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Greetings,

We would like to welcome you to the first official edition of the Undergraduate Psychology Journal (UPJ) since 2003. Over the past year, our team members, faculty advisers, and peer editors have worked diligently to produce this issue of UPJ. Built on the belief that undergraduates should have the opportunity to experience the process of constructing, designing, and being exposed to research, they should be rewarded and encouraged for their efforts. One such reward is to have one's work published and acknowledged by their peers – which is in fact, what actually occurs in professional journals. Beyond this, we hope to inspire promising future researchers in their quest for providing answers for some of Psychology's perplexing problems.

Psychology is a fascinating research field and here at UCLA, and talented students are completing studies every day. The UPJ hopes to give some of those bright students such as yourself the chance to share their hard work with other students, faculty, and others. Edited and reviewed by fellow students, every paper in the journal is a testimony to the huge impact the next generation will have on psychology, starting now. We encourage you to keep reading the journal and submit your own work to be reviewed. Thanks again for reading!

- UPJ Staff

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Cytokines link to Major Depression in Chemotherapy

Nasir Hali

Whitcome Summer Undergraduate Research Fellowship Research

Abstract

Cancer has progressed to become the number one cause of death among American's under the age of eighty-five (Twombly, 2005). The most common form of treatment for this disease is chemotherapy. Patients undergoing chemotherapy show significantly increased levels of major depression in post-regimen evaluations (Mills, Parker, Dimsdale, Sadler, & Ancoli-Israel, 2005). Examining previous research, we hypothesize there may be a link between the brain mechanism of depression and the brain mechanism of chemotherapy; cytokines trigger increased adenosine signaling in the striatum leading to conservational withdrawal, the fatigue component of major depression. 5-Fluorouracil is a predominant chemotherapy treatment and has been linked with increased depression in patients. Using Sprague-Dawley rats as a model, we will administer clinically relevant chemotherapy schedules and measure levels of depression. Two following experiments will attempt to reverse this depression through the administration of adenosineA2A receptor antagonist. The protocol for this study has been submitted and is currently under review. Ultimately, it would be our hope that a drug could be administered before or simultaneously with the chemotherapy agent in order to prevent or significantly reduce depression in patients. I have learned the process by which research is conducted and will continue to work on this research project. I express my most sincere gratitude to Dr. Minor and those that made the Whitcome fellowship possible.

Introduction

The number of cancer related deaths has been increasingly steadily over the last century to the extent that cancer has progressed to become the number one cause of death among American's under the age of eighty-five (Twombly, 2005). Cancer has become an increasingly prevalent issue in society and its most predominant treatments consist of surgical procedures to physically remove a tumor, along with appropriate regimens of chemotherapy to reduce cancerous cell activity. The prognosis of cancer is a life-altering condition for patients and can be accompanied with feelings of despair and fear even with the most positive outlook for successful treatment. It is not surprising then that the prevalence of depressive symptoms among cancer patients has been reported to be as high as 50% (McDaniel, Musselman, Porter, Reed, & Nemeoff, 1995).

Chemotherapy in particular has several deleterious effects that can often overshadow the disease which it treats, significantly reducing the patient's quality of life. Common side effects of chemotherapy can include rapid weight loss, nausea, fatigue and hair loss. Furthermore, chemotherapy and the increased prevalence of depressive symptoms among cancer patients are not independent of one another. Baseline levels of behavioral depression among cancer patients can be influenced by both social factors including age, gender, and social support, as well medical variables including prior surgery, metastases, and cancer location. (Kim, Hickok, & Morrow, 2006) While baseline fluctuations exist, utilizing the Center for

Epidemiological Studies-Depression (CES-D) scale, known for its reliability, validity, and ease of administration, researchers examined the level of depression among patients both before and after administration of chemotherapy regimens and found significant increases in post regimen levels of depression in comparison to preregimen levels (Mills, Parker, Dimsdale, Sadler, & Ancoli-Israel, 2005).

The implications of these findings are significant because the level of depression among cancer patients has been correlated to increasing length of hospital stays, failure to comply with treatments, and even to the extent of affecting long-term mortality rates (Buccheri, 1998 & Herman et al., 1998). While it would be convenient to assume that major depression among cancer patients is solely the result of the impact of the life circumstances related with disease itself, we hypothesize there may be a link between the brain mechanisms of chemotherapy and the brain mechanism of major depression.

Previous research has shown the brain mechanism by which major depression is induced. Cytokines are a group of proteins and peptides utilized by the body as signaling compounds. An increase in cytokine signaling and the subsequent activation of adenosine A_{2A} receptors in the striatum has been shown to lead to conservational withdrawal, the fatigue component of major depression (Minor, Huang, & Witt, 2006). Furthermore, researchers were able to reverse this component of behavioral depression with systemic injections of adenosine receptor antagonists to the striatum. The chosen antagonist, 8-(3-Cholorstyryl) caffeine (CSC), acts to block adenosine A_{2A} receptors; thus inhibiting this depression pathway. Continuing research on this model for major depression, we hypothesize that chemotherapy patients may experience major depression along this same pathway due to the increased levels of cytokines accompanied with chemotherapy treatment.

Several parameters needed to be examined in choosing the chemotherapy drug for this study, such as behavioral effects, toxicity, amin-

istration, and generalizability. 5-Fluorouracil was chosen as the most ideal candidate for several reasons. While studies specifically examining the effects of chemotherapy on major depression have been lacking, studies have shown that chemotherapy regimens utilizing intravenous administration of 5-Fluorouracil significantly increased post-regimen levels of depression in patients (Mills et al., 2005). Also, because 5-Fluorouracil was one of the first chemotherapy drugs approved, several studies have examined the relationship between its dosage, toxicity, and effectiveness against tumors; this provides a considerable literature database to determine the safest and most effective dosage for both human case studies and rat animal models. Furthermore, 5-Fluorouracil has been applied as an effective treatment against several types of cancer, including very predominant forms such as breast and colorectal. 5-Fluorouracil is classified as an antitumor metabolite and it functions by acting as a thymidine analog. Because the drug is integrated in place of thymidine in cellular DNA during the replication process, the DNA is not able to maintain its structure and is subsequently destroyed, effectively inhibiting cell replication. Unfortunately as with all chemotherapy drugs, 5-Fluorouracil acts on all cells in the body not only cancerous cells, which over the period of the regimen can heavily tax the body.

This study will examine the effects of two clinically relevant 5-Fluorouracil chemotherapy regimens on the level of conservational withdrawal in our animal model. Subsequently, we will try reversing these symptoms through the administration of an A_{2A} receptor antagonist (8-(3-Cholorstyryl) caffeine).

Method

Subjects

Sprague-Dawley rats will serve as the animal model for this research experiment. One hundred twenty rats will be required and be composed equally of males and females. Subjects will begin the experiment at ~200g and be maintained with free access to food and water and be placed on a standard twelve hour light dark cycle.

Drugs

5-Fluorouracil will be supplied from Abraxis Pharmaceutical Products in a ready-to-use clinical solution in 10ml vials that contain 500mg of drug (50mg/ml). 8-(3-Cholorstyryl) caffeine (CSC) will be supplied from Sigma-Aldrich in a solid white powder form ready to be placed into solution. All drugs will be diluted in saline (0.9%NaCl) in order to be administered to the test subjects.

Design

This study will consist of three central experiments. The objective of the first experiment is to establish which of two clinically relevant schedules produces the highest levels of behavioral depression in our animal model. All groups will consist of eight rats in order to maintain the minimum level of statistical power needed. Subjects will be randomly assigned into one of two 'chemotherapy' or two 'non-chemotherapy' groups. An intravenous (i.v) tail-injection of our chemotherapy agent, 5-Fluorouracil, will be administered. Subjects in the 'non-chemotherapy' groups serve as controls, and will also undergo an intravenous tail injection but with saline at appropriate physiological pH. To maintain the appropriate levels of control, the volume of saline injected will be matched with amount given to the respective 'chemotherapy' groups. on the subject's back and firmly clinched around the waist of the animals by a secured loop of Velcro. The forced swim test consists of taking a rat by the base of the tail, placing it in a 3 1/2 X 2 foot cylindrical tube filled $\frac{3}{4}$ of the way with water, and then videotaping its swimming behavior for 15 minutes via closed circuit television using an infra-red camera. After the 15 minutes have elapsed (or if circumstances require), the subject is extracted, thoroughly dried, and monitored until it completely recovers. The videotape is subsequently scored in our lab and the amount of time a subject spends floating during the 15-minute time period is measured. Each

subject will undergo only one swim test. For the 25mg/kg/day regimen schedule, the forced-swim test will be performed the morning following the completion of the regimen, on day 6. For the 100mg/kg/week regimen schedule, the forced-swim test will be performed the week after completion of the regimen on the morning of week 5. The two chemotherapy regimens chosen to analyze were shown to have significant anti-tumor activity while being the safest tolerated dosages by our animal model (Cao, Trout, & Rustum, 1998). The two schedules are either a) 25mg/kg/day for a duration of five days total or b) 100mg/kg/week with treatment continuing for four weeks with regimen dosages based upon initial weight of the test subjects. All groups will receive their respective injections early in the day and will be monitored daily. The level of depression in each group will be measured by a forced swim test which has been shown to be an appropriate model for measuring the level of behavioral depression in an animal model (Borsini & Meli, 1988).

To perform the forced swim test each subject will be affixed with a pair of "water wings" prior to immersion in the test chamber; this step ensures that the subjects do not drown. The "water wings" consist of a form-fitting piece of Styrofoam placed The objective of the second experiment is to reverse the chemotherapy induced depression established by the first experiment. The chemotherapy regimen utilized for this experiment will be the regimen schedule that displayed the highest levels of behavioral depression. The objective of this experiment will be to gauge the effectiveness of varying dosages of intraperitoneal (i.p.) CSC to reverse the 5-Fluorouracil chemotherapy induced depression. Similar to experiment one, in this experiment subjects will receive a relevant chemotherapy regimen, but in addition will receive an i.p. injection of CSC ten minutes before the forced swim

morning of week 5. The dosage administered will be dependent on the treatment group being tested and in order to gauge the sensitivity to CSC, the following dosages will be tested .01, .1, 1.0, and 2.0(mg/kg). In order to allow for sufficient recovery time from the surgical procedures. The objective of the third experiment will be to deliver a dose of CSC to the ventral medial striatum to reverse the chemotherapy induced depression. A stereotaxic surgery will be required to insert a two-prong guide cannulae into the ventral medial striatum, located +1.5 AP, +/- 1.5 Lateral, and -7.5 Ventral to the medial cross section. The surgery will be performed seven days prior to the intracerebrovascular (i.c.v.) injections via the cannulae in order to allow sufficient recovery time from the surgical procedures. In this experiment subjects will receive a relevant chemotherapy regimen, but in addition will receive an i.c.v injection of CSC ten minutes before the forced swim test is administered. Of course, the exact timing of this CSC administration will be dependent on the chosen regimen and will parallel the forced swim task; if the 25/mg/kg regimen is utilized the CSC administration will be on day 6, however if the 100mg/kg schedule is chosen the administration will occur on morning of week 5. The dosage administered will be dependent on the treatment group and the following dosages will be tested 5.0, 15.0, and 30.0(nM).

Results

We have made all the necessary preparations to conduct this study effectively, including laboratory preparations as well as ordering the experimental drugs. The study's protocol has been submitted to the Animal Research Committee (ARC) and is currently under review.

Discussion

The design of this study is a very logical continuation of established research. We are confi-

dent that the drug will produce significant levels of conservational withdrawal in the subjects. We do expect to see lower levels of conservational withdrawal as the dosage of CSC is increased incrementally; however, previous research suggests that directly administering CSC to the ventral medial striatum via a cannulae will be more effective than an intraperitoneal (i.p.) injection of CSC in reversing major depression.

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Long-Term Multisensory Statistical Learning:
Implicit or Explicit Learning?

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Abstract

Research on multisensory statistical learning investigates how humans automatically process and integrate the sensory signals they perceive from the world around them. In this experiment, streams of auditory and visual stimuli were presented in a specific sequence with a computer. The subjects returned 24 hours later to be tested on their learning of the statistical regularities between the stimuli, if that learning had sustained over time, and whether they learned using explicit or implicit knowledge. The results were significant ($p < 0.01$) in showing long-term statistical learning, both multisensory and unisensory. Participants' scores on a post-hoc questionnaire suggested that explicit processing was involved in the learning. The long-term learning results strengthen previous findings and extend the current understanding of this paradigm. The evidence for explicit involvement contradicts long-held assumptions that statistical learning is solely implicit. Further research is needed to clarify these results and distinguish between explicit and implicit performance on statistical learning tests.

Introduction

A single object can give multiple sensory signals simultaneously. For example, an approaching car signals a pedestrian to stay out of the road through visual, auditory, and sensory cues: the shape of the car grows bigger in the pedestrian's range of vision, the sound of the engine gets louder, and the ground vibrates as the car approaches. How do humans integrate all these signals into one coherent experience? Scientists may say that as we form connections between various perceptions, we are able to make sense out of our vast sensory input and use that knowledge to respond to and interact with the surrounding environment. Therefore the question becomes: how do humans learn the associations between different sensory signals?

Imagine another example: a family cooking a large Thanksgiving dinner. The stove is covered with bubbling, simmering, and steaming pots, the oven has been on all day, and the surrounding countertops are filled with dishes and discarded food from the efforts. Suddenly, one component starts to burn—the steam turns to smoke, the smell of burning slowly overpowers the other smells, and maybe the fire alarms beeps shrilly. We would not be surprised if the cook noticed the visual (smoke), olfactory (burning), and auditory (alarm) cues in this scenario, and concluded that they were all sending him the same message: the stuffing is burning! But how did his brain associate those three signals, of three different modalities? And after

And after associating them, how does he know how to react? Statistical learning experiments investigate how humans associate stimuli, or learn the regularities between them. On a simplified level, the results from these experiments help explain how people make associations in real-world situations, like the cook connecting the smoke, burning smell, and alarm as cues from the same underlying cause.

The scientific study of learned sensory associations requires the creation of controlled sensory events in the laboratory that can be manipulated to observe associative learning. Simplified immensely from real world scenarios, the stimuli in these studies are often a set of black and white images as simple as the shape of a pinwheel, cross, or checkered rectangle. The shapes are presented in spatial or temporal patterns, meaning in a specific repetitive sequence or in certain locations on a computer screen, in an order that is unbeknownst to the experimental subjects. Later, the subjects' knowledge of the planned statistical presentation of the stimuli demonstrates their level of learning.

Primarily, statistical learning has been studied for auditory stimuli, such as words or tones, and visual stimuli ranging from simple images to complex visual scenes. In everyday interactions, however, we not only associate sounds with sounds and pictures with other visual stimulation, but we use information from auditory, visual, tactile, and olfactory signals simultaneously. In order to generalize experimental results to humans' experience in the real world, statistical learning studies must move past unimodal presentation and investigate new realms of multisensory statistical learning.

In terms of the experimental setup, typical statistical learning experiments are composed of two stages: the exposure phase and the testing phase. In the exposure phase, participants passively observe and/or listen to a stream of stimuli without instructions relating to the statistical relationships presented. Research has been conducted on statistical relationships including joint probabilities—when the appearance of one stimulus always predicts the simultaneous or consecutive presentation of a second stimulus—and condi-

tional probabilities—when one stimulus predicts a second stimulus a preset percent of times (Seitz, Kim, van Wassenhove, & Shams 2007). Learning after exposure to stimuli with various types of statistical relationships has been shown to occur for both joint and conditional probability learning (Fiser & Aslin 2001; Seitz et al, 2007). The current study will only investigate joint probability learning, with presentation of stimuli either simultaneously or sequentially with 100% probability.

In the second stage of statistical learning experiments, the testing phase, researchers collect performance data to measure subjects' level of learning compared to control conditions or chance performance. For example, two-interval forced choice (2IFC) tests ask the participant to choose the more familiar stimuli interval between two choices, potentially drawing on both explicit and implicit memory. Explicit memory is the conscious recollection of, in this case, a stimulus or pattern, whereas implicit memory is unconscious and unintentional, more like a vague sense of familiarity. In this test, the proportion of times subjects chose the previously shown, associated stimuli as more familiar (the correct response) as opposed to choosing the non-associated or novel sets of stimuli indicates their level of learning. Post-test questions are also frequently asked to examine subjects' conscious awareness of their own learning (Baker, Olson, & Behrmann 2004; Fiser & Aslin 2001; Fiser & Aslin 2002; Seitz, Kim, van Wassenhove, & Shams 2007).

Recent research has shifted from using unisensory sets of images or sounds to multisensory stimuli. Multisensory learning experiments are arguably more demonstrative of the real-world associations people make and may generalize more easily to realistic learning scenarios. Preliminary evidence has shown that people can learn associations from two separate information streams of different modalities independently and simultaneously (Conway & Christiansen 2006). More realistic multisensory exposure requires presentations in which statistical relationships *connect* stimuli of different modalities.

Successful performance under these conditions would prove the ability of participants to learn associations *between* modalities—what will now be referred to as multisensory statistical learning.

Results of multisensory statistical learning experiments suggest that it can actually be more robust than unisensory learning (Seitz, Kim, van Wassenhove, & Shams 2007). The exposure phase in Seitz et al. (2007) consisted of a visual image stream and an auditory sound stream presented simultaneously, but with statistical regularities between individual stimuli. The presentation was such that certain image pairs were always presented with a certain pair of sounds. Under these conditions, participants not only learned the statistical regularities in the visual and auditory stream separately, but also the consecutive, or sequential, auditory-visual and visual-auditory pairs that appeared in the exposure (Seitz et al. 2007). This is similar to the statistical setup of stimuli in the present experiment, portrayed in Figure 1.

Multisensory research is growing rapidly and yet many of the findings in this area are not fully understood. The present study aims to extend current research on multisensory statistical learning through an investigation of two realistic and useful dimensions. Specifically, the experiment will first investigate long-term retention of multisensory statistical learning. Past experiments have tested subjects' learning directly after exposure, proving short-term retention but preventing the opportunity to test long-term learning. Because the short-term results have been encouraging thus far, this study hypothesizes that the learned associations can also be maintained in memory for longer periods of time.

Secondly, a follow-up questionnaire will be used to distinguish the influence of implicit and explicit encoding of the statistical relationships between stimuli presented during the exposure. Although the cited responses from participants after completing the testing phase of a statistical learning experiment indicate no awareness of learning, observations also yielded participants who seemed more consciously aware of the patterns they were

presented with. Therefore, this study hypothesizes that multisensory associations are encoded through a combination of explicit and implicit processes.

Method

Participants

Sixteen undergraduate students (12 women and 4 men, ranging from 18 to 22 years of age) from the University of California, Los Angeles (UCLA) participated in the study. The students received credit for their participation to fulfill a course requirement. They were naïve to the purpose of the study throughout the 24-hour experiment period. The study was approved by the Institutional Review Board of the University of California and conducted according to the Declaration of Helsinki.

Design

The participants in this experiment all experienced the same condition, and behavioral data was collected from each participant to answer two separate research questions. First, learning was measured approximately 24 hours* after the initial exposure phase to assess long-term retention of multisensory statistical learning. Second, a short questionnaire at the end of the second-day testing phase measured the explicitness of the previously demonstrated statistical learning.

Stimuli

The stimuli during the exposure phase (approximately 20 minutes long) consisted of simultaneously presented visual and auditory streams. The stimuli were created in Matlab (version 7) and presented to individual subjects on a computer (Mac OS 9). The visual stream was composed of eight arbitrary complex black figures on a white background, adapted from Fiser and Aslin (2001). The auditory stream was made of eight distinct sounds, also complex and unfamiliar so that they could be easily discriminated. The duration of each sound and presentation time of each image was 300 ms, with a delay of 300 ms before the next sound- image pair.

The 300 ms time period was chosen based on intervals that induced the greatest learning in a previous multisensory statistical learning study by Seitz et al. (2007).

The sets of eight images and eight sounds were each split into four pairs that always occurred in the same order. The unimodal pairs (A-A and V-V) were randomly assigned, but once assigned were always presented in the same consecutive order. In addition, each image (V) was always presented together with a specific sound (A) that was not presented with any other image. The simultaneous sound-image pairs (AV) were also randomly assigned. Due to the synchronous presentation of the streams, the participants essentially observed a rapid-serial presentation of four different AV-AV quartets. The AV-AV quartets were presented repetitively in a random order, without consecutive repetitions of quartets. Figure 1 illustrates the eight images and sounds, and the construction of an AV-AV quartet. The quartets were each repeated 200 times during the exposure phase.

Procedure

The experiment took place in a dimly lit experiment room, so the images on the computer screen would be clearly visible. Participants sat 57 cm away from the computer monitor, with their head comfortably stabilized by a chin rest. The auditory stimuli were presented binaurally through two speakers placed on either side of the monitor, at the same height as the visual images. The sound pressure level was adjusted before each exposure phase to a comfortable listening level of about 60 dB.

On Day 1 (exposure phase) of the experiment, subjects were told that they would be presented with a series of sounds and images and their only task was to pay attention. No further instructions were given, and the participants were left alone during the exposure. Since the exposure phase was somewhat long (20 minutes) there was a break halfway through. At the end of the second half of the exposure, the participants were directed to leave the experiment room and get the experimenter. At this point, they made an appointment

to come the following day (after approximately 24 hours), but were still unaware of the purpose of the experiment, what would occur during the second appointment, or any subsequent testing phase.

Day 2 of the experiment was the testing phase, which included two short tests. First, the participants' learning was measured with a 2IFC paradigm. The task was to determine which of two intervals contained the stimulus pair that seemed more familiar. One interval contained a stimulus pair that had been repeatedly presented during the exposure phase. The repeated pair was one of four possible question types: two sounds (A-A) presented consecutively, two images presented consecutively (V-V), a consecutively presented sound and image (sequential A-V), or a simultaneously presented sound and image (simultaneous AV). The other interval contained a stimulus pair of the same type, but that was a novel (non-presented) combination of images and/or sounds from the sets of stimuli. Participants could either have selected the correct option by chance or because they had implicitly or explicitly learned the relationships in the AV-AV quartets they observed on Day 1.

Every possible relationship of stimuli within the four types of question was tested, with eight repetitions for each question. The four question types in the testing phase (A-A, V-V, sequential A-V, and simultaneous AV) were tested in a random order, making a total of 128 trials (4 question types x 4 possible relationships for each type x 8 repetitions) during the 2IFC familiarity test. Subjects were given at most 2 seconds to respond to each trial (with a "1" or "2" key press, according to their chosen interval) and the entire test took about 12 minutes.

The second task during the testing phase was an 8-question questionnaire intended to measure the explicitness of the visual statistical learning. The questionnaire presented subjects with one image and asked, "Which image is related to this one?" Underneath the first image were the seven other images, in a random order and subjects-

answered 1-7 according to their explicit memory of the statistical relationship between images. There was one trial for each image, and subjects were given at most 8 seconds to answer each question. There was no feedback given in either task during the testing phase.

Results

Long-term statistical learning

The first research question was whether subjects would demonstrate any statistical learning after a 24-hour break between exposure and testing phases. Figure 2 shows the average statistical learning recorded during the 2IFC familiarity test, with separate bars for the four types of questions in the test (sequential A-V, A-A, V-V, or simultaneous AV). The average statistical learning results for the four types of questions ranged from 0.67 to 0.82, with simultaneous AV questions receiving the greatest proportion of correct answers (0.82, $SE = 0.03$) and sequential A-V the least (0.67, $SE = 0.04$). Collapsed across type of question in the 2IFC familiarity test, the total average statistical learning for the 16 subjects was 0.74 ($SE = 0.03$). Since there were only two choices for each question in this test, a person randomly choosing intervals would by chance be expected to get 50% correct. Therefore, the proportion of correct answers that demonstrated learning would need to be significantly greater than a chance performance of 0.5.

Two-tailed t-tests comparing the average statistical learning for each type of question to chance performance found that subjects did perform significantly better than chance in every category (sequential A-V: $t(15) = 4.51, p < 0.01$; A-A: $t(15) = 5.77, p < 0.01$; V-V: $t(15) = 5.52, p < 0.01$; simultaneous AV: $t(15) = 11.10, p < 0.01$). These t-test results suggest the occurrence of long-term statistical learning for both unisensory and multisensory associations in the study. To determine

whether the differences in learning between the four types of questions were significant, paired-sample t-tests were conducted, comparing two means at a time. This analysis required a Bonferroni correction, so the alpha level changed to $0.05/4$, or 0.0125. The only significant difference was between mean performance on the simultaneous AV and sequential A-V questions ($t(15) = 4.11, p < 0.01$).

Explicit involvement in statistical learning results

The results for involvement of explicit learning were measured by participants' performance on the questionnaire at the end of the study. The percent of correct answers on this questionnaire varied considerably, with one subject scoring 0% correct, 4 subjects scoring 50%, 3 subjects scoring 100%, and everyone else somewhere in between. The average score on the explicit test was fairly high at 62% ($SE = 8\%$).

Looking at subjects' results individually, the higher scorers on the explicit questionnaire also had higher long-term statistical learning. Figure 3 depicts this correlation, which is significant with a correlation coefficient R of 0.72 and $p < 0.01$. More specific correlational analyses of the four types of questions from the 2IFC familiarity test with explicit scores show significant correlations with only the V-V questions ($R = 0.80, p < 0.01$) and sequential A-V questions ($R = 0.75, p < 0.01$). Recall that the explicit questionnaire included only visual stimuli; no significant correlations between explicit learning scores and A-A or simultaneous AV questions is neither surprising nor disappointing. Generally, the data suggest that the subjects' explicit knowledge of the consecutive relationships between the visual stimuli can be used to predict their long-term statistical learning scores.

Discussion

Regarding long-term statistical learning, the results suggest that both unisensory and multisensory associations between stimuli were learned and retained for at least 24 hours. Recalling that the stimulus presentation interval was only 300 ms, the participants were not instructed to look for patterns during the exposure, and the 2IFC test switched randomly between four types of questions, such robust learning effects are encouraging. Unfortunately, there was no way to test participants' level of learning directly after exposure, so that it could be compared to learning 24 hours later, without revealing the purpose of the exposure phase from Day 1. However, we can compare the amount of learning in this experiment with previous work, such as the 2007 study by Seitz et al., in which learning revealed by a similar 2IFC test was in the 60-75% range. If the immediate learning of the subjects in the current study was also around 60-75%, they would have retained nearly all of their learning over 24 hours to perform so well on the familiarity test on Day 2.

The presence of long-term learning, especially for multisensory associations, is an unprecedented finding in statistical learning research. Applied to everyday experience, however, this finding may not be so surprising. Although short-term statistical learning is interesting, long-term learning is much more useful for real world associations. Returning to the example of an approaching car, once children learn that a rapidly growing shape and sound signify an approaching object, they are able to avoid oncoming traffic for the rest of their lives. It would not be as useful—but rather harmful—to make this association one day, only to have to relearn it for every subsequent moving object.

Although every type of question in the testing phase showed significant learning, the results for the multisensory sequential A-V questions were the lowest, and therefore a bit disappointing. Pre-

vious studies concluded that multisensory statistical learning might be *more* robust than unisensory learning (Seitz et al. 2007) when testing directly followed exposure. Current researchers hope for indications of multisensory learning because such indications would bring psychology one step closer to understanding how humans make associations in the real (multisensory) world, as opposed to artificial, computer-imposed situations. Instead of the sequential A-V questions in this experiment, the multisensory stimuli in the Seitz et al study were presented as complete AV-AV quartets. Therefore, the information provided by unisensory stimuli may have boosted the participants' multisensory learning score. In the present study, the complexity of the sequential A-V pairs may have been too much to allow robust long-term learning of multisensory associations.

Based on previous experimental conclusions and statistical learning assumptions, the evidence for explicit involvement in this study may be surprising to many researchers. Explicit knowledge was only tested for the consecutive V-V associations because this relationship was the simplest to ask about explicitly. The significant positive correlation between explicit questionnaire scores and the V-V statistical learning from the familiarity test is easily explained by their shared visual modalities. However, the correlation between explicit scores and sequential A-V learning requires a more complex interpretation. If the correlation is due to a causal relationship, then explicit knowledge would be aiding long-term multisensory statistical learning as well as unisensory learning.

Despite the clear involvement of explicit knowledge, the data suggest that it cannot be the only mechanism behind the learning results. Even the subjects who did poorly on the explicit questionnaire performed better than chance on the 2IFC familiarity test. Also, follow-up questioning of the participants revealed that many of them were unaware of most or all of the relationships between the stimuli despite showing statistical learning.

However, the evidence does bring into question if performance in a 2IFC familiarity test should be attributed solely to implicit mechanisms. Perhaps even in previous experiments explicit knowledge was involved in testing phase performance but went undetected because the tests used were assumed to measure only implicit performance. The results of this experiment illustrate the importance of scientific proof that backs up assumptions, no matter how logical or intuitive the assumptions may seem initially.

As indicated previously, the greatest limitations of the current study were inherent to the experimental design and testing setup. It would have been useful to test participants' learning directly after exposure, in order to understand how the long-term learning changed over the 24 hours between exposure and testing. An additional testing phase could not be included, however, without revealing the purpose of the exposure phase before 24 hours had passed. Eliminating conscious awareness about the purpose of the study, or anticipation of a subsequent testing phase, reduces potential biases or confounds from appearing among the participants. Similarly, the explicit questionnaire was deficient in only asking about V-V pairs. It would have been valuable to record any explicit learning or memory for the auditory stimuli as well, especially since this experiment had a multisensory focus.

Clearly, further research must be done to elucidate the causal influence of explicit versus implicit knowledge on statistical learning results. Baker, Olson, and Behrmann (2004) advocated using a more exclusively implicit procedure to measure statistical learning. An appropriate follow-up study to this experiment would replace the 2IFC test with an implicit priming test to investigate whether participants show similar levels of learning. Evidence of learning from a priming test would more convincingly prove that statistical learning can be carried out by the implicit memory system independently of explicit memory contributions.

The current experiment led to some new findings and unprecedented evidence in terms of multisensory statistical learning research. The results are encouraging for researchers seeking to understand and characterize how humans make associations between the myriad cues they receive every second through visual, auditory, and sensory input. Furthermore, the findings not only relate to how people *make* multisensory associations, but also how they *remember* them over longer periods of time. Further investigations on these issues are warranted, and should continue in the future.

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A Moment With Dr. Patricia Greenfield

Interview by Goldie F. Salimkhan

It was two after two and I had been staring at the clock for quite a while. Perhaps I was just thirty minutes early. Finally I heard her voice approaching from down the hall and in she came smiling her warm smile that invited me into her office.

Patricia Greenfield is best known around Franz Hall as a successful scholar and effective professor. Currently a professor of psychology at UCLA, her research is focused on culture and human Development.

Greenfield went to Harvard graduate school and initially did research under the mentorship of Robert Rosenthal (now at UC Riverside), who is known for his experimenter expectancy studies. Greenfield did experimenter expectancy studies and published several articles with him. But despite the statistically significant effects, their small absolute size made her feel like they were not substantially significant, that they lacked real world significance, so she moved on to other pursuits.

As a young, adventurous graduate student, she was interested in traveling and so contacted famous researcher Jerome Bruner, and said “Do you remember that I took your graduate seminar when I was an undergraduate? I understand that you have some things going in other countries. Is there something I can do?” He happened to be looking for someone to go to Senegal to do research and she happened to speak French, so he sent her to Senegal with full funding from the Ford Foundation. While in Senegal, shortly after their independence from France, she conducted cross-cultural studies of Piagetian conservation concepts and their development; and through these experiences found her life’s work.

Later on she returned to the Harvard Center of Cognitive Studies as a post-doctorial researcher. One of her colleagues was a famous pediatrician by the name of T. Berry Brazelton who was developing a newborn test that is very widely used now. He had partly developed it in a Maya community in Chiapas, Mexico with a group called the Zinacantecs. He had found that the Maya newborns behaved differently from Euro-American newborns and so invited Greenfield to go and follow up his work with older children because he knew she was interested in culture and human Development. The intrigued Greenfield then started working in Chiapas where she has been following a group of families there ever since, eventually investigating how social change affects their development and socialization.

While Greenfield was at Harvard, she heard a lot about the linguist Noam Chomsky and his theories about language development. At the time her daughter was beginning to talk, she noticed that the process was completely different from the little grammar machine Chomsky had described. Initially, she was relating single words to her own actions, gestures, and objects in the environment - not to other words, as Chomsky posited. Greenfield became completely fascinated by her language development and its theoretical implications. These observations started a train of research that began with a book, *The Structure of Communication in Early Language Development*, and that has been ongoing ever since.



While in the middle of this early research, Greenfield heard Beatrice and Allan Gardner speak about Washoe the chimpanzee and her sign language developed through human training and became interested in the parallels between child and chimp. Eventually some other famous primatologists, Duane Rumbaugh and Sue Savage-Rumbaugh, got in touch with Greenfield. Sue Savage Rumbaugh who was working with chimpanzees to communicate with visual symbols, felt that Greenfield was the first person in child language who was describing what she thought was happening with the apes and their language use. That started collaboration where Greenfield compared the language and cognitive development of children and apes, a line of research which has continued to the present.

Greenfield was also the first person to talk about the cognitive skills involved with playing video games and developed a whole line of research on video games publishing a book in 1984 called *Mind and media the effects of television, video games, and computers*.

As I listened to her narrative about her life in research and her amazing story, I couldn't help but ask what advice would she give a young undergraduate interested in graduate school and a similar life of adventures.

“Well I think that the main thing is only do it if you really love it. Research is really hard...it takes a really long time...there is no immediate gratification. Each study is a very long process and sometimes you don't really get any feedback when you publish it. I think the average study is read by only five people...so you really have to love it. For people who really want to go to graduate school and really are trying to prepare to go to graduate school, I would say to get research experience while you are in college. Pretty much everyone does that; but what I think makes a difference is if you stick with a project. What is important is to have the continuity of completing the project and also experiencing and participating in the different stages of the research.”

“What has been most rewarding in your work, researching and teaching?”

“You know at different times I've found different things most rewarding. At times when my research wasn't so interesting I found teaching really exciting...you know mastering teaching a large class was really hard for me...I found that really exciting for a while; and then when I make a big discovery, I find the research really exciting. Right now I find developing a big theory very exciting because I have a theory that can explain a lot. I've always been interested in trying to explain things that you can see in the real world and this theory is that kind of theory.”

When Greenfield isn't teaching, researching, or spending time with her family, she is most likely to be found rowing, skiing, or salsa dancing.