent with retrieval induced forgetting, because the more amount of activation the information received by subsequent recall, the more it induced forgetting of the related details of the event. They did demonstrate in further studies that eyewitness memory can be accurate if questions are asked in a neutral way or if participants were warned to be cautious of misinformation. However, it is common for eyewitnesses to crimes to be constantly questioned by police, media, friends, and family members. It is possible that the RES phenomenon is influencing the court system through the mechanism of retrieval induced forgetting, which I found quite fascinating. Since this seemed to be a potential problem, I wondered if there were any cases in which retrieval induced forgetting did not impair memory.

I found an article that had started to ask these same questions about how retrieval induced forgetting could enhance improvements in memory of activated items as opposed to forgetting. Bäuml and Samenieh address this phenomenon in their article, "Selective memory retrieval can impair and improve retrieval of other memories." They found that there were certain conditions that benefitted from selective retrieval and others that were negatively affected. Bäuml and Samenieh conducted experiments that provided evidence that retrieval aids in the recall of listwise directed forgetting and context dependent forgetting. Listwise directed forgetting is when participants are asked to study two lists and then given a cue to forget one of the lists. Typically, this will result in participants' enhanced memory for the list they are told to remember. The experiment conducted by Bäuml and Samenieh demonstrates that memory retrieval can have both detrimental and positive effects on memory. In the experiment, participants were presented with two lists of words. List 1 contained target and non-target items (known to experimenter only). The target items all began with a unique letter and the non-target items began with a unique word stem. The participants began the experiment by studying List 1 and List 2. They were either given a cue to remember or to forget the list. Then, they entered the study phase where they were presented with the word stems and in random order of target and non-target items. List 2 words were also intermittently displayed. Then, the subjects were tested for their recall of the target words. Recall of non-target items impaired the recall of to-be-remember items, whereas retrieval of retrieval of non-target items improved recall of to-be-forgotten items. It seems that when you're told you don't have to remember certain items, the reactivation of related items does not impair them as much. In fact, it even aided the memory of these items. In the context of our lab discussion retrieval induced forgetting so often, I thought this finding was quite interesting because it shows a counterexample of times when retrieval induced forgetting mechanisms of reactivation do not necessarily cause forgetting. This demonstrates that the memory status of non-target items effects whether or not it induces forgetting.

I found Bäuml and Samenieh's second experiment quite interesting. They used the materials as in Experiment 1. The procedure was almost identical as well, except they added a task that was meant to induce context-dependent forgetting. Context-dependent forgetting is a phenomenon in which imagination or daydreaming causes an individual to be mentally transported to another place. This mental imagination task was added after the study phase of List 1. For the control condition, participants were asked to count backwards, a task that is known to not produce any mentally transporting effects. Then, as in Experiment 1, the subjects studied List 2. Then participants were asked to recall the target items from List 1. They were either asked to recall these items after they had been prompted to retrieve non-target items, or instead immediately after viewing List 2. The results of the experiment demonstrated that whether or not non-target items impair memory depends on the state of mental transportation. When subjects were asked to perform the mental imagination task, their mind was transported to another time and place and (in theory) the words from the List 1 were no longer activated. Thus, when they were presented with non-target items after List 2, the non-target items are brought back into their mind, which aided them in their memory of the target items. This brought to mind times when I've taken a break from studying and had to "get back into the groove" by looking at notes or doing a problem more slowly, before I can actually reach the level of understanding I was at before taking the break. Conversely, when the participants were in the counting down condition, they never were mentally transported. The non-target words were still active in their mind during the retrieval phase and this reactivation caused retrieval induced forgetting of the target words. Thus, when the participants were not mentally transported, the retrieval of non-target words impaired recall of the target words. This article goes on to discuss a possible explanation for these findings by introducing a two faces model of memory retrieval. The authors argue that the fact that retrieval can have both positive and negative effects on memory support two faces of memory retrieval.

This lab has been both challenging and fascinating. I have gotten so much more insight into the interworking of memory than I could from any class through the insightful discussion during Lab Meetings and Journal Clubs. For next quarter, I would like to become more involved in understanding the implications of the research of Michael Cohen and Alan Castel. I understand the current experiment that we are running, but I would like to understand more about where this lies in scope of memory research in this field. For next quarter, I would like to start attending the Castel Lab meetings as well as the Bjork lab meetings in become more familiar with other types of research in this area.

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Binocular Rivalry in Action Perception

Crystal Mac

The ability to perceive other people's actions, emotions, and intentions is a very important and highly refined skill most humans have developed as highly social creatures (Blake & Shiffrar, 2007). The visual system provides a rich source of information in human action perception and prediction. Although it is possible to interpret emotion in a static picture, motion provides much more reliable and useful information when it comes to understanding other people's acts and feelings. Being able to interpret and respond to others' actions allows humans to physically interact and work together towards a common goal. It also provides a way to protect oneself from potentially threatening acts from others.

Many previous studies involving the role of motor involvement in action perception have employed the technique of human point-light (PL) animations to isolate the dynamics of body movement from outside noise, such as texture. This technique was first developed by Etienne-Jules Marey in 1884, with the goal of highlighting the kinematics of the human gait. Marey created a high-speed photographic technique, known as chronophotography, which captured up to twelve consecutive frames in a second onto the same picture. To study human motion, Marey filmed a person walking wearing a black suit with markers placed only on the joints. The resulting photograph allowed him to study the changing positions of the joints.

With this starting point created by Marey, Swedish psychologist Gunnar Johansson was able to further develop this technique in 1973 by creating a new technology known as PL animation. Similar to Marey's technique, Johansson portrayed human motion with small light markers placed on the head and joints of the body. The resulting video clips showed only the movement of these lights, leaving out the rest of the body. To add form information to the PL animations, some experimenters have connected the joints creating human stick figures. (Hodgins et al., 1998). Interestingly, when shown only static frames of these figures, observers cannot discern what they are looking at, appearing as nothing more than a meaningless array of dots. Once frames are shown in rapid succession, the motion of a human figure becomes apparent. This highlights how efficient the visual system is in receiving dynamic local signals and creating a globally coherent walking figure (Watson, et al., 2006).

A vast amount of information can be portrayed through these PL animations such as gender, identity, activities involving two or more individuals (e.g., dancing or fighting), facial expressions (when viewing PL faces), as well as the emotional implication of an action. Even under impoverished conditions in the presence of dynamic noise or in ambiguous situations, "human action perception is remarkably robust" (Blake & Shiffrar, 2007). An important exclusion to this robustness is the vulnerability to the inversion effect, in which human action is difficult to perceive in inverted PL animations (Sumi, 1984).

Previous research has employed the technique of PL animation to investigate perceptual grouping in binocular rivalry. Binocular rivalry is a phenomenon in which two different visual stimuli are presented to corresponding locations of each eye, creating a multistable percept as each of the stimuli compete for perceptual dominance, or a piecemeal composition, combining parts of the monocular stimuli (Silver & Logothetis, 2003). With this form of perceptual bistability, or stimulus rivalry, periods of perceptual dominance alternate between the two stimuli. Fluctuations in perception has also been observed in famous ambiguous figures, such as the Necker cube or the spinning dancing girl illusion. Binocular rivalry has been used in previous studies to explore mechanisms of selection and suppression in visual perception (Alais & Blake, 1999). Silver & Logothetis (2003) were able to demonstrate that a period of unitary perception of one stimulus tends to be succeeded by another unitary perception of the other stimulus even when a mixed percept was presented for the majority of the time.

Watson and his colleagues (2004) aimed to demonstrate that high-level perceptual grouping can increase the rate of rivalry between stimuli that would generally be perceived as non-rivalrous. Perceptual grouping was created with PL animations simulating a human walker. They found that when PL walker stimuli were presented to each eye in different colors and configurations, strong rivalry occurred. In contrast, minimal rivalry occurred when the two walkers were split between each eye or when both were presented to one eye. These results suggest that the visual processing of the animated walkers promote rivalry between different stimuli from each eye rather than between higher-level representations of the walkers. Watson and colleagues further hypothesized that awareness during binocular rivalry involved activity from both higher-level perceptual mechanisms and lower-level ocular suppression. The results of their research led to the conclusion that binocular rivalry occurs at multiple levels within the visual system, stemming from the lower-level ocular representations and rising to the higher-level pattern representations. They concluded that rivalry between PL walkers depends on the global processing of the stimuli but occurs mainly as a result of dominance of signals from one eye to the other.

Neri and colleagues (2006) conducted behavior experiments to determine whether visual discrimination of a human agent is influenced by a second agent. Researchers tested both synchronized and desynchronized fighting sequences to determine if the manipulation influenced the observers' efficiency in discriminating between the target and non-target stimuli. For an observer to be able to distinguish between the 'sync' and 'deSync' conditions, the observer must understand the semantics of fighting. They found that effect in visual discrimination was contingent upon whether the two agents interacted in a meaningful synchronized fashion that allowed the actions of one agent to serve as a predictor for the actions of the second agent. Even in the presence of impoverished visual information, the visual processing system relies on the semantic interaction between the two figures to retrieve information about each individual.

The current study I have been assisting in looks to further these findings by posing the question: can meaningful human interaction influence the rate of binocular rivalry when a biological motion stimulus is presented to each eye? Researchers use ten salsa dancing motion sequences presenting two figures, one male dancer and one female dancer. Each trial is composed of about 2000 frames, lasting 20-30 seconds. In each trial, a green male dancer and a synchronized (matched) blue or red female dancer is presented to one of the observer's eyes; in the other eye, the same green male dancer is presented but with a desynchronized (mismatched) blue or red female dancer. The dependent variable is measuring the pattern of whether the dominant female dancer is matched or mismatched. This is measured by the difference in the percentage of total number of frames in which participants choose the synced female dancer or the deSynced female dancer to be more visually dominant.

The colors of the synced and deSynced female dancers (either red or blue) and eye presentation (either left or right) are counterbalanced for each subject. Also, the luminance levels of the colors for each figure (green male dancer and red or blue for the female dancer) were controlled for. Subjects are asked to view the dancing motion sequences and determine from the red or blue female dancer, which they perceive as more visually dominant. They are instructed to hold down the right arrow when they see the red female dancer as more visible, the left arrow when they see the blue female dancer as more visible, or the down arrow when they cannot discern a difference or perceive a piecemeal composition. Prior to starting the actual experiment, subjects participate in a number of practice trials to rehearse this procedure. Instead of salsa dancers, they view upright or inverted walking figures walking in opposite directions, intended to replicate previous results found by Watson and colleagues (2004). Following the actual experiment, subjects are asked to complete a questionnaire intended to measure the Autism-Spectrum Quotient (AQ) test to measure each participant's autism score. This is to control tested for because previous research has shown that people who score positive on the Autism Spectrum Disorders (ASDs) have a specific deficiency in properly processing information regarding biological motion (Blake et al., 2003).

Although some data has been obtained, this experiment is currently undergoing changes to try to find an appropriate mismatched female dancer. The results of the current data have yet to show a meaningful difference between the perceived synced and deSynced female dancer. However, some promising results have emerged from inverting the female dancer in the same movie 180 degrees around the vertical axis. In this condition, the matched female dancer seems to be significantly more dominant than the mismatched dancer. Future attempts will be made to improve the design of the experiment.

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Review of Survey Responses for Distributed Spacing - Adaptive Learning Study

Jon Lexa

Fixed, fixed with intervals, and adaptive fixed learning techniques were examined to determine which was the most effective method in this between subjects study. Subjects were trained on African geography and tested one week later. After finishing the second part of the study, 17 subjects completed a short survey that consisted of 13 questions asking them to tell the researchers their thoughts on the techniques used and to give their general impressions of the study. Previous research has asked subjects to do similar surveys. Kornell and Bjork (2008) found that subjects think they do worse when trained with spaced intervals compared to massed intervals, and we wanted to see if these findings would be consistent in this study, even though it does not examine massed versus spacing. Metamemory and metacognition surveys have shown that learners are not accurate about how their minds work (Roediger & Karpicke, 2006).

Of the 17 subjects, 10 did not know what the term spaced or distributed practice was. Sixteen had no prior knowledge of the term increasing schedules of practice. Thirteen were unaware of the term adaptive scheduling techniques for memory and learning. When given descriptions for the three methods, 10 subjects stated that they used something like the three methods when studying for tests. The reader should note that the subjects probably employed a technique that was not anyhow similar to the experiment's methods. For those that claimed they used a variation of fixed spaced intervals, the subjects did not state if they timed the intervals; instead, they mentioned that they used approximations of break time between studying. This would not have the same effect as the experiment's condition because there is no control for timing effects. The lack of strict timing would allow for other factors to possibly contribute to learning. One subject mentioned that they "tend to study things all at once instead of spaced in time" and that this practice has seemed to work "so far." This is a great example of how metacognition and meta learning is not always accurate at telling us how we are cognitively doing.

When asked if they had been taught these techniques, only one subject expressed that they intuitively felt these methods were better for learning material for test day. Other subjects mentioned that they had heard of the practices from psych classes but never tried to incorporate it into their study, and the majority was never taught these techniques.

Regarding the timing of the repetitions, subjects varied on their opinion. 8 of the subjects said the time between repetitions were too short, four said they were just right, two said they were too long, and four abstained. What is interesting to note is that some of these subjects may have had the expanding interval, meaning that they may have thought that the expansion of intervals was not right or the actual time between certain intervals was not right (the condition of the participants who answered this would have to be examined to know for sure).

Subjects were asked to state whether they felt like they learned the countries relatively well. 14 of the 17 could not confidently state they learned the countries well. This is consistent with previous findings that people do not feel confident about their learning when trained with spaced methods.

When asked to speak about how the information was displayed with regards to timing, most felt that the timing was appropriate. Two subjects wanted the number of times a country was presented to be equal (not sure which phase) and some wanted the countries to be presented in different colors. The different colors idea is an interesting lead; however, it does not relate to the spacing studies and would confound any results.

The subjects were also asked to state whether they thought they could have learned the countries better if the presentation was order differently. Fascinatingly, only two subjects answered no. One subject did not respond, and 15 others all had varying opinions on how the presentation could have been ordered differently. Eight of the subjects stated that they would have learned better if "the countries were displayed in order of region." One subject thought that they would have learned better if the presentation of items were back to back, essentially in a massed format. Another subject thought they remembered the "ones [they] learned at the beginning of the learning session better." One particular subject responded that they would have done better if they were given feedback during the first phase instead of not telling them anything at all. This contradicts findings by Kornell, Hays, & Bjork (2009). Kornell, et al., found that subjects did better at recalling answers about facts when given an unanswerable question before the testing question and answer. Lastly, one subject felt that the number of presentations was overwhelming, and they would have done better if they were given a fewer number of countries to learn during each set of trials.

The final set of questions acted as a guide to help us evaluate how engaged each participant was during the experiment. They simply asked the participant to state whether they felt rewarded or frustrated when receiving feedback and if they were able to focus and concentrate at the task at hand. What is interesting is that reward can be associated with confidence levels. If the subjects felt that they did better when they actually did not (in conjunction with findings by Kornell & Bjork), they may do better when they struggle, in line with the desirable difficulty hypothesis. This hypothesis summarizes the articles cited in this paper by stating that subjects learn better when given a harder learning task. A side effect of the harder learning task is that participants think they do worse. It would be interesting to examine the relationship between occasionally giving false feedback to the subject, thus inducing a negative response, and their ability to learn the material. False feedback would have to be given for novel information and early on during the learning phase otherwise the subject could easily pick up on the strategy and possibly lose confidence in the training method and structure.

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Studying Perception and Conception in Learning Statistics

Joseph Truong

Traditionally, students are taught to learn a subject using a lecture as a cornerstone, and building a mastery of the subject with a hands-on experience or practice, and more lectures. Another view of education by Goldstone & Barsalou suggests that conceptual learning and perceptual learning are very similar, such as the way they both represent and process information. In addition, they believe that perception is the foundation for conception, that "perceptual processes guide the construction of abstract concepts" (Goldstone & Barsalou, 1998). This means to say that students use perception to help set up a starting base for learning a subject, in which learning takes place in an abstract manner, then allowing conceptual learning to fill in the gaps with specific details more effectively.

Perceptual learning involves placing information into structures and categories, allowing for the identification and classification of objects, such as identifying a given animal despite varying appearances. This is possible because it does not depend heavily on the container metaphor of learning, where information is simply stored in memory and retrieved when needed (Kellman & Garrigan, 2009). Instead, information is obtained dynamically by using pre-made associations and relations. Thus, we can say that learning (through perception) is essentially limitless; learning starts with a basis that is constantly built on and interwoven with new information.

In addition, perceptual learning involves discovery and fluency—discovery refers to pattern recognition by discovering features similar to one another, while fluency refers to being able to respond almost automatically because of practice when facing a problem

(Kellman, Massey & Son, 2009). Experience correlates with perceptual learning, while formal instruction correlates with conceptual learning. In Kellman, Massey, and Son's (2009) study, a perceptual learning module (PLM) was implemented to teach participants to recognize patterns and be able to answer questions quickly (fluently) as they continued with the module. The control group received a packet to work on, with an answer key provided to check on their work, but without providing feedback. Conceptually, this would make participants think of the problems in terms of memorization as opposed to thinking in terms of patterns. The problems given on both the PLM and the packet consisted of translation problems for linear equations, asking participants, given a word problem, graph, or equation, choose an answer that depicts a new representation as either a graph or an equation, resulting in four types of translation problems (Kellman et. al, 2009). Results indicated that participants who underwent through the PLM were better at transferring what they learned onto different cases and presentation types.

Learning is also perceptual in arithmetic operations, as shown in a study conducted by Goldstone, Landy, & Son (2009). They found that participants "tended to look at the multiplication portion of the expression" initially in a problem such as "2 x 3 + 4." This shows that participants were able to automatically apply the precedence rule just by searching for the multiplication sign first and calculating the math that occurs there. This result was seem as "people's perceptual systems becom[ing] rigged up over practice ... to automatically gravitate" to where the equation should be handled first (in this case, multiplication) (Goldstone et. al, 2009). In addition, the multiplication sign attracted more attention than the addition sign, regardless of the problem. This shows that through perception, attention is selective in going to operators of higher precedence for varying problems, non-specific to the type of calculations actually needed.

Using these ideas, this study, conducted in the Human Perception Lab at the University of California, Los Angeles, was designed to test whether learning was more effective when participants went through perceptual learning followed with conceptual learning, or when participants went through conceptual learning followed with perceptual learning.

Participants for this experiment consisted of students at the University of California, Los Angeles participating in the study for course credit with no monetary compensation. Participant registration was restricted to students who did not take a Psychological statistics course or the Psychology research methods course, which emphasizes learning main effects and interactions in terms of statistics, but has been changed to allow students to participate in the experiment if they are concurrently enrolled in a Psychological statistics course.

The study was a 2 x 2 experimental design with the PLM and the video as one independent variable and the order in which the PLM and the video were used. The PLM was designed to be mostly perceptual, while the video was designed to be mostly conceptual because perceptual learning and conceptual learning are closely tied to one another. The use of a PLM for perceptual learning was effective in that explanations of main effects and interactions were not explicitly stated verbatim, but instead, it was designed to have participants pickup patterns from each problem and transfer each pattern regardless of the scenario issued (Kellman et. al, 2009). The dependent variable was the number of correct answers chosen on the paper tests issued after each instance of training from the

PLM and from the video, measured on an interval scale (compared with the pretest conducted before the experiment began).

The experiment used a PLM and a video about main effects and interactions, not requiring participants to have a background in the subject matter. The PLM was designed to ask participants one of three different trials: participants were given a graph and told to choose the correct statement verbally describing the effect(s) shown; participants were given a statement and told to choose a graph depicting this; and participants were given a graph and asked to describe the main effect or the interaction (depending on the situation) in terms of 'greater than,' 'less than,' or 'equal to.' The PLM and video were runnable on either a Macintosh or Windows platform, with the PLM having a point-and-click interface similar to the MultiRep PLM (Kellman et. al, 2009). The situations used were produced by an experimenter and were equally paired with each combination of main effects and/or an interaction in order to hint to the participant that the situation was an arbitrary factor in thinking about main effects and interactions. The experiment contained eight possible combinations of main effects (one of each) and/or an interaction, resulting in 24 different questions. Both bar graphs and line graphs were used. The module was designed to ask the participants a select number of the 24 different questions, and was adaptive in retiring certain questions in which participants were able to answer quickly and correctly while adding a new question for each one retired. The program would later reintroduce the question to check for whether the participants had mastered the question to the point of the question being answered almost automatically. Feedback was given for each question, where each incorrect answer was compared with the correct answer. After 15 trial questions, a progress report was shown to each participant detailing their accuracy and reaction time. Mastery was defined as answering the question correctly five out of six times, having a reaction time of 10 seconds or less, and having answered for both line graph and bar graph scenarios. Participants were told to continue the module until they mastered each of the 24 different questions, at which point, the module would come to a halt. The video was around 10 minutes long and was given to participants to watch and study for up to 20 minutes. It consisted of definitions for main effects and interactions, and drew examples of each using bar graphs and line graphs. The presence/absence of main effects and interactions for each example used were stated, along with the means compared to find the main effects and interactions. Explanations of the presence/absence of main effects and interactions were shown through a printed statement, using visual cues to hint at where to look in the graphs, and read aloud by a speaker in the video. Both the PLM and the video did not purely contain only perceptual learning and conceptual learning. However, each was designed to consist of a majority of perceptual learning and conceptual learning, placing an emphasis on each one respectively. Three similar paper tests were issued to the participant: one before the experiment; one after either the PLM or the video, and a final test after the follow-up learning mechanism (the PLM if the video was shown first and vice-versa). In the past, the experiment was conducted for two hours, but the experiment has been revised to be conducted for a three hour session, in addition to some changes that were incorporated above (e.g., new feedback, additional question type).

This study is currently being conducted, after gathering some pilot data and making adjustments to the study as felt necessary. Implications for this study can apply to the educational setting, changing the way students are taught in order to improve fluency of a subject. By being more fluent, one is able to learn new things much easier using older subjects learned as the foundation.

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Connectionist Models of Perceptual Learning: A Review

Lehel Kovach

Perceptual learning can be defined as the ability to improve performance in tasks of perception through practice and training. It has been a subject of study ever since Gibson (1959) published her book on the subject in which she showed that by altering presentations of two visual stimuli with few differences, subjects were able to discriminate between the two through pre-exposure.

The ability to discriminate between to different sensory stimuli is not just limited to visual modality—it is an ability to discern between sights, smells, tastes and tactile input into the nervous system, Furthermore, the ability to learn the difference in sets of perceptual information is a cross-species phenomenon.

The importance of studying how the nervous system of humans and other animals is able to learn how to discriminate between similar stimuli (and then able to make associations to different stimuli) is not only important to the study of psychology, but also of importance to the world of technology so that technologies can be invented to be able to perceive sensory information and learn discriminations as well.

This paper reviews three different studies on models of perceptual learning that are based on a connectionist paradigm. Since human (and non-human) perception systems have been successfully modeled using connectionist schemes, the aim of this paper is to review connectionist models of perceptual learning. This paper seeks to examine the Dosher & Lu perceptual learning model (Petrov et al., 2005), the McLaren & Macintosh associative learning model (McLaren & Macintosh, 2000) and Chen et al.'s visual perceptual learning model (Chen et al., 2010). This paper will explain the structures of each model, explain differences between the models, outline any weaknesses or questions brought about by the models by the researcher and, finally to compare the models, querying what types of research is needed to test, improve and converge such models into a better, more inclusive connectionist model of perceptual learning.

Dosher & Liu Model

Dosher & Liu (1998) outlined a model for perceptual learning that involved a connectionist model in which the weights of connections between the early cortical representations and the specific contexts of perceptual tasks were reweighted. In this model early representations were not affected; in other words, low-level, initial perceptions of stimuli were not changed. The model supposed that *learning* was represented by the change in weights of connections later on in the perceptual pipeline—specifically, in the connections to representations of a perceptual task at hand. Therefore, there model supposes that perceptual learning is not a result of representing the stimuli differently, but how the representations are associated within the level of decision-making and the constructs of decision-making units. This type of reweighting then disallows transfer from stimuli to the next based on which type of decision-making task is occurring. The model's output of representation never changes, even if there are differences in input differ; the "read-outs" (Petrov et al., 2005, p. 715) from the representation units are weighted with the decision-making units of the perceptual task, and learning is then the result of the new weighting.

Petrov, Dosher and Lu (2005) went about enhancing the model and then testing it by creating a computer program that compared its performance to humans. Their research tested whether or not early representation modification was a viable model versus the task-specific selective reweighting model. The results of their study indicated that the latter model was comparable to human performance. The model used Hebbian-type reweighting between representation units and decision-making units to account for complexity of tasks. Their model, therefore suggests that perceptual learning is a form of associative learning that is statistically driven.

Their paper does make note of the fact that early representation modification is not entirely ruled out. What their conclusion suggests is that their hypothetical model for perceptual learning supports previous physiological and psychometric data and that "reweighting will still be involved to fully account for behavior" (Petrov et al., p.718). The model was tested, though, divorced from any early representation modification functionality and still performed well, according to their results.

It should also be noted that their model was limited to testing visual perception and comparing it to human performance. The model still lacks general testing with other perceptual modalities and further experimentation to non-human animal performance could be a possibility of strengthening this model.

McLaren & Macintosh Model

McLaren and Macintosh (2000) developed a connectionist model of associative learning that encompassed stimulus representation formation and association with response units via a Rescorla-Wagner (Delta Rule) algorithm. The model was able explain how animals are able to represent stimuli of virtually any modality, where stimuli can be varied along a spectrum such as light frequency. The model employed stimulus sampling theory in order to explain how stimuli are represented. Different representations of stimuli are accounted for by lateral, weighted connections between "micro features" (McLaren & Macintosh, 2000, p.211) of a stimulus that are reweighted (that can be inhibitory or excitatory) based on conditioning through the presence or absence of the micro features.

Perceptual learning, according to McLaren & Macintosh, therefore is a specific example and prediction of their model. The model demonstrates perceptual learning as an occurrence of inhibitory connections between features in a representation of a stimuli. For instance, if a stimulus AX (containing features of A and X) was conditioned into the network, BX would have the same response due to generalization (X conditioning transfers). If AX and BX were conditioned separately, inhibitory connections to B would form in AX as well as inhibitory connections between A and BX due to the lack of presence; lack of presence would be trained through error-correction negatively in the weights, thereby outputting different responses.

The model, as stated previously, is an overarching model for associative learning. While the perceptual learning can be adequately explained through their model, lack of testing with present data is lacking. The authors make mention of this fact. While their model accurately explains other learning phenomena such as latent inhibition, their model might be at odds with Petrov et al.'s research. Finally, their model suggests that perceptual discrimination occurs early in representation. Therefore, connections between representation "microfeatures," might need to be readjusted if this is theorized in a representation layer.

Chen, Chen and Lu Neural Network Model

Chen, Chen and Lu (2010) developed a theoretical neural network model to be able to learn discriminations between Chinese characters. The model employed a three-layer network that included lateral connections in the middle layer. The results of this model demonstrated the ability to code an artificial neural network that was able to learn the difference between similar visual stimuli.

Further testing of their model involved creating purposeful damage to some of the connections in the middle layer. The results demonstrated that the network was still able to adequately discriminate between the characters after training and damage. The damage was a hypothetical analogy to a study on damage to the somatosensory cortex of owl-monkeys that were still able to discriminate tactile stimuli.

While this simple neural network model was able to perform in the desired fashion, the conjectures by the scientists were problematic in that they were inferring that damage to somato-sensory areas of an owl-monkeys cortex can translate to damage in the visual system since these are two different modalities. Furthermore, their model was never compared to human or animal performance and leaves questions as to how a biological perceptual learning system could differ from their purely computational model.

Conclusion

Of the three models reviewed in this paper, the Petrov et al. model served as the best explanation for human visual perceptual learning due to its testing of human performance and physiological data. Although the Petrov et al.'s model and experimentation correlated best with human visual perceptual learning, the fact that perceptual learning in other modalities still needs to be tested through their model. Otherwise, it could be conjectured that perceptual learning systems are domain-specific, or modality-specific. Furthermore, the Petrov et al. model makes the claim that early representation is unaffected but the selective reweighting scheme suggests the possibility that actual representation of each discriminated stimuli could lie in these connections themselves.

The McLaren & Macintosh model, while being an overreaching model to account for all perceptual learning is weak in that it has not been tested against human or animal performance. Their model is still at a purely theoretical level. But their model makes good predictions and should not be discounted, especially since the model predicts more than just perceptual learning. The question is whether or not representations of stimuli occur at a low-level or not, which would contradict the findings of Petrov et al. The McLaren & Macintosh model claims that lateral connections that are inhibitory in nature can account for perceptual discrimination.

While the Chen et al. model is a simplistic neural network to discriminate between Chinese characters, it serves as a good foundation for examining how neural networks can be trained to perceptually learn. The model echoes McLaren's model in that lateral connections are employed. But their model is crude and does not really try to compare with animal performance.

Regardless, there are discrepancies in all the models that should be taken into account. Namely, perceptual learning occurs in all of the senses. Also, perceptual learning occurs in both non-human animals and humans. Third, two of the models use lateral connections as a mechanism for perceptual learning while the Petrov model does not. Finally, the Petrov model conjectures that *early* representation modification need not be changed to account for perceptual learning phenomena; yet, representation (in a grander sense than early representation) could be the very reweighting they are encoding in their model.

All in all, the Petrov model needs to be tested against animal performance and also needs to be expanded to test for perceptual learning in modes of auditory, gustatory and tactile stimuli. Meanwhile, a model should be devised and tested that incorporates the Petrov et al. connectionist model that can account for associative learning in general so that a unified connectionist model of learning could explain all phenomena seen in animals and humans.

Finding Efficient Category Learning

Mark Corre

Abstract

Previous research on category learning (Zeithamova and Maddox, 2009) showed that the most efficient ordering of stimuli varies on whether or not feedback is given. In addition, there has been much debate over what types of spacing is the most efficient for learning. Here I propose that Kellman's model along with Zeithamova and Maddox work allows for a better version of category learning.

Finding Efficient Category Learning

Zeithamova and Maddox showed that the ordering of stimuli has a profound effect on the categorization of stimuli (2009). Their data is shown in figure 1 at the end of the paper. Participants who were not provided with feedback tended to form bimodal categories more easily when stimuli were presented moving incrementally along an irrelevant unimodal dimension and then a stimulus was presented that varied greatly on both the irrelevant dimension and the relevant bimodal dimension. However, participants who were provided feedback tended for form categories more easily when presented with an alternating pattern of stimuli along on the bimodal dimension while moving incrementally along the unimodal dimension.

Jones, Love and Maddox (2006) argue that the more recently a stimulus is presented the stronger effect it will have on the perception of future stimuli. Therefore a possible explanation is that a sudden "shock" in recent information forces participants to separate the items into separate stimuli. In addition, this "shock" may need to be sudden and strong for categories we are not provided feedback while constant and weaker for those in which we are provided feedback for. Other research has shown methods which may also be used to quickly pick up and retain a category.

Spacing

Spacing is the presentation distance between a category or a stimulus and that same category or stimuli. Spacing has been used to increase the efficiently of learning in a variety of subjects including math (Rohrer and Taylor, 2007) and language (Pavlik and Anderson, 2005). Spacing an item far apart increases memory retention, however, if we want to learn a category or concept in the shortest amount of time we want to reduce this lag between items. Kellman has proposed a model of adaptive spacing which spaces items based on correctness and response latency, once is correct and has a low enough response time, the item is considered “mastered” and the frequency of the item is reduced to increase memory retention. Once an item is sufficiently mastered there is a great distance between its next presentations in order to stimulate memory retention.

Pairing

Zeithamova and Maddox (2009) only presented one stimuli at a time, however, presenting two stimuli at a time can speed up the learning process. Participants would have to transfer more information from trial to trial such as category exceptions. This could mitigate the memory retention lost due to the spacing of stimuli.

Simple vs. Complex Categories

Complex categories contain many irrelevant dimensions of difference and similarity whereas simple categories contain few irrelevant dimensions. Kellman tested categorization with complex categories such as butterflies. Using these complex categories introduces a lot of noise such as the overall proportionality, orientation, etc. However, simple categories (i.e. lines categorized based on length) mitigate these irrelevant categories. This allows the most efficient knowledge transfer with the least interference from item to item. This way we can find which methods are best at transferring category rules rather than which best allows us to sort through relevant and irrelevant dimensions.

Proposal

I propose an experiment be run in which Kellman's model of presentation and category mastery is used with simple category pairs and Zipper ordering to figure out if the Zipper modeling combined with Kellman's model allows for even more efficient category learning.

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Evaluating Generic Priors for Causal Reasoning by Iterative Learning

Alice Merrick

Abstract

Humans are expert at learning causal relationships, even from limited data. One principle that people might use to make inferences about causal relationships is simplicity. According to the "sparse and strong" (SS) power model (Lu et al., 2008), which has formalized the role of simplicity in causal reasoning, learners are guided by priors that favor a minimal number of causes (sparse), each individually of high strength (strong). An iterated learning design was employed, which involved having a series of participants make causal inferences, with the data for each being generated by responses from the previous participant. The task involved judging the causal strengths of certain exotic fruits that may produce a rash in tourists. Participants were shown the results of eating a particular pair of fruits, after which they judged the strengths of each fruit individually. The SS power model predicts that over the course of several generations of examples derived from a series of learners, participants' judgments of causal strength will converge towards their sparse and strong priors.

Introduction

Previous research has shown that people of all ages have a remarkable ability to learn causal relationships often from only a handful of examples, but it isn't obvious how a reasoner comes to recognize these relationships. As philosopher David Hume pointed out, our observations don't inherently include any causal information. This suggests that causal relationships must therefore be inferred.

One principle that people might use to make inferences about causal relationships is simplicity. This idea is often referred to as Occam's razor: According to Isaac Newton's first Rule of Reasoning in Philosophy, "We are to admit no more causes of natural things, than such as are both true and sufficient to explain their appearances." Although seemingly common sense, simplicity is both difficult to quantify and to justify as a guide for induction.

Nevertheless, we do find evidence for it. In trying to answer why, given that data are inevitably consistent with multiple explanations, are some causal explanations chosen over others, Lombrozo (2007) explored the role of simplicity in evaluating competing explanations. Lombrozo found that simpler explanations are assigned higher prior probabilities. Her findings suggest that simplicity *is* used as a basis for evaluating explanations and for assigning prior probabilities (2007). In other words, people prefer explanations that require fewer causes.

The "sparse and strong" (SS) power model (Lu, Yuille, Liljeholm, Cheng, & Holyoak, 2008), has formalized the role of simplicity in causal reasoning. According to the SS power model, learners are guided by priors that favor a minimal number of causes (sparse), each individually of high strength (strong). A number of previous models of causal reasoning have been proposed to explain how causal inferences are made and have attempted to predict human judgments about causal relationships. Before going further, we will briefly review the two that most directly influenced the SS power model: the power PC theory (Cheng, 1997) and the causal support model (Griffiths & Tenenbaum, 2005).

Older models of human causal induction have focused on comparing the probability of an effect occurring in the presence and absence of a cause (e.g., Ward & Jenkins, 1965; Cheng, 1997) (Griffiths & Tenenbaum, 2011). One such model, the power PC theory, reconciles the idea that causal relationships are not directly observable with the idea that people hold prior beliefs about the power causes have to produce or prevent their effects (Lu et al., 2008).

According to the power PC theory, human judgments of causal strength are equal to the probability of the cause producing the effect in the absence of all other causes. The power PC theory provides a better fit for some human data than its precedent, the ΔP model, in which causal strength is based on the difference between the probability of the effect occurring when the cause occurs and the probability of the effect occurring when the cause does not occur (Ward & Jenkins, 1965), but neither model provides a full account of human performance. The SS power model incorporates the core claims of this theory (Lu et al., 2008), namely that people have four general prior beliefs with respect to causal learning:

1. The background and candidate causes influence the effect independently.
2. A background cause could produce the effect but not prevent it.
3. The causal strengths of the background and candidate causes are independent of the frequency of their occurrences.
4. An effect does not occur unless it is caused.

In the case of two potential causes, these assumptions imply that the probability of observing the effect e is given by the Noisy-OR function,

$$\mathrm{P}(e^{+}|b, c; w_0, w_1) = w_0 b + w_1 c - w_0 w_1 bc \qquad (1)$$

where b and c are two potential causes (background and candidate) and w_0 and w_1 are the strength of the background cause and candidate cause respectively. This generating function was subsequently employed by models using Bayesian statistics. More recent work has explored the notion that human induction is guided by prior assumptions people make about the nature of causal relationships by combining ideas from Bayesian statistics and human cognition. (Griffiths & Tenenbaum, 2005; Lu et al., 2008). Griffiths and Tenenbaum first proposed a model based on Bayesian statistics that used causal graphical models. (2005). The use of causal graphs made it possible to distinguish between causal structure and causal strength. Griffiths and Tenenbaum (2005) gave an account of learning causal structure while Lu et al. (2008) showed how this approach could be extended to infer causal strength (Griffiths and Tenenbaum 2011).

Although the graph structure specifies the causal relationship among variables, a function is necessary to specify the strengths of those relationships. This model therefore uses Noisy-OR (for generative causes) parameterizations to characterize the function form of causal relationships in which causes are assumed to have the power to cause or prevent the effects independently (Griffiths & Tenenbaum, 2011). This is the same function given by (1). The probability of getting the observed data from a causal relationship with weights w_0 and w_1, $P(D|w_0,w_1)$, or the likelihood of the data, is given by the product of observing (or not) the effect, given c,w_0, and w_1 over e^+ and e^- and c^+ and c^-. By applying Bayes' rule, we can then use the likelihood function to compute the posterior distribution over w_0 and w_1:

$$P(w_0,w_1|D) \propto P(D|w_0,w_1)P(w_0,w_1) \qquad (2)$$

where $P(w_0,w_1)$ is the prior on w_0 and w_1.. But in order to do this, first we must estimate the priors on w_0 and w_1. Lu et al. (2008) evaluated different kinds of priors on causal strength by testing predictions of different models implementing those priors (2008). Because people have a preference for causal models with fewer causes (Lombrozo, 2007), and for causes that minimize complex interactions (Novick & Cheng, 2004), the priors we will be testing are the sparse and strong priors (Lu et al., 2008).

Whereas previous research tested models over various data sets (Griffths & Tenenbaum; Lu et al., 2008), here we are using an experimental method based on iterated learning to test if people are using generic priors. Iterated learning can be explained as having a chain of agents in which one agent answered data that was generated by the previous agent and then forms a hypothesis about how that data was generated and then generates new data for the next agent (Griffiths & Tenenbaum, 2011). A classic example of this is language learning, and in fact, iterated learning was first used in studying cultural transmission.

Previous analyses of iterated learning with human learners indicates that when people learn from one another, “they converge to a distribution over hypotheses determined by their inductive biases” (Griffiths & Kalish, 2005; Griffiths & Kalish, 2007; Kalish, Griffiths, & Lewandowsky, 2007), which suggests that iterated learning can be used as a method for exploring the biases that guide human causal learning. If the agents are using a Bayesian inference then as the chain gets longer the probability that an agent picks a particular hypothesis converges to the prior probability of the hypothesis (Griffiths & Tenenbaum, 2011).

While the simulation of the SS power model with iterative learning is in progress, our aim in this study was to show that over several iterations, participants’ responses will converge to the generic priors they use to estimate the strength of causal relationships.

Methods

Participants. The participants were University of California, Los Angeles, undergraduates. They were recruited from the Psychology Department's subject pool and received course credit for participating.

Stimuli and Procedure. Similar to the previous version of the experiment, the cover story concerned a doctor trying to determine how likely it is that certain food(s) are causing his patients' allergies. The experiment was run in MATLAB with an interface created with Psych toolbox. The participants were asked to answer a causal attribution question, which was suggested by Patricia Cheng, to test if they were using causal inference.

> We conduct a study of medicine X, and find that: 50% of the participants who received medicine X (those in the experimental group) have headaches. Likewise, 50% of the participants who did not receive medicine X (those in the control group) have headaches as well. Recall that participants were randomly assigned to the two groups. Can the headaches in the experimental group be attributed to medicine X?

The participants clicked a "yes" or "no" button to respond. If a participant answered "No" to the above question, they were considered to be using causal inference. Then the participants were given the following scenario:

> Recently a large number of tourists have visited an island in the South Pacific, and soon afterwards developed an unusual skin rash. A doctor has narrowed down the possible causes to three exotic fruit, called cherimoya, melona, and Buddha's hand. [pictures]

Now the doctor is trying to determine how likely it is that eating each of the fruit will cause the rash. He also knows that the skin reaction is caused by individual fruits, not special fruit combinations. However, this task is more difficult because it turns out that the fruits are always served as a salad, in which exactly two fruits are mixed together.

Your job is to play the role of the doctor trying to assess the effect of each fruit on the rash. You will see a series of samples of tourists who ate various fruit combinations, and will be able to see how many came down with the rash, and how many did not. You can assume that the unusual skin rash has no possible cause other than one or more of the three exotic fruits. Based on this information, you will have to answer a series of questions about the how likely it is that each individual fruit causes the rash.

At the start of the first generation the fruits were assigned probabilities of causing an allergic reaction. The initial parameters were 0.2, 0.5 and 0.8. These probabilities were randomly assigned to each food at the beginning of each trial. For each pair of foods, the probability of either food causing an allergic reaction was calculated on the basis that the two were independent events,

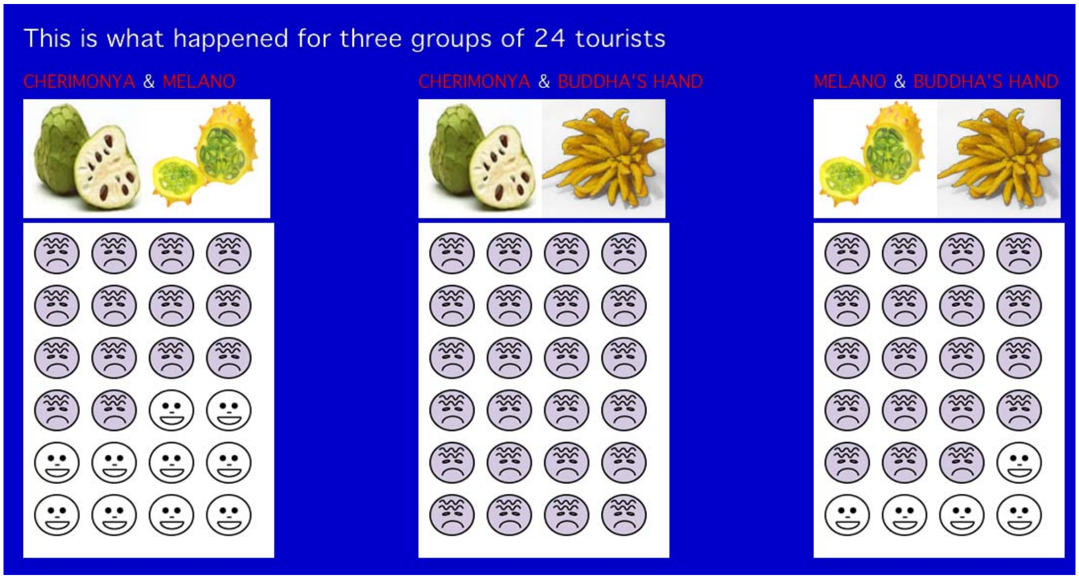

Figure 1: A screenshot of the initial data presented to each participant. The frowning face represented the occurrence of the rash.

using the Noisy-OR function given by (1). The data were presented graphically using pictures that showed the total number of tourists in each group as well as the number that developed a rash. In the previous version of this experiment, the total number of tourists remained constant throughout the experiment at 24, the idea being that sparse data will make participants more likely to rely on priors (Lu et al. 2008). In the present version, however, the data were presented in three different sample sizes: 16, 24 and 32. Each sample size was shown twice for a total of six presentations. For each presentation, the participants were then asked:

> Suppose that there is a sample of 100 tourists without the rash. If these 100 tourists ate [FRUIT X] alone, how many of them would have the rash?

All three data summaries remained on the screen while the participants responded to alleviate demands on memory. Participants entered their responses via keyboard. Originally we used a within-subjects iterated learning design in which a participant's responses were converted to probabilities and used to generate the data in the next generation for a total of 10 generations per participant. This was determined to be too taxing for some subjects, so in this version, each participant was only responsible for a single generation. If the participant answered “No” to the causal attribution question, their responses to the six data presentations were averaged and used to generate the data for the next participant.

Results

The results from using initial probabilities of [0.2, 0.5, 0.8] are yet to be determined due to unreliable and insufficient data. So far, one chain has converged to probabilities [0, 0, 1]. A couple others converged to [0, 0, 0] or [1, 1, 1], but we have reason to suspect that at least some participants were not using causal inference. Such cases were often characterized by incoherent responses or by strangely consistent responses that were radically different from the data they were shown (e.g. inputting 93 for every response). In the event that a participant was not using causal inference, (but answered the causal attribution question correctly) the entire chain was disrupted.

Discussion

In the current version of this experiment, we eliminated the memory demands of previous versions, as well as the tediousness of answering reliably for ten generations. We made the generated probabilities more robust against error or negligence by effectively asking the same question six times, presented in three different sample sizes, and averaging the results. Even with this safety feature, however, the chains were sensitive to unreliable participants, which our causal attribution question failed to filter out. Additionally, the sample sizes may have some systematic effect on an individual’s responses. We were not able to test this statistically with our current data, because the sample sizes shown were not recorded with their respective response (an unfortunate vestige of previous versions of the program, which did not vary in sample size).

Our plans for future work on this problem include establishing a standard for determining whether or not a participant's data is reliable. Our first step towards this goal is to keep track of sample size for each response and testing for significant difference between responses to sample sizes of 16 and 24, and 16 and 32. We also aim to further develop a program that integrates the SS power model simulation with the method of iterative learning, in order to see if our human data matches the predictions of the SS power model.

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Object Recognition

Nicole M. McIntyre

If a human sees a coffee cup with a lid, chances are that he/she will later be able to recognize the lid. How he/she does this is not such an easy question to answer, however. Nevertheless, the existing literature gives us some insight into the process. Fisner and Aslin (2001) conducted three experiments that investigated the ability of human observers to learn the joint and conditional probabilities of shape co-occurrences. They found that learning was both rapid and automatic; subjects were not instructed to attend to any part of the display but they still learned the objects. And, they didn't only learn single-shape frequencies; they also learned higher-order aspects of the structures. These findings support Barlow's theory of visual recognition, which holds that detecting coincidences of elements is necessary for efficient learning of new visual features.

Then, in 2005, they conducted another experiment on statistical learning of visual feature hierarchies. They looked at how adults encoded and remembered parts of multi-element scenes that were comprised of recursively embedded shape combinations. They found that embedded shape combinations were less well-remembered than non-embedded ones. The results suggested that a bootstrapping approach of constrained statistical learning presents a good framework for the future investigation of the formation of different internal representations in pattern and scene perception.

Orban et al (2008) investigated the learning mechanism that combines lower-level features into higher-level chunks with a visual pattern-learning paradigm. They used a Bayesian model to develop an ideal learner that extracted and stored only the chunks of information that were barely sufficient to encode a set of visual scenes. It both reproduced the results of a larger set of previous empirical findings and made key predictions that were confirmed experimentally. Human performance was found to be well above chance when pair-wise statistics in the exemplars contained no relevant information. Therefore, it is thought that humans extract chunks from complex visual patterns by generating accurate yet economical representations and not by encoding the full correlational structure of the input.

Method

Participants

Fourteen younger adults (age range: 18-22 years) from the University of California, Los Angeles were recruited through classes offered through the Psychology Department. Participants were given extra credit as compensation for participating in the study.

Design

Each experiment started with a familiarization phase that was followed by two phases - a training phase and a testing phase. Subjects were shown 6 base pairs of objects, for a total of 12 different objects. The pairs were also shown together with the same relation to one another. The assignment of the 12 shapes to the 6 pairs was randomized to make sure that no one was pair was more easily learned than the others.

Materials and Apparatus

We conducted the experiment on a computer; participants saw images on the screen and recorded their answers using a standard keyboard. A chin rest was used to ensure that all participants saw the screen from the same distance. An adjustable-height chair was used for comfort using the chin rest.

Procedure

To begin the process, we thanked the participants for their interest in our experiment and introduced ourselves. We then took them into a well-lit room and shut the door. Next, we asked them for some basic personal information - initials, age, and sex. We then began the experiment by entering their initials and setting the random seed. After the experiment began, we stayed in the room with them for the training phase to answer any questions they had and to ensure they kept their head in the head rest. The first phase was a familiarization phase in which the participants stared at a pair of shapes (let's call these EG) for thirty seconds. Next, there was a phase 1 training that lasted about 8 minutes in which participants saw scenes with two of IJ, KL, and EG. Subjects were instructed to indicate whether the scene they saw contained the familiar shape - EG. Then we moved to phase 1 testing in which the familiarity of IJ/KL/EG was tested. Next, there was phase 2 training that also lasted about 8 minutes in which participants saw scenes with all combinations. Lastly, there was phase 2 testing in which the familiarity of all combinations was tested.

Results

The effectiveness of the training session was measured and we would found that participants could detect EG with a mean accuracy or .9844 (sd = .0121). The phase 1 testing phase demonstrated that participants could identify the presence of EG very well; the mean accuracy was 1.000 (sd = 0.00). When presented with IJ or KL, the mean reports of detected existence were much lower - .2500 and .3750, respectively.

When participants were shown EG in phase 2, they were very good at detecting EG as well, both in the form of EFGH (mean = .9464 and sd = .0945) and simply EG (mean = .9375 sd = .2007).

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Aging & Value-Directed Remembering

Shruti Ullas

In most situations, we try our best to remember information that is most important to us, since we can generally only handle so much information at one time. For example, when studying for an exam, we may not try to remember every single piece of information said during lectures, but rather, we may try to remember the most important concepts and topics that were covered. Similarly, in lab settings, subjects must decide what is and is not important to remember during studies of value-directed remembering. In value-directed paradigms, subjects are presented with word lists, where each word is associated with a point value, and the subject's goal is to achieve as high a score as possible. Thus, the subject is encouraged to focus on remembering words with the highest point values in order to maximize their score. Several studies have investigated if older adults show any differences during these value-directed tasks. In general, memory declines with age, so it could be assumed that older adults may be less efficient at completing these tasks compared to younger adults, however, a study by Castel, Benjamin, Craik, and Watkins (2002) found that older adults are just as good at focusing on high-value words as younger adults.

Castel et al (2002) examined how well older and younger adults performed on a value-based remembering task. Subjects studied and recalled words from lists, where each word was assigned a different point value ranging from 1 to 12. A selectivity score was also calculated based on the number of words recalled. The selectivity score represents how efficient the subject was in remembering valuable words, depending on the total number they remembered. For example, if a subject remembered 3 words from a list that was worth 12, 8, and 7 points, or 27 total points, their ideal score based on 3 words would have been 12, 11, and 10 point words, for 33 total points. Essentially, the selectivity index compares the subject's actual score with an ideal score, which summarizes how selective the subject was in choosing words to try to remember.

The authors predicted that older adults would be less efficient and have poorer overall recall for the words compared to younger adults. To their surprise, while older adults did recall a fewer number of words overall, they were actually more efficient than younger adults in selecting high value words. This was inferred by higher selectivity scores for older adults than younger adults. Additional experiments found that older adults appeared to be better at focusing on the high value words because they also ignored the low value words more than younger adults. Younger adults showed a tendency to recall a few high value words, like the older adults, but to also throw in a few low value words they remembered, which the older adults avoided. This appeared to contribute to higher selectivity scores for older adults and lower selectivity scores for younger adults.

Overall, these results were somewhat surprising. Based on previous studies, it was expected that older adults would be less effective at focusing on important information, while placing less emphasis on less important information, as is expected in value-based remembering tasks. Older adults were believed to possess less cognitive control, but based on the results of this study, this idea appears to be untrue. Older adults were actually more efficient at extracting important information, such as high value words, and ignoring the less important information, or the low value words.

A related study by McGillivray and Castel (2011) also compared older and younger adults to see how well they could encode more valuable words, but with a slightly different study design. In addition to recalling words after studying them, this study added included a metacognitive component. During the study phase, subjects would “bet” on whether they would remember the word or not. If they bet on the word and were able to later recall it, they would receive points, but if they bet on the word and did not recall it, they would have those points subtracted from their score. Similar to the Castel et al (2002) study, subjects were trying to get the highest score they could and each word was associated with a point value, but now subjects had to try to predict what they were capable of remembering.

This study design was also a departure from the standard usage of JOLs in many studies of metacognition, where subjects try to predict their performance by assigning a “judgment of learning” to each word, which represents how well they believe they will be able to later recall that word. The authors believed that making bets was a more active process, and required subjects to be more accurate in their metacognitive judgments, as more was at stake. If subjects made poor bets, their scores could be drastically decreased, so making good bets were integral in order to achieve a high score.

Additionally, McGillivray and Castel (2011) wanted to investigate how multiple study-trials affect performance. With feedback on performance after several lists, it was queried whether subjects could learn to place better bets on their memory. Also, the authors also wanted to find out if older adults’ performance would improve or worsen with several trials, and if their performance was similar or different to that of younger adults.

The study found that with multiple study trials, performance improved. At first, both older and younger adults overestimated how much they could remember by placing too many risky bets. With each list following the first, performance steadily improved. Subjects seemed to realize how overconfident they were and learned to change their bet-placing strategy. By the last list, subjects had significantly improved their performance, and were far better at calibrating how much they could remember. Subjects improved scores by betting by focusing on high value words, while earlier on, they may have bet on too many words without targeting the high value words.

Older adults showed a similar pattern of performance to younger adults. Older adults also started off overconfident (even more so than younger adults) but eventually learned how to place bets more effectively on subsequent lists. Older adults showed no impairment in this learning, so the ability to gauge memory capacity appears to remain unaffected with age.

Altogether, both of these articles established proved that certain aspects of memory remain intact throughout the aging process with the use of value-based remembering tasks. Castel et al (2002) found that older adults could complete these tasks quite effectively, and were actually better than younger adults at focusing on high value words, which was actually an unexpected result, since previous research seemed to conclude that older adults actually have poor cognitive control. Similarly, McGillivray and Castel (2011) also found that older adults were able to recall high value words just as well as younger adults. They also found that the ability of older adults to predict their performance was comparable to younger adults, based on the results of the betting paradigm. Both groups started off overconfident in their predictions, but after completing several study trials followed by feedback, they were able to make more accurate predictions. In conclusion, these papers showed that while memory does show some declines with age, this does not mean that every facet of memory is impaired, and some components stay strong throughout the aging process.

While working as a research assistant, I believe I learned a great deal about how research is conducted. Compared to the previous quarter I spent working here, I helped with experiments where I had to observe participants more than I had before. I found it quite interesting to see how people handle tasks and the various approaches used in trying to tackle them. The experiments I ran this quarter also required me to be more careful and observant, as errors could easily arise if I wasn't fully attentive. I ended up making some mistakes, and realized the importance of focus even when tasks do not seem very difficult.

I also presented at Minifog this quarter. Before this, I had never presented in front of a group for an hour, and I was very nervous beforehand. Looking back, I think this was a very valuable experience. Preparing for the presentation helped me to have a better understand of how the current experiments tie into previous work. I also realized that presentations are not as daunting as they sometimes seem, and can go reasonably well as long as I practice.

I enjoyed attending the journal club meetings as well. At the start of the quarter, I thought we would end up reading articles similar to ones we read last quarter, but I was glad to read about other research going on in the lab that I wasn't really aware of. I particularly enjoyed reading a chapter from a book written by Robert Bjork. I thought it summarized the uses of forgetting in clear and informative way.

Next quarter, I am excited to be able to help with the fMRI study. I find brain imaging quite fascinating and am very happy to get the chance to learn more about it in a more practical sense, compared to than the condensed versions in articles I have only read about so far.

Learning Patterns and Facts Study

Stephanie Dunn

Learning through technology has become a primary focus of learning pattern research. As the functionality of Internet resources broadens to more versatile use, the accessibility and development of educational applications increases and becomes more main stream. The present study in the Kellman Lab is testing learning algorithms within a data set to assess accuracy and response time. Supportive research derives from the Mettler, Massey, and Kellman (2011) study that looked at a new learning algorithm called ARTS in teaching geography and mathematics in an educational environment. This innovative learning algorithm was compared to the old pattern of Atkinson (1972) that used a Markov model. The comparative learning patterns showed higher accuracy recall for the ARTS learning pattern condition than the Atkinson condition.

The Mettler et. al (2001) study used insights found in a Storm, Bjork, and Storm (2010) study that provided support for expanding intervals. Researchers presented stimuli to participants to-be-learned on equal and expanding intervals. The results showed much higher accuracy recall for the expanding condition. The implication of this study was that the expanding schedule only caused enhanced recall when the task between successive retrievals was highly interfering with memory for the passage. These results suggest that the extent to which learners benefit from expanding retrieval practice depends on the degree to which the to-be-learned information is likely to be forgotten. Storm et. al reasoned that when tests are given immediately following presentation, learners are able to access information from memory in a way that affords little or no benefit. However, when tests are delayed, the to-be-tested information has become less accessible and learners are forced to engage in the type of processing that promotes learning and long-term retention. A dilemma lies in delayed presentation because the likelihood of the learner being able to successfully retrieve the item from memory decreases with the delay between learning and test. Storm et. al combatted this with expanding schedule.

Kang et. al (2010) argues that there are two limitations in this framework: the short time scale of experiments and the focus on a final test. These are related because when the time scale of training is short and items are practiced multiple times within a single session, the recallability of material between retrieval attempts is irrelevant, but in the natural learning environment (which operates over a much longer time scale), the recallability of material between study sessions may be more important than the recallability following the end of the study period. Researchers conducted a language learning experiment over equal and expanding intervals between groups. A final session 60 days later was held. In the extremely delayed post-test, the expanding condition yielded numerically higher recall than equal interval but the difference was not statically reliable, argues Kang et. al.

The researches of the Kang et. al (2010) study argue that there is no way to accommodate for forgetting. Forgetting is related more strongly to the nature of interpolated activities or changed cues than to the actual passage of time. When multiple items in memory are associated to the same retrieval cue, recall of a particular item can suffer competition from other items thereby producing forgetting.

Currently, in the Kellman lab, an empirical approach to learning patterns ensues. The current study observes two different training schedules. One is fixed and the other adaptive. The adaptive condition is based on an algorithm similar to Everett et. al (2011) and changes as a function of user interaction. The other condition has two fixed schedules. One is an equal fixed schedule, and the other is expanding at a 1-5-9 pace. The present study observes elongated training phases and has warranted results that show improved accuracy in the adaptive and fixed expanding conditions.

In Figure 1 is an encouraging graph of the accuracy seen in the delayed post-test. This shows a significantly higher recall for the accuracy in the adaptive condition than the fixed. This is indicative of the Storm et. al (2010) claim that the post-test allows that information has become less accessible and learners are forced to engage in the type of processing that promotes learning and long-term retention.

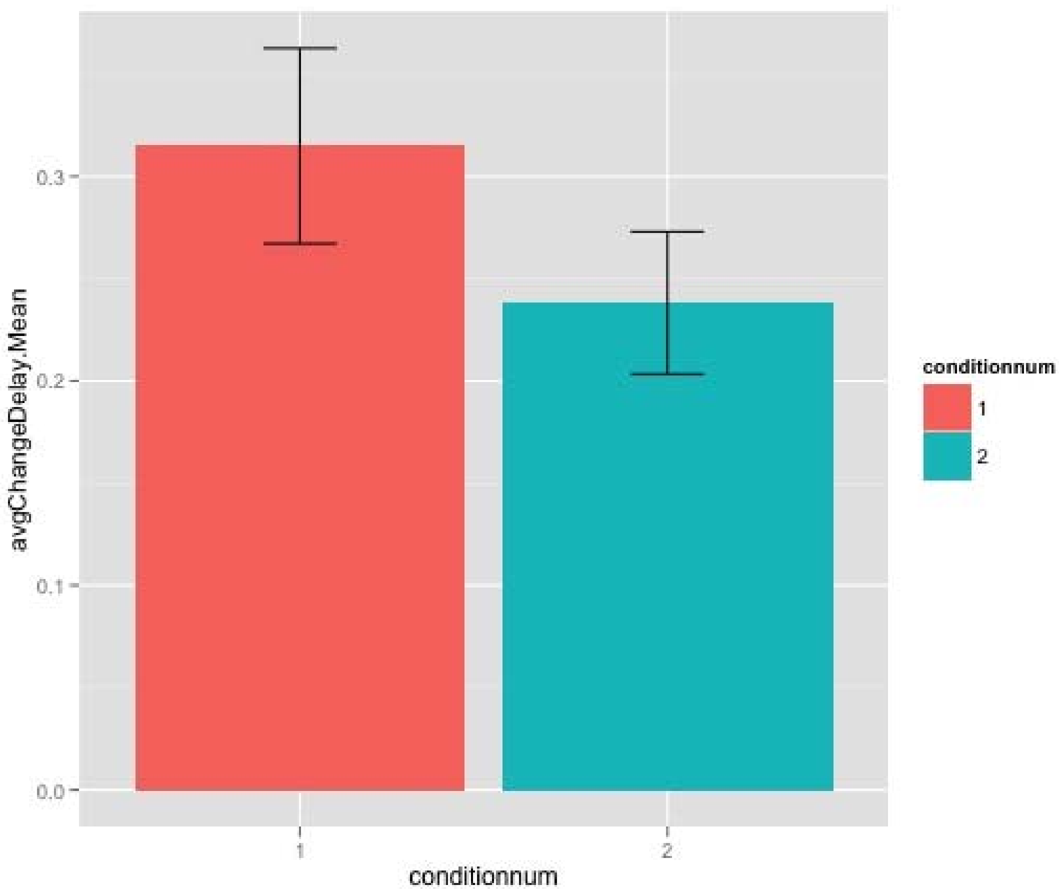

Figure 1. Average accuracy in the fixed and adaptive conditions for the delayed post-test.

Figure 2 shows the average accuracy for each segment of the experiment. The first (zero) segment is before the learning phase and the second is the post-learning phase test. The third is the delayed post-test. Unsurprisingly, accuracy initially boosts after the material is learned, but drops off considerably at the delayed post-test. The details to pay attention to include which condition has the highest drop off and which condition has the highest overall accuracy. It appears the fixed equal condition has the highest forgetting rate and the adaptive has the lowest forgetting rate and highest overall accuracy.

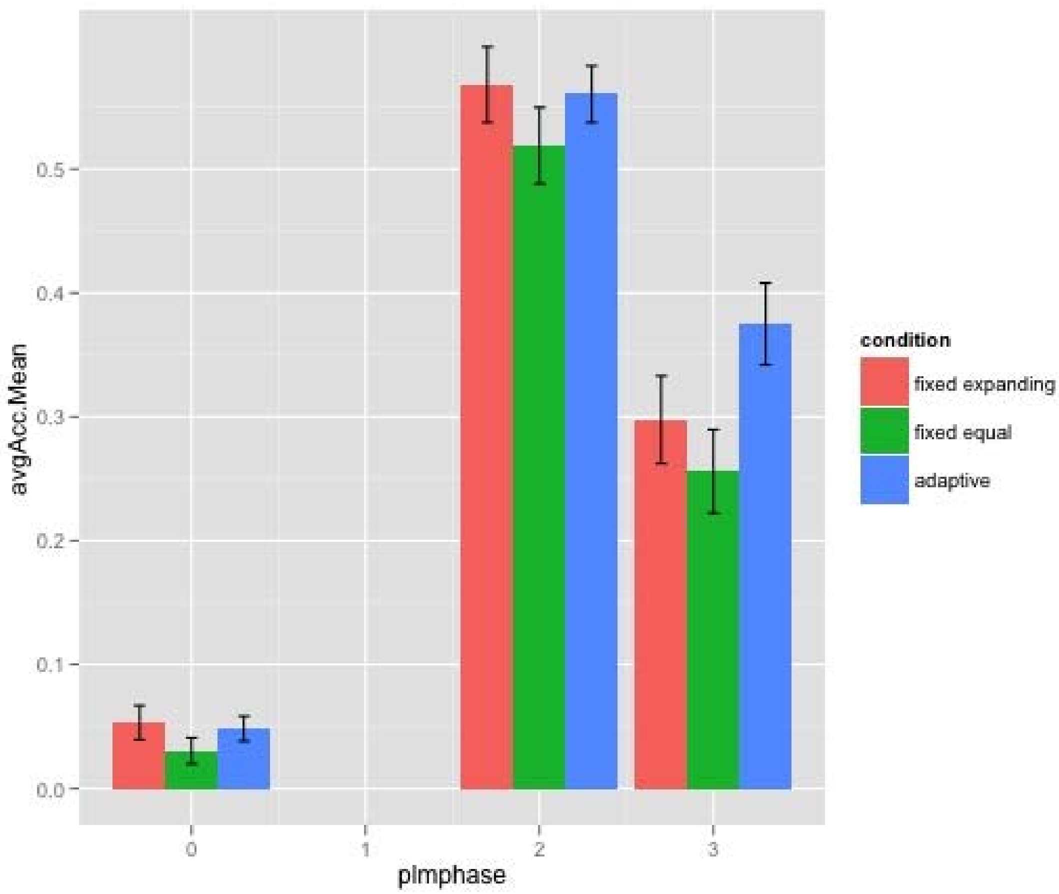

Figure 2. The average accuracy for each condition across the different segments of the experiment.

Figure 3 displays the average accuracy for each trial, the number of which is accumulated throughout the segments of the experiment. This figure does not account for condition of learning algorithm, but it appears that the accuracy and incorrectness rates are about the same for the delayed post-test. This may be due to the combination of conditions.

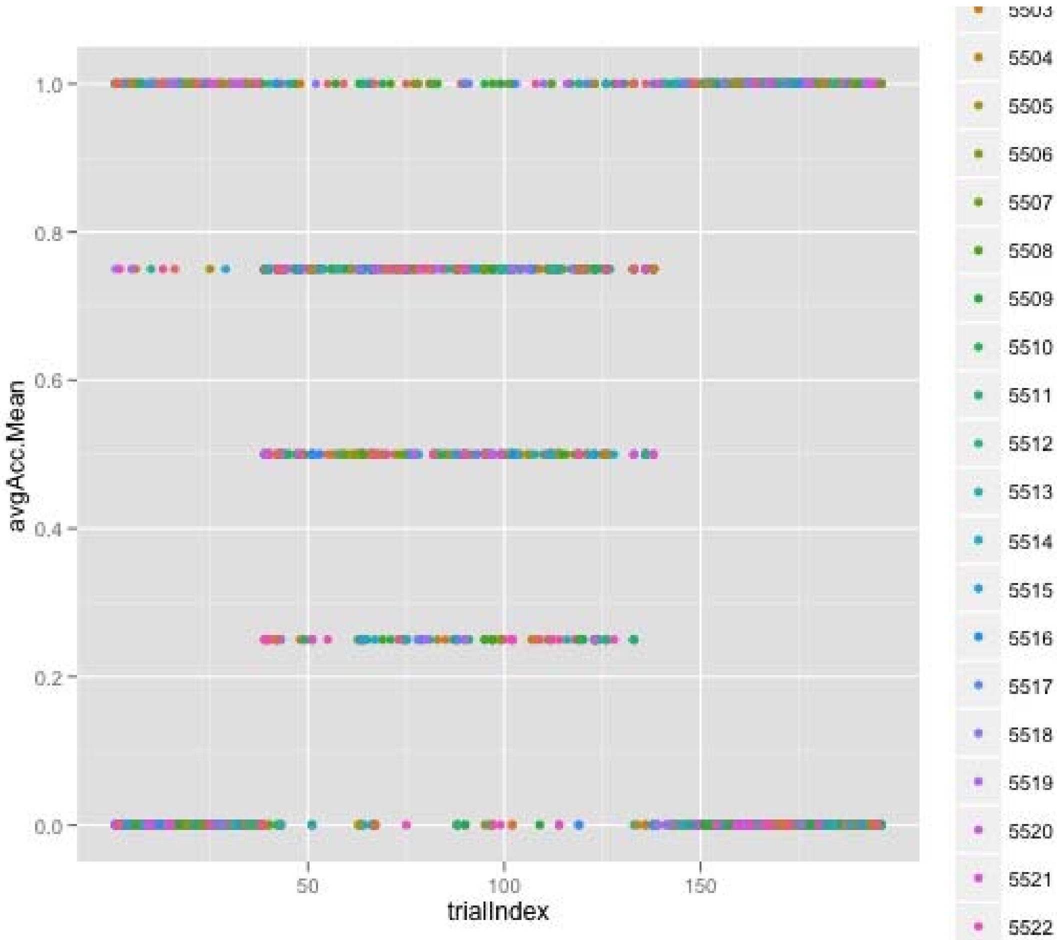

Figure 3. The participants' average accuracy for each trial in the experiment.

The figures in from this experiment show that the adaptive learning algorithm has the lowest forgetting rate and the highest accuracy rate. In other words, it is working. Further analysis lies in observing the data as a linear model and quantifying the delay to the resultant accuracy. This is a necessary approach because it observes overall accuracy in terms of delay rather than by condition. In the end, regression is to be observed with this linear model. The linear model will also help make the experiment more generalizable because it makes each variables a unit and displays how it effects other variables (per unit). This will offer more insight into what is going on and may settle the concerns of Kang et. al's (2010) issue with the lack of reliability of learning algorithms.

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Breaking Barriers through Analogical Reasoning in

Mapping-Induced Forgetting Experiment

Steven Braverman

Humans have been able to create some of the most sophisticated objects in existence today: we have built pyramids and skyscrapers that loom above the ground, automobiles have been made commercially available to the general public, planes soar thousands of miles above the Earth and have expedited transcontinental travel, the Internet allows us to instantly video-chat with someone as if we are speaking face-to-face with that person (even if he or she is in another country), and we have even left our nourishing atmosphere and entered the oxygen-less emptiness of space where we have placed satellites in orbit around our planet and man has set foot on extraterrestrial objects. Humans could not have achieved all of our successes and failures without our brains, and yet, the way our brains function and allow us to perform these miraculous feats continues to puzzle us. In attempt to learn more about the brain, and more specifically, to examine the reasoning behind the mind's actions, I joined the reasoning lab at University of California, Los Angeles, run by Holyoak. My adviser was Vendetti.

Gentner and Markman (1997) hypothesized that forming both analogies and similarities constitute similar processes that are in themselves sophisticated and central to the cognitive mind. Analogies allow for intelligent, creative, and novel ideas (Gentner & Markman, 1997). Neural networks have been proposed to serve as analogies to brains. Artificial neural systems neither equate physiologically with the brain, nor do they represent exactly how the nervous system operates. They can however produce working models that are comparable to different functions that the brain is capable of computing through the use of algorithms and statistics (Anderson 1995). How is it that the human mind can make an inference that a neural network is analogous to the human brain?

In order for an analogy to be made, an alignment of relational structure must be made along three distinct constraints: alignments must sustain structural consistency, items are to contain a relational focus, and there needs to be systematicity within the elements you are matching (Gentner & Markman, 1997). Looking at the brain and neural network example, a brain contains neurons that send electrochemical signals to each other through synapses. This alignment is similar to the structure of a neural network that contains vectors with different weights acting upon each other through different layers (structural consistency). No neural network functions in exactly the same way as the brain does because it is made up of different attributes and elements; if neural networks were exactly the same as brains then in place of an analogy there would be equality (relational focus). While brains and neural networks are two distinct systems, both can be given input and return similar output such as edge detection through the use of lateral inhibition (systematicity).

Markman and Gentner (2000) follow up from their previous article claiming in order for a comparison to be made, two objects must align with respect to each other, the semantic properties between the two objects must be stripped, and a search for the common parts that are shared between the two items must commence. Objects that deem as alignable share important aspects among each other, similar to that of a brain and a neural network. A non-alignable comparing of two items shares no central attribute (Markman & Gentner, 2000). For example, let's examine an image with a person holding a knife and another image with a person holding a gun. In this case, the gun and knife are the alignable objects; a gun and a knife can both be used for self-defense. In another example, one image contains a person holding a gun, while the other image portrays a person holding a banana. The gun and banana are the non-alignable objects in this case. A banana and gun share no commonality other than in both cases the two objects are being held by a person.

The previous research has sprung forth the current research underway. In the studies conducted by Markman and Gentner, subjects performed better at a recall task when pertaining to alignable objects while non-alignable objects provided poor performance in the recognition task. (Markman & Gentner, 1996, 2000; Gentner & Markman, 1997). These studies did not acknowledge what was occurring to the non-alignable memories.

One hypothesis attributes analogical mapping to empowering the connections of the alignable objects, and therefore, improving performance in a recognition task for these objects (Markman & Gentner, 1996, 2000; Gentner & Markman, 1997). Another hypothesis follows that if a subject has to generalize an item more in order to fit it into an analogy (alignable object), then that subject may actually perform better at recognizing non-alignable objects where no transformation was necessary to apply to the non-allignable association. (Gick & Holyoak, 1983).

The mapping-induced forgetting experiment was used to test these hypotheses. Sixty-four participants who gave consent and voluntarily signed up for the experiment through the Psychology department's online research participation program made up the pool of subjects. Nine sets of triads consisting of different scenes were used: each triad consisted of a base image, and 2 secondary images. Every subject viewed the base image first and only one set of the secondary images second. The design for the experiment was a 2 (compare vs. contrast) by 2 (alignable vs. non-alignable) mixed design. Subjects were instructed to either compare the two images or describe them once their attention was directed on the secondary image. A mask was briefly shown in between the two images. After all nine sets of triads had been viewed and the respective tasks completed, the subjects underwent a distractor analogy task. Subjects determined whether analogies presented one at time were in fact analogies or not. After completing this distractor task, subjects were given the recall portion of the experiment. This recall task consisted of 36 images. 18 images consisted of 9 alignable and 9 non-alignable images from the scenes previously seen in the first part of the experiment. The last 18 images were foils, or images that looked similar to those previously seen but were not the identical replications; 9 of these were alignable and the rest were non-alignable.

My first task as a research assistant consisted of giving mock answers to an fMRI sheet of relational pairs. The sheet contained sets of objects, words, and/or feelings that could be compared or associated with an analogy. Answers were based off of questions on the attributes of the pairs; the pairs consisted of synonyms, antonyms, superordinate, and unrelated sets. This experiment will deal with the way people form analogies and what parts of the brain are activated and require more blood flow during an fMRI scan; this experiment is to be performed in the near future.

I aided in the mapping-induced forgetting experiment; my duties consisted of running test subjects from the University of California, Los Angeles' Psychology undergraduate research program. Subjects were placed into random groups based off of order of arrival. Once the sample pool of subjects had been completed, I assisted in cleaning up the raw data received in order to better capture the important information from the individual files.

Another undergraduate student and I then helped to qualitatively analyze subjects' responses to the tasks from the experiment at hand; we were kept blind from whether the subject was placed in the comparison or describe group, and looked for instances where subjects compared and/or contrasted a set of items from the current image and the previous image. Each time a compare/contrast instance was noted the subject received a point for that section. Tallies were recorded for each pair of images. Our overlap in ratings was really high (r=.993).

The undergraduate and I then switched gears and rated the same subjects using a different scale. We were given an answer sheet containing all of the objects that a subject could possibly discuss during his or her compare/contrast task for all the different triads in the experiment. A point was given each time the subject mentioned an object on this list. Another score was added up if an object mentioned was from a list of alignable objects. In this way, subjects received points simply by writing about/mentioning the objects and alignable objects in the pictures. Differences were noted in how the subjects used up their time during the compare/describe task and will help to determine what happened to the memories of the non-alignable objects.

Lab meetings were held each week. They consisted of going over the current tasks at hand, going over articles that were in current circulation, and those that pertained closely to the projects at hand within the reasoning lab. Articles were read beforehand by the members of the lab and we engaged in discussing their meaning during lab meetings.

The next phase of experiments will deal with running subjects inside an fMRI machine to determine activation of different parts of the brain while making/examining analogies. Results stemming from this research will help to solve more mysteries regarding mental illnesses that befall humans: namely schizophrenia, attention-deficit-disorder, and depression. These studies will also help in understanding how the mind can generalize so well across so many different domains. This in turn may allow for better learning programs to be implemented. I just completed a neural network class this quarter. Applying analogies allowed for my understanding of the many complex topics. This manifested to me just how important analogies are and how they directly impact my life. While astronauts have broken the barrier between us and our atmosphere, these studies will help break the barriers between humans and our brains, allowing us to dig deeper into the mysterious organ.

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Deficient Causal Power in Narcissism as Evidence for Failure of Cognitive Development

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Abstract

Jean Piaget's stage theory delineates a progression of cognitive development through adolescence. The present paper examines the interaction of two lower stage concepts from the sensorimotor stage: causality and object permanence, and its influence on the development of higher stage concepts including elimination of egocentrism. Narcissistic personality disorder, commonly linked with egocentrism, is examined to understand the effects of a deficiency of either of the lower stage concepts on future development.

Keywords: Causality, Cognitive Developmental Theory, narcissistic personality disorder, object permanence, Power PC Theory

Humans will never have the ability to fully understand one another – not that this is not a good thing to attempt; stepping into the shoes of others is a great exercise that improves your ability to empathize. Try to imagine the complexity of just yourself. How have past interactions with other people influenced your life? What is the reason you hold on so strongly to some of your beliefs? Why did you choose to skip breakfast the other day? It's pretty difficult to come up with direct answers even for yourself, let alone a whole other human being. Although we cannot fully understand the people around us, it is our duty to make an attempt to understand and empathize with our cohabitants. Unfortunately, this is not possible for everyone to do. Narcissism is a personality disorder in which an individual places an inordinate amount of attention on themselves exhibiting heavy egocentrism.

People diagnosed with narcissistic personality disorder will often believe that they are more important than others and that others' opinions are less valid than their own.

Though the cause of narcissistic personality disorder is largely unknown, many of the popular contributing factors include improper learning during education such as overindulgence by parents or emotional abuse during childhood. Seeing as how many of the underlying causes for narcissism stem from adolescence, it seems intuitive to examine the cognitive processes of developing adolescents. One quite old, yet influential theory of adolescent development provides insight into the cognitive phenomena of egocentrism.

Jean Piaget's (1929) cognitive development theory, also known as developmental stage theory, describes a way in which human cognitive development evolves through stages and that language development is contingent with cognitive development. Piaget's theory organizes adolescent development into four stages: the sensorimotor period which begins from birth until 2 years old, preoperational thought which begins after the sensorimotor period until about 6 or 7 years old, concrete operations which begins after preoperational thought until 11 or 12 years old, and formal operations which begins after concrete operations and continues through adulthood. Piaget has noted that transition from stage to stage is not uniform for all individuals and that the age bracket is simply an approximation. Of the major cognitive developments there are two concepts that are worth noting: object permanence and causality. According to Piaget, children learn object permanence during the sensorimotor stage, and causality, which does not develop until the concrete operational stage.

Half a century after Piaget's original theory of cognitive development, many cognitive psychologists have made attempts to disconfirm his theories. Alison Gopnik, David M. Sobel, Laura E. Schulz, and Clark Glymour (2001) produced a series of experiments using "blickets" to examine causal inferences from co-variation information in 2-4 year olds. Just a few years later David M. Sobel and Natasha Z. Kirkham (2006) produced a similar series of experiments to examine the development of causal reasoning in 19-24 month olds as well as infants as young as 8 months old. These two studies disprove Piaget's claim that infants are pre-causal and places the learning of causality somewhere along the lines of the sensorimotor stage.

If causal learning is developed in the sensorimotor stage, this means that it is learned during the same stage on cognitive development as object permanence. There is little direct correlation between object permanence and causality, but the parallel development of the two ties these two concepts together. To best juxtapose these two concepts it would be ideal to break them down individually.

Causality is simply the concept that one event is caused by another event. There have been many proposed models that attempt to best describe the properties of causality, but the focus for this paper is on the power PC theory (Cheng 1997). The power PC theory is a fusion between the delta-p association model and causal powers. The delta-p association model examines covariance information in a given environment, allowing us to determine which events are highly correlated with one another. However, correlation does not imply causation, which is where the causal power comes in. Causal power is based on "the intuitive notion that one thing causes another by virtue of the power or energy that it exerts over the other" (1997), essentially meaning that for an event that causes another event, the prior must have some inherent trait that gives it the power to generate effects. Kant believed that people have the a priori knowledge that every event is caused.

Combining causal power with the delta-p association model brings the best of both worlds together to create a model that understands associations and infers causality.

Object permanence is the idea that we are able to understand that an object still exists even though it may not be currently visible. It would be bizarre to believe that only the objects that were presently visible were the only things existing in the world at that moment. This may seem intuitive to many adults, but most infants do not have an understanding of object permanence until around 7 months old. This is the reason why babies love the "Peek-A-Boo" so much; it must be an exhilarating experience to have your parents playing with you only for them to completely disappear and then reappear as if by magic. Object permanence seems to be the first evidence of infants being able to maintain a working memory of an object that was not currently present. In regards to causality, this can be looked upon as the first signs of developing a priori information about objects or events.

In regards to the power PC theory, a priori information about an event would be represented by its causal power. Causal power happens to also be the most convenient component that can be manipulated because it is the only subjective evaluation in the equation. The probability that an event or cause will occur – represented as P(i) – depends only on the event itself, eliminating any possible subjective bias, whereas the causal power – represented as pi– is a subjective inference of the causal influence that the event has.

A highly egocentric or narcissistic point of view can be expressed using the causal power theory. Narcissistic people tend to believe that they are at least as good if not better than their peers whether or not this is in fact the case. Because of this, narcissists will have an expected view of themselves as well as an unobserved actual view of themselves. The expected view of the self is how the narcissist thinks of themselves, while the actual view is largely ignored by narcissists as such, the more egocentric a person is, the greater the disparity between each of the views. In this example we examine the respective views of a narcissist and a higher performing peer as they measure their ability to correctly answer a question proposed by a professor. Using the standard format of the causal power theory, we can examine the individual component differences in each of the views. The candidate cause of answering the proposed question correctly would be a subject's work ethic. The alternative causes of answering the proposed question would be all other contributing factors such as inherent talent and personal background to answering the question correctly. We can describe each personal evaluation using the causal power theory being:

P(e) = P(i)pi + P(a)pa – P(i)pi* P(a)pa

P(e)=probability that the effect occurs

P(i)=probability that the candidate cause occurs

P(a)=probability that alternate causes occur

pi= causal power of the candidate cause

pa=causal power of the alternative causes

P(i)pi= the causal influence of the candidate cause

P(a)pa= the causal influence of the alternative causes

If in this case work ethic is actually the greatest contributing factor to correctly answering the question, the influence of the candidate cause, which is represented by the product of both the probability that the cause would occur and the causal power associated with the candidate cause [P(i)pi]. This would be greater than the influence of the causal power of the alternative causes, which is the product of the probability that the alternative causes may occur and the causal power of the alternative causes [P(a)pa]. The narcissist may have seen his peer correctly answer the question and thus provide an incorrect judgment of learning for himself, leading him to believe that he too would be able to correctly answer the question. The narcissist is very egocentric but he is not so blind as to believe that he has the same capacity for work ethic as his studious peer. In order to convince himself that he is equally able to provide the correct answer, a boost in influential weight is made attributing more influence to the alternative causes and leaving the causal power of the candidate cause static. Unfortunately for the narcissist, in reality he is actually unable to answer the question correctly reducing his probability of answering the question correctly. Because of the equivalency in the power PC theory a reduction of the influence of a cause or multiple causes is also necessary. For the omniscient observer it is obvious which mistake the narcissist made when evaluating his own expected ability. To accurately depict the narcissist's ability to answer the question, he must undo the boost in the causal power of the alternative causes. In reality the narcissist is neither talented nor hard working enough to answer the professor's question. This example describes a possible cause of narcissism due to an inability to accurately assess causal power or a priori information.

Interestingly enough, the elimination of egocentrism occurs in a later stage, the concrete operational stage, according to Piaget's stage theory. The ability to accurately combine the concepts of causality and object permanence may be a significant contributing factor to the eventual elimination of egocentrism in adolescents. If this is indeed the case, narcissistic personality disorder may be due to an incomplete development of either causal learning, object permanence, or both. We examined one possible example where a deficit in a priori understanding, linked to object permanence development, influenced a high degree of egocentrism. A future study may attempt to examine the effects of a deficit in causal reasoning on the elimination of egocentrism or ever other higher stage concepts.

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