Annual Meeting of Investigators

Science of Behavior Change Common Fund and Basic Behavioral and Social Science Opportunity Network

National Institutes of Health

MEETING SUMMARY

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The NIH Common Fund

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Executive Summary

The National Institutes of Health (NIH) Science of Behavior Change (SOBC) Common Fund program seeks to promote basic research on the initiation and maintenance of behavior change, and the application of such research toward personalization of interventions. This effort is intended to lead to an improved understanding of the underlying principles of behavior change by integrating research across disciplines. The 2012 annual meeting of SOBC investigators was held jointly with investigators from the Basic Behavioral and Social Science Opportunity Network (OppNet) focused on basic mechanisms influencing behavioral maintenance.

The integrated meeting provided an opportunity to explore areas of common interest and promote cross-fertilization between these related research efforts. Investigators presented progress on their work and participant discussions focused on exploring common themes and identifying next steps. The research presented at the meeting bridges work done in the laboratory and the field. The participants represented a cross-section of disciplines (behavioral economics, psychology, neuroscience, neuroeconomics, genetics, pediatrics, and clinical medicine) and included work at multiple levels of analysis (social, contextual, behavioral, psychological, neurobiological, and genetic).

SOBC projects included focus on various aspects of emotional self-regulation, behavioral economics, genetics, and social media. OppNet projects included characterizing habitual and goal-directed behavioral control systems, overcoming the persistence of first-learned habits, and neural mechanisms of habit formation and maintenance.

Several themes were apparent across multiple projects: the role of emotions, motivation, self-regulation, individual differences, and the different mechanisms underlying behavioral change versus behavioral maintenance. Behavioral change involves transitioning behavior from maladaptive habitual control to goal-directed control. Stress is known to interfere directly with the balance between goal-directed and habitual control and thereby impeding behavior change. There may be a variety of techniques to favor engagement of goal-directed mechanisms to gain control from adverse habits and several of these were presented and discussed during the meeting—meditation for stress reduction, explicit training then overtraining of new behaviors, cognitive or regulation strategies, and efficient incentive structures. Behavior maintenance likely involves both establishing new habits and inhibiting old habits. Individual differences play a large role at each stage and it will be important to understand genetic mediators as well as the computational and neural mechanisms.

The basic science of behavior change should be closely linked to planning policy. Suggestions for future meetings included a more active agenda involving collaborative discussion or problem-solving, strategies for optimizing multidisciplinary understanding, and engaging other stakeholders.

Introduction

The National Institutes of Health (NIH) Science of Behavior Change (SOBC) Common Fund program seeks to promote basic research on the initiation and maintenance of behavior change, and the application of such research toward personalization of interventions.[1] By integrating work across disciplines, this effort is intended to lead to an improved understanding of the underlying principles of behavior change. NIH awarded 10 grants in fiscal year 2010 in response to the request for applications (RFA) titled Science of Behavior Change: Finding Mechanisms of Change in the Laboratory and the Field (R01).[2] The investigators on these grants are undertaking behavior change research in a variety of disciplines—behavioral economics, psychology, neuroscience, neuroeconomics, genetics, pediatrics, and clinical medicine. The projects bridge work done in laboratories and in the field, and they are intended to stimulate investigations of basic mechanisms at the social, contextual, behavioral, psychological, neurobiological, or genetic level of analysis.

NIH convened the second annual meeting of investigators in Bethesda, Maryland, on June 20-21, 2012, jointly with the grantees from an RFA supported by the Basic Behavioral and Social Science Opportunity Network (OppNet).[3] OppNet focuses on addressing the research gaps in basic processes and mechanisms and has supported 17 RFAs on topics of relevance to multiple NIH Institutes and Centers. The grantees from the OppNet RFA, Basic Mechanisms Influencing Behavioral Maintenance (R01), are working on basic processes and mechanisms involved in sustaining newly learned effortful behaviors and goals over time.[4] This meeting is particularly interesting because of the opportunity it affords for the SOBC and OppNet grantees to find areas of common interest and promote cross-fertilization between these related research efforts. It is hoped that in the future, lessons learned collectively from these grantees will be applied to generating new approaches to behavior change in policy and practice.

The SOBC Working Group co-chairs, Patricia Grady (Director of the National Institute of Nursing Research [NINR]), Richard Hodes (Director of the National Institute on Aging [NIA]), and Richard Suzman (Director of the Division of Behavioral and Social Research, NIA), welcomed participants and expressed enthusiasm about the potential to advance the science of behavior change in a cross-disciplinary manner. Each participating grantee was given an opportunity to present his or her work and respond to questions and comments. Time for open discussion was provided throughout the meeting. Two grantees, Drs. John O'Doherty and James Hudziak, were invited to provide keynote presentations with the goal of integrating the themes that emerged across the SOBC and OppNet Behavioral Maintenance projects.

[1] http://commonfund.nih.gov/behaviorchange/
[2] http://grants.nih.gov/grants/guide/rfa-files/RFA-RM-10-002.html
[3] http://oppnet.nih.gov/
[4] http://grants.nih.gov/grants/guide/rfa-files/RFA-HL-11-035.html

Investigator Presentations

Emotions and Choice: Mechanisms of Behavior Change

Elizabeth A. Phelps, PhD, Silver Professor of Psychology and Neural Science, New York University

Current findings from affective neuroscience demonstrate that emotions and reasoned decision making are not competing processes. Emotion has a modulatory role in cognition and in value computation. Dr. Phelps and collaborators, including Drs. Colin Camerer and Paul Glimcher, are investigating whether the tools of affective neuroscience and neuroeconomics can be used to characterize more precisely how and when emotion is incorporated into value computation and decision making, and how the process can be altered.

Both emotion and decision variables are involved in behavioral choice. Emotion consists of several components—subjective feelings, bodily response, expression, and tendency to action. This project differs from studies that rely on self-report measures by using physiological responses as the primary indicators of emotional states. The components of decision making that are being quantified include loss aversion, risk sensitivity, and temporal discount rate.

Dr. Phelps presented progress on one study from each of the three aims of the grant. The specific aims of this grant, for which both the behavioral outcomes and their underlying neural representation will be investigated, are to 1) investigate the link between variability in loss aversion, risk sensitivity, and temporal discounting and physiological arousal response to choice options or outcomes (Study on arousal and temporal discounting); 2) examine the impact of altering arousal on these decision variables (emotion regulation and pharmacological manipulation) (Study on neural correlates of the regulation of loss aversion); and 3) explore the impact of stress on the decision variables and the effectiveness of the techniques used to alter arousal (Study on the impact of stress on emotion regulation).

Study on Arousal and Temporal Discounting

In this parallel study of discounting, the participant has the option of two possible rewards—immediate or delayed. The delay options included delays of 7, 30, 60, 100, or 180 days. The subjective value of delayed reward relative to immediate reward can be calculated, and from these subject values a smooth curve reflecting the participant's discount rate can be derived. A larger discount rate indicates more impatience (i.e., a preference for rewards sooner rather than later).

Pupil dilation was used to measure physical arousal because the time course of this physiological signal is more amenable for the proposed analyses than the skin conductance response. Pupils dilate not only with increased ambient light levels, but also with increased sympathetic nervous system arousal. The hypothesis was that participants whose pupils indicate higher arousal (greater excitement) with the immediate reward would be less likely to wait for the delayed reward (i.e., they would be more impatient and have larger discount rates). Previous work has demonstrated that parts of the midbrain dopamine system are

activated differentially by decisions involving immediate rewards as compared to delayed rewards.[5] In this study, measurements of the participants' pupils 1-4 seconds after the Choice Screen and Outcome Screen were used to indicate arousal levels evoked by those stimuli.

Contrary to the hypothesis, the study demonstrated that there was greater arousal, as measured by pupil dilation, when the participant chose the *delayed* reward. In other words, pupil dilation at choice onset predicts choosing the delayed reward. This unexpected result leads to a different interpretation of the situation than the one that was hypothesized. There are a few studies that suggest temporal discounting is related to the ability to project into the future. If this were happening in this experiment, then it is possible that individuals who are better able to project into the future also can get more excited about the future and future outcomes. In order to replicate this unexpected finding and test this possible interpretation, Dr. Phelps and colleagues are conducting two additional studies.

Study on Neural Correlates of the Regulation of Loss Aversion

Emotion regulation strategies can alter behavioral and physiological responses to emotional stimuli, and we can observe the neural correlates of those responses in brain regions including the amygdala and striatum. In decision making, regulating emotion with reappraisal-focused strategies that encourage taking a different perspective has been shown to reduce loss aversion, and this effect can be observed both in choices and in the relative arousal responses to actual loss and gain outcomes. In this study, participants were offered the option of 1) a risky gamble comprising two amounts, one positive and the other negative, each with a 50-50 chance, or 2) nothing. Loss aversion is quantified by varying the amounts in the risky gamble option. Previous pilot work has shown that arousal tracks loss aversion (more sweat per buck, more loss aversion) and that losses are more arousing than gains. However, individuals can regulate their emotional responses, leading to changes in behavior, arousal, and their neural correlates. For example, applying a cognitive strategy for decision making can decrease loss aversion.

Research on the neural correlates of the effect of a regulation strategy on loss aversion shows amygdala activation in response to losses versus gains (individuals' behavior with a difference in activity to outcomes).[6] The amygdala is known to be involved in mediating the effect of emotional arousal on several aspects of cognitive processing, including attention and memory. Therefore, it is not surprising that patterns of amygdala activity parallel the previously observed arousal responses to outcomes. The finding serves as further evidence that behavioral loss aversion as observed in choices may simply reflect arousal-related responses to outcomes.

An a priori hypothesis that activity related to behavioral regulation would be found in the prefrontal cortex follows from previous imaging studies implicating areas of the dorsolateral

[5] McClure, S. M., Laibson, D. I., Lowenstein, G., & Cohen, J., D. (2004). Separate neural systems value immediate and delayed monetary rewards. *Science, 306*, 503-507. Retrieved August 27, 2012, from http://psych.stanford.edu/~jlm/pdfs/McClureEtAl04Science.pdf.

[6] Sokol-Hessner, P., Camerer, C. F., & Phelps, E. A. (2012). Emotion regulation reduces loss aversion and decreases amygdala responses to losses. *Social Cognitive and Affective Neuroscience*, doi:10.1093/scan/nss002.

prefrontal cortex in various kinds of regulation and effortful control. Dr. Phelps and colleagues looked for voxels with greater activity when regulating versus attending at the time of the decision, and thereby identified a region of the dorsolateral prefrontal cortex. Because participants were completing small blocks of "attend" trials and small blocks of "regulate" trials, the investigators were able to observe baseline shifts in activity over the course of each block. During regulation, activity was greater not only during decision, as expected because of how the region was identified, but notably also during outcomes, in a similar fashion as observed in previous studies of regulation.

Study on the Impact of Stress on Emotion Regulation

One hypothesis is that stress impacts the prefrontal cortex, which regulates emotion. However, no one has shown that stress actually impacts emotion regulation. Study 3 involves a cold pressor stress test, which increases cortisol, impairs performance on tasks that require prefrontal cortex, and enhances amygdala responses to stimuli. Day 1 of the study includes questionnaires, a fear conditioning protocol, a 20- to 30-minute cognitive remediation therapy (CRT) session targeting self-regulation (for half of the participants), and cortisol measurements (beginning of the day, and before and after the CRT session). The CRT session was intended to teach participants about the relationship between thoughts and emotions using cognitive behavioral therapy. Day 2 of the study includes a questionnaire of self-reported anxiety, ratings of the stressor (cold pressor test or respective control task), a fear conditioning protocol identical to that of day 1, and three more cortisol measurements as on day 1. Preliminary results show that there is a differential cortisol response in the stressor group but not in the control group and that the efficacy of emotion regulation CRT is lower for the stressor group compared to the control group. This is consistent with the hypothesis that stress impairs the ability to regulate.

The next steps for this study include investigating how non-specific stress impacts loss aversion and temporal discounting generally as well as the success of regulation of loss aversion.

Question and Answer

One question raised the possibility that cognitive capability might lead to individual differences in regulation and therefore might be a factor, in addition to emotional response, affecting pupil dilation, which could explain the results of experiment two. One could attempt to assess this possibility by measuring baseline cognitive ability in participants, but cognitive measures are not being added to the study at this time. Rather, the team will first work on replicating and confirming the unexpected result of the pupil dilation study. In addition, the team plans to begin work on the pharmacological intervention proposed as part of this research aim.

It was also noted that a body of literature on future orientation in adolescents might provide an interesting link to the arousal and temporal discounting study. The sample population for this study is drawn from students at New York University, and different results might be expected for subjects from more representative backgrounds.

Affective and Genomic Mediators of Sustained Behavior Change

Sara Algoe, PhD, Assistant Professor of Psychology, University of North Carolina at Chapel Hill

The overarching aim of this project is to investigate how positive emotions alter bodily systems in ways that ultimately reinforce sustained behavior change. The Upward Spiral Model of Lifestyle Change, developed by Dr. Barbara Fredrickson (Principal Investigator), posits that if and when a new wellness behavior elicits positive emotions, it triggers a cascade of biological changes (e.g., in vagal tone, oxytocin, blood pressure) that reshapes key bodily systems in ways that increase the subsequent positive emotion yield of that behavior and enhances its nonconscious motivational pull. This model can be tested in an experimental way because positive emotions and wellness behaviors can be introduced to participants.

There are three project aims informed by Dr. Fredrickson's previous work, social genomics work from a co-investigator, Dr. Steven Cole, and the cytokine theory of depression. The specific aims are to 1) identify peripheral biological resources and genetic polymorphisms that moderate the link between wellness behaviors and their positive emotion yield; 2) identify the biological signaling pathways that mediate the proposed association between increases in positive emotions and changes in inflammation-related gene expression; and 3) investigate the pathways through which increases in positive emotions influence changes in inflammation-related gene expression, sustained wellness behavior, and associated health outcomes.

Hypothesis 1: Laboratory Test of One-time Dose of Meditation

The majority of the work completed to date is the laboratory testing portion of aim 1, identifying peripheral biological resources and genetic polymorphisms that moderate the link between wellness behaviors and their positive emotion yield. The targeted wellness behavior is meditation with and without positive emotions. Loving-kindness Meditation (treatment) practices concentration and amplifies the generation of positive emotions toward self and others. Mindfulness Meditation (control) focuses on cultivating attention to the present moment.

The first laboratory study included a one-time exposure to one of the two types of meditation to determine if positive emotion yield can be measured with the first dose and if the yield can be predicted by biological measures. Biological measures included vagal tone, oxytocin, ribonucleic acid (RNA), blood pressure, body-mass index (BMI), and C-reactive protein. All of the measures are associated with biological health and inflammation, which is important for the genomics piece of the study. Participants provided blood samples to enable the testing for gene expression. Emotional response to wellness behaviors was collected through self-report questionnaires and facial electromyography (fEMG).

The first hypothesis of aim 1 is that people with healthy biological profiles (i.e., high 24-hour oxytocin and resting respiratory sinus arrhythmia and/or low blood pressure and C-reactive protein) would respond differentially to Loving-kindness Meditation practice and receive a higher positive emotion yield out of that practice. Preliminary results from 79 participants point to some promising findings. Baseline vagal tone interacted with type of meditation practice to

predict self-reported positive emotion. Consistent with the hypothesis, among those randomly assigned to Loving-kindness Meditation, participants with higher vagal tone reported more positive affect. In contrast, among those randomly assigned to Mindfulness Meditation, participants with lower vagal tone reported more positive affect. A similar pattern was found for BMI (range: 19-53, mean=28.8). Participants with a healthier (lower) BMI extracted more positive emotion from Loving-kindness Meditation than did participants with less healthy (higher) BMI, and the reverse was true for Mindfulness Meditation. These findings suggest that whereas Loving-kindness Meditation may fuel positive upward spirals, Mindfulness Meditation may aid in slowing downward spirals.

The preliminary results from the laboratory test are informing the next phase, a longitudinal study of the two meditation conditions. The investigators are considering adding a no-meditation control group. Mindfulness Meditation is a tight control for Loving-kindness Meditation, and a third control group may be needed to be able to show differences.

Hypothesis 2: Gene Expression Analyses

The second hypothesis of aim 1 is that individuals with certain gene expression profiles show greater increases in positive emotions during and following their enactment of Loving-kindness Meditation compared to individuals without those profiles. The idea is that in the same way that genes in the inflammatory processes promote sickness behaviors and cause people to withdraw and heal, the same processes in inflammation-related gene expression might contain a signature for health-promoting behaviors.

RNA was extracted from the peripheral blood mononuclear cells of 79 participants and the team assayed the expression of 34,592 human gene products (including mRNA and miRNA) using Illumina Human HT-12 BeadArrays. The preliminary analysis supports the hypothesis; several genes were identified (e.g., ATP6V1C2, SPRY4, ATP2A1, FRMD6, FLJ32063, TMEM198, NHEDC2) that interacted with the meditation condition such that individuals showing higher average levels of gene expression reported greater positive affective responses to Loving-kindness than to Mindfulness Meditation. Several genes also were identified for which individuals showing high levels of gene expression reported greater positive affect response to Mindfulness than to Loving-kindness Meditation.

The team is now conducting additional bioinformatics analyses to identify any commonalities among the distinct gene sets that appear to predict more favorable affective responses to Loving-kindness versus Mindfulness Meditation. Thus far, however, these data clearly suggest that individual differences in gene expression may contribute to the proposed upward spiral of positive behavior change by affecting the positive emotion yield of different meditation practices. The team has developed a new analysis strategy that looks at gene expression dynamics as moderating a psychological outcome. Positive social genomics is a new area of study and is a work in progress.

The initial analyses of gene expression data also have yielded new insights into the gene transcriptional correlates of general psychological well-being. Previous social genomics studies

have examined relationships between leukocyte gene expression profiles and negative psychological states and/or adverse life stressors, and they typically find increased expression of pro-inflammatory cytokine genes and decreased expression of genes involved in innate antiviral responses (type I interferon-related). The analyses done through this study represent what is thought to be the first investigation linking positive psychological conditions to differential gene expression, and they find a different set of gene transcriptional correlates. In short, there is evidence that gene expression dynamics correspond to trait-level markers of psychological well-being. Gene expression dynamics appear distinct for chronic stress and adversity, hedonic well-being, and eudaimonic well-being. The ongoing bioinformatic analyses are seeking to confirm these results and clarify their biological significance and potential molecular mechanisms.

The team has not identified specific genes to date. Dr. Cole is examining variation in gene expression across 34,000 gene products to look for patterns influencing reactions to the meditation practice. Changes in gene expression as a result of practice of the wellness behavior will be examined in the second study.

Hypothesis 3: Event Reconstruction Method

The third aim 1 hypothesis is that individuals with healthy biological profiles report greater increases in positive emotions when engaged in other wellness behaviors (versus control behaviors), compared to individuals without healthy biological profiles. Supporting this hypothesis, preliminary results from 79 participants yielded an interaction between BMI and wellness behaviors assessed within the Event Reconstruction Method portion of the study in which participants described their emotional responses to a range of health and wellness-promoting behaviors versus neutral behaviors. For example, participants with healthier BMIs reported greater positive emotions while eating a healthy meal than did participants with less healthy BMIs.

Next Steps

Study 2 will involve a field test of the entire model involving a 90-minute laboratory visit, 2 weeks of baseline daily reporting, a 7-week meditation workshop followed by 3 weeks of daily reporting, and another 90-minute laboratory visit. The 12-month followup will include 1 week of daily reporting and a laboratory visit.

Question and Answer

The laboratory test of a one-time dose of meditation appeared to yield a massive main effect for Mindfulness Meditation, which is intended to be the control, and a weaker effect on Loving-kindness Meditation. Dr. Algoe noted that this is a one-time dose for novice meditators, and it is not clear if it will be indicative of long-term practice.

Volunteers for meditation studies tend to be healthy women in mid-life, but the actual level of their health is not known. Loving-kindness Meditation has produced changes in vagal tone, and, theoretically, Mindfulness Meditation should have the same result because it is an attention focused activity and vagal tone is an index of control. Dr. Wendy Weber from the National Center for Complementary and Alternative Medicine (NCCAM) noted that data from the

National Health Interview Survey indicate that, generally, those who meditate are less likely to be overweight or obese, although that may or may not be true of the participants of this study.

General Discussion

The role of individual differences, while an important topic of study, is not the focus of either of these projects. Dr. Phelps' study aims to discover how emotion is linked to decisions. An emotional model for temporal discounting has been discussed, but no one has ever measured it. The mechanism needs to be fully explored and explained before the implications of individual differences can be understood. Dr. Phelps' study does screen for mental disorders, and Dr. Algoe reported that depressive symptoms are being measured among the participants in the meditation study. Life changes, stressful events, and other possible sources of individual differences are assumed to be randomly distributed in the samples.

Characterizing Habitual and Goal-directed Behavioral Control Systems in the Human Brain Using Computational and Multivariate fMRI

John O'Doherty, PhD, Professor of Psychology, California Institute of Technology

Research from Balleine and Dickinson (1998) provides evidence that the control of behavior by reinforcement relies on two distinct mechanisms: goal-directed versus habitual control.[7] Goal-directed control is slow, deliberative, and makes high resource demands sensitive to incentive value of outcome; in addition, there is a causal relationship between action and outcome. Goal-directed decisions are defined as those decisions made by a person who both considers consequences and chooses deliberate actions. Habitual control is rapid and reflexive, and makes low resource demands insensitive to outcome value; it is also indifferent to the causal structure of the situation. As a consequence of these properties, habitual decisions persist even if the value of the goal changes. In the associative learning literature, goal-directed decision making is linked to reward-learning where associations are formed between actions and value of outcomes attained as a result of pursuing those actions. Habits, by contrast, are viewed as a relationship between stimulus and outcome (i.e., a Pavlovian process).

The specific aims of this project are to 1) elucidate the brain systems encoding goal-directed versus habitual associative structures; 2) determine the computational underpinnings of goal-directed and habitual control, using functional magnetic resonance imaging (fMRI); 3) explore the brain systems involved in the dominance of one system over the other.

Balleine and Dickinson have shown with rodents that behavior is initially sensitive to outcome devaluation. (Outcome devaluation refers to the phenomenon that, after moderate training, animals tend to stop responding or respond less to an outcome that has become devalued, for example by the experimenter adding an unpleasant taste to a food pellet that had been a reward.) After overtraining, however, the animal becomes insensitive to outcome devaluation and will emit the overtrained response even if that action is associated with a devalued

[7] Balleine, B. W., & Dickinson, A. (1998). Goal-directed instrumental action: Contingency and incentive learning and their cortical substrates. *Neuropharmacology, 27*, 407-419.

outcome. Other work with human subjects shows a similar result is observed when training continues for one versus three days.[8]

There is evidence, moreover, that neural signals can track this process of habit formation. A putative habit signal in the posterior dorsolateral striatum increases over time in people developing habit activity. There is indirect evidence to implicate this part of the brain in habit learning, but what is going on in this region is still unknown.

One goal of this project is to decode the associations underpinning value signals in the ventromedial prefrontal cortex and putamen. Dr. O'Doherty seeks to understand exactly what kind of representations are present within the putamen when participants are making choices between actions that lead to different outcomes and contrast it with activity in the ventromedial prefrontal cortex, which seems to be involved in goal-directed control. Multivariate fMRI enables the team to look for changes in activation on average within a region related to some task. This procedure thus provides information about what is actually processed, and it has been successful in the analysis of fMRI data obtained from the visual systems, where it has helped elucidate what kinds of information are encoded in specific cortical areas.[9]

Aim 1: Mapping Structures of Habitual Control

The investigators are training participants to associate a stimulus with one of three actions. The training phase occurs outside the scanner and continues until the participants perform five correct discriminations between the stimuli and perform the appropriate action. In the context of the study, participants need to select a particular action to pursue the outcome they want. The choice phase is implemented in the scanner with 60 trials presented over the course of 20 minutes. A second session conducted at a later time is structurally the same, but the associations between stimuli and actions are changed. The goal is then to train a pattern classifier to recognize functional images corresponding to different types of information at the time of making the choice (e.g., an outcome classifier will be trained on fMRI images corresponding to brain activity recorded at the outcome time, whereas an action classifier will be trained on action time–related data). Essentially by definition, we expect a region can be identified as goal-directed if both the outcome and action classifiers identify that it is active during the task, whereas a habit region will be identified by an action classifier but not an outcome classifier.

The criterion for classifier accuracy is currently just better than chance performance. Preliminary results show that the ventromedial prefrontal cortex does indeed perform better than chance on information related to both outcomes and actions. The putamen, on the other hand, is clearly recognized by the action classifier as encoding information related to actions,

[8] Tricomi, E., Balleine, B. W., & O'Doherty, J. P. (2009). A specific role for posterior dorsolateral striatum in human habit learning. *European Journal of Neuroscience, 29*, 2225-2232.
[9] Hampton, A. N., & O'Doherty, J. P. (2007). Decoding the neural substrates of reward-related decision making with fMRI. *Proceedings of the National Academy of Sciences, 104*, 1377-1382.

but it does not appear to encode much information about outcomes. These results need to be replicated with a larger sample.

A key goal of the project under Aim 1 is to develop a task that can induce habits without overtraining. Although the behavioral demonstration of habits typically depends on overtraining paradigms, these procedures can be cumbersome, they introduce confounds in interpretation, and they rely on between-subject manipulations (thus they have less statistical power to detect effects because of individual differences). O'Doherty and his colleagues have developed the beaker task of rapid elicitation of habitual control. This test uses a within-subjects design where the participants experience both the goal-directed and habitual conditions of the test. The goal-directed condition requires a specific action sequence that uniquely maps onto a particular outcome (depressing a certain beaker). The habitual condition includes particular discriminative stimulus that signals the appropriate response. After training, one of the beakers is devalued. The behavioral measure is of the response for the now devalued outcome.

Preliminary behavioral results for the rapid elicitation of habitual control task (n=15) show a difference in response between the two conditions. In the habit condition, 80 percent of the participants responded on at least one devalued trial, whereas in the goal-directed condition, only 25 percent responded on at least one devalued trial. The preliminary evidence points to the possibility that habits can be induced without overtraining. The brain imaging results corresponding to this task indicate that the caudate is more active in the goal-directed conditions and the putamen is more active in the habit condition, although additional follow-up studies need to be performed. In summary, these results represent significant progress toward the goal of mapping out the brain structures involved in habitual control.

Aim 2: Computational Underpinnings of Goal-directed and Habitual Control

Daw et al. (2005) showed that the different learning processes could be mapped onto two different types of reinforcement learning.[10] Goal-directed control is characterized as model-based reinforcement learning wherein an internal model of the world is used to calculate values in real time. Habitual control is characterized as model-free reinforcement learning where approximate predicted values for actions learned via simple model-free reinforcement are applied (i.e., trial and error). These two different mechanisms might give us insight into how the different systems are implemented computationally. Both systems work by means of prediction error, which is simply the difference between what you expect and what you get.

The uncertainty of these models about the state of the world can be computed on the basis of state prediction error (corresponding to model-based reinforcement learning) and reward prediction error (seen in model-free reinforcement learning). The team is developing a Bayesian model based on using prediction errors as proxies for likelihoods corresponding to both model-based and model-free systems. The computation also incorporates differential cognitive effort

[10] Daw, N. D., Niv, Y., & Dayan, P. (2005). Uncertainty-based competition between prefrontal and dorsolateral striatal systems for behavioral control. *Natural Neuroscience, 8*, 1704-1711.

(goal-directed control is cognitively effortful; it is more efficient to switch to habitual control, all else being equal).

The model can make unique predictions about when behavior should be under control of model-based versus model-free systems: 1) if state prediction errors are high, then the model-based system should have high uncertainty (and thus lower likelihood of being correct) and the behavior should become habitual and 2) if reward prediction errors are high, then the model-free system should have high uncertainty (and thus lower likelihood of being correct) and the behavior should become goal-directed. The team has run a pilot test using a rapid trial-by-trial devaluation procedure with 11 subjects. Next steps include scanning the participants while they perform the task and testing for regions correlated with model-based and model-free value signals (aim 2) and areas correlating with signals underlying arbitration (aim 3).

Overcoming the Persistence of First-learned Habits to Maintain Behavioral Change

Tom Schonberg, PhD, Postdoctoral Fellow, University of Texas at Austin

This work (PI: Dr. Russell Poldrack) is based on a well-established idea from learning theory that there are fundamental differences between first-learned and later-learned behaviors. First-learned behaviors are the default behaviors that generalize over contexts and time. These first-learned behaviors are not over-written as they are replaced, but instead are retained in a latent state. This understanding helps to explain why a person can change a behavior at home (e.g., snacking on carrots instead of potato chips) but when in other contexts, the first-learned behavior of snacking on potato chips re-emerges. Later-learned behaviors are contextually sensitive. The maintenance of later-learned behaviors requires suppression of the first-learned behaviors.

The two-fold approach explored in this project is to enhance later-learned behaviors as well as suppress first-learned behaviors to encourage better behavior maintenance. The specific aims are to examine 1) the neural systems that underlie learning of later-learned behaviors and how they differ from those that support first-learned behaviors; 2) theoretically motivated mechanisms to improve learning and maintenance of later-learned behaviors and prevent renewal of first-learned behaviors; and 3) the neural basis of improvements in maintenance of later-learned behaviors.

Phase 1 of the study involved a laboratory exercise where pre-experimental preferences were used as a proxy for first-learned behaviors (i.e., initial snack choices after period of fasting). Overtraining was then used to change participants' existing preferences to choose the less preferred snack option. Finally, the behavior change was probed. The pre-experimental preferences were established using an auction system that assesses willingness to pay. The overtraining process was successful; participants chose the low-valued item a significantly higher number of times among the trained pairs compared to the untrained pairs of food items. The preliminary imaging results indicate that the auction did indeed capture participants' true values. The areas of the brain involved in response inhibition were activated, which indicates the need to overcome tendency for first-learned preferred items.

The next laboratory exercise focused on suppressing the first-learned behavior. Again, pre-experimental preferences were used as a proxy for first-learned behaviors. Instead of overtraining to choose the lower valued item, the participants were trained to inhibit responses to high and low stimuli using a stop signal task, followed by a probe of behavioral change. Verbruggen and Logan (2008) have demonstrated that if participants are consistently trained on a stop signal task and a certain item is associated with the stop signal, participants will continue to inhibit their response (slower reaction time) even when the stop signal is omitted.[11] The goal is to achieve automatic response inhibition. Participants were trained to stop for 25 percent of the items. The training results indicate a significant difference in stop-signal delay between high- and low-valued items. Not surprisingly, there is a differentiation between higher and lower valued items: it is easier to stop for lower valued items. The preliminary results suggest an automatic mechanism at work. More statistical power in future tests is needed in order to conduct the probe of behavior change.

Next steps will include planned behavior manipulations informed by the learning and memory literature. One goal of the grant is to determine how behavior change is maintained; that is, what will happen if participants are brought back a day or week later. The first manipulation to test sustainability is to space the training over a series of sessions or days. The memory literature has shown that this manipulation gives better maintenance of the behavior. The second strategy is to conduct the training in a variety of contexts to promote generalization of the later-learned behavior. Novel imaging methods will be used to estimate the neural changes occurring during behavioral change and maintenance. The investigators will be able to estimate the neural signature of first-learned versus later-learned behaviors.

Question and Answer

It was suggested that a good way to analyze the imaging data is to examine metric structural MRI changes. In addition to cognitive neuroscience, the grant includes analyses involving diffusion tensor imaging (DTI) and high-resolution images. It also was suggested that epigenetics could be examined within the context of this study. The team intends to expand its current plans and recruit participants from a different, large, University of Texas study that includes blood sample collection in order to correlate genetic information with its findings.

Several participants noted that habits or first-learned behaviors are not necessarily negative. Habits can be linked to both negative and positive behaviors. There is a need to understand both types of behavior systems and their interaction (e.g., maladaptive behaviors hijacking goal-directed systems). Newer work examining mechanisms of rewriting and relearning (neuroplasticity) suggests that first-learned behaviors might be more malleable than is often assumed.

[11] Verbruggen, F., & Logan, G. D. (2008). Automatic and controlled response inhibition: Associative learning in the go/no-go and stop-signal paradigms. *Journal of Experimental Psychology: General, 137*, 649-672.

It was noted that the notion and use of the term "limbic system" is inaccurate and outdated because it is based on historical concepts of brain anatomy that are no longer accepted as correct. It is especially important in the context of cross-disciplinary activities that scientists recognize and convey the complex neuroscience interactions that exist and resist using simplistic outdated terminology.

Neural Mechanisms of Habit Formation and Maintenance

Henry Yin, PhD, Assistant Professor of Psychology and Neuroscience, Duke University

This project uses animal models to focus on the same systems described by Dr. O'Doherty. The goal-directed system is controlled by the anticipation of the goal; actions are rapidly acquired and flexible. The habitual system is automatically triggered by antecedent states; habits are gradually acquired and inflexible. The major finding with animal models by Balleine and Dickinson is that behavior can become habitual with overtraining and devaluation procedures.

A fairly substantial literature on neural substrates has shown that there is a switch from an associative network (action-outcome) to a sensorimotor network (stimulus-response) with habit formation. Extended training in rats induces the control of behavior to shift from the dorsal medial to dorsal lateral system. This is true not only for the striatal regions but also for the cortical and medial dorsal thalamus areas. However, questions remain concerning the role of dopamine in habit formation, and it is unknown whether a direct or indirect pathway in the striatum is involved in this type of learning.

The overall aim of this project is to examine the neural substrates of the habit formation process more closely using mice. With mice, the investigators are able to manipulate neural circuits and record neural activity, which cannot be done with humans. The specific aims of this project are to 1) identify specific feedback patterns that promote habit formation and maintenance; 2) measure plasticity in basal ganglia pathways during habit formation using *in vivo* multi-electrode recording; 3) examine the cellular and molecular mechanisms of plasticity in the basal ganglia; and 4) examine the role of A2A adenosine and N-methyl-D-aspartate (NMDA) glutamate receptors in habit formation.

Laboratory Procedures

Dr. Yin described several of the laboratory procedures being used to address the aims. Random and fixed interval feedback schedules are being used instead of simple overtraining. There is a time lapse before the reward is available. The mouse's first press on the lever earns a food pellet; presses during the interval have no outcomes. Previous work has shown that the pattern of feedback can be manipulated. The animal presses continuously with the random interval schedule but only presses when the reward time is approaching for the fixed interval schedule. The behavior will shift to accommodate the fixed interval. When behavior is examined with a devaluation test, the task shows that behavior becomes more habitual with extreme random interval schedule and that there is no sensitivity to outcome devaluation. The behavior is more directed and sensitive to outcome devaluation with a fixed interval schedule.

A variation of the procedure involves a different pattern of feedback and the relationship between action and outcome. This test manipulates the causal relationship (lever press cancels the reward instead of earns it). Behavior is much more consistent with random awards, even with the omission test. Conversely, behavior stops immediately with a fixed interval schedule. Delay to primary reinforcement is correlated with habit formation.

Previous work on the basic neural circuit in the cerebral cortex was done on the striatum, and little is known about the relative involvement of the direct and indirect pathways in the dorsal striatum. The D1 receptor projects to the substantia nigra pathway, and the D2 receptor goes to the striatopallidal pathway. Using multi-electrode recording in mice, the team is examining the neural activity in these areas. The multi-electrode recording shows reward evoked phasic activity in the substantia nigra. The dopamine neurons show a phasic burst as soon as the reward is delivered. The gamma-aminobutyric acid (GABA) neurons also show a phasic burst of activity, which is a new finding. The GABA neurons are high tonically. The phasic aspect burst firing is modulated by the motivation of state of the animal. Over 2 hours with the animal receiving a reward every 60 seconds, the mouse is sated and does not check the food cup as eagerly. The phasic activity of dopamine neurons changes over time.

Preliminary tests show substantia nigra activity for the 60-second fixed interval schedule. In this scenario, the behavior is goal-directed and the animal is timing the behavior. There is a significant difference between the dopamine neurons that burst right before the action and the GABA neurons that ramp up more slowly before the action. Next steps include examining the data from the random interval schedules.

Other procedures will include examining the direct and indirect pathways in the basal ganglia using fluorescently tagged cell populations. Striatonigral and striatopallidal pathways can be clearly delineated by fluorescent tags, permitting the visualization of these specific populations in the brain slice. Next steps include measuring synaptic transmission from brain slices of habitual and non-habitual mice expressing Drd1a-tdTomato and Drd2-EGFP, which allow simultaneous visualization of striatonigral and striatopallidal pathways. Dr. Yin and his colleagues also will examine the role of NMDA glutamate receptors and A2A adenosine receptors in habit formation.

Question and Answer

Dr. Yin clarified that the multi-electrode recording captures all brain activity and does not require selecting specific neurons. His lab uses 16-32 electrodes in each mouse. He noted that the mice behave quite normally and do not appear to be traumatized from the electrodes. Other labs may use more electrodes, which could negatively impact the mice.

Dr. Yin's hypothesis is that uncertainty is driving the behavior to form habits. He provided an illustrative example of when a person is expecting an important email. The person checks constantly, trying to minimize the delay in receiving the reward of the email. This is driven by uncertainty. Most of the times the person looks, there will be no reward. The hypothesis is that instead of the primary feedback being sought (the email), the behavior is controlled by

secondary feedback, such as opening and loading the email window. This idea needs to be tested explicitly.

Motivational state plays a role as well. Tonic firing is not modulated by motivational state as much as is dopamine firing. When mice are pre-fed, their motivational state is altered. Tonic activity is insensitive to manipulation. Dopamine has a very important role in striatal plasticity; therefore, whether there is a phasic burst of dopamine or a slower tonic level of dopamine has important effects on the pattern of activity of D1 and D2 receptors. One will have a higher affinity for dopamine. What happens downstream is probably what is responsible for changes in behavior. D1 and D2 are not coupled.

It was pointed out that the correlation of GABA neurons or any neuron pattern of activity satiety does not mean that satiety is being encoded, nor does it mean the neurons receive projections. There could be a number of explanations. It is likely that the overall level reflects the overall arousal of the animal.

Integrating Keynote: Linking Mechanisms of Behavioral Change and Long-term Behavioral Maintenance

John O'Doherty, PhD, Professor of Psychology, California Institute of Technology

Multiple systems for behavioral control have adapted over time in response to environmental challenges, each of which can be crudely mapped onto particular parts of the brain: reflexes (e.g., brain stem), Pavlovian conditioning (e.g., amygdala, ventral striatum, cerebellum, midbrain), habit learning (e.g., dorsal striatum, premotor cortex), and goal-directed learning (e.g., prefrontal and parietal cortices, dorsomedial striatum, possibly hippocampus). It is speculated that the adoption of more complex behavioral control strategies has demanded the emergence of additional neural tissue. The phylogenetic and ontogenetic structure of the brain reflects the relative time of emergence of these different strategies during the course of evolution.

A gross generalization of emotions is to think of them as essentially reflexes, or stereotyped behaviors elicited in response to a stimulus. Environmental stimuli can come to elicit specific emotions through the Pavlovian learning system.

The systems of behavioral control interact and can lead to conflicts in the motor system where actions are programmed (Figure 1). The goal-directed system can conflict with a strong habit (e.g., driving on the wrong side of the road in another country), or a Pavlovian response predicting a bad outcome. These conflicts can lead to adaptive or maladaptive behavior.

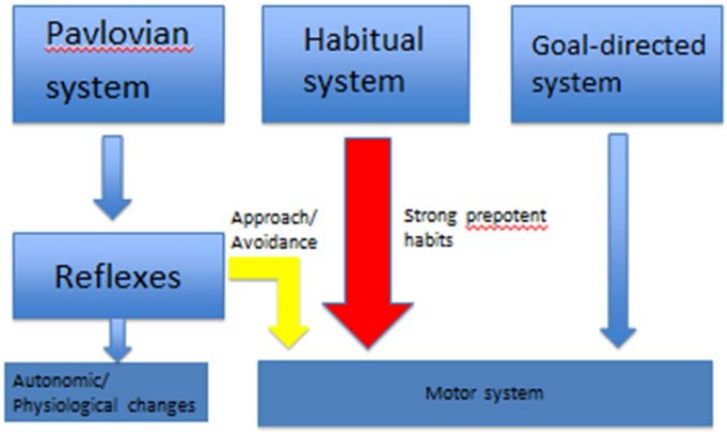

Figure 1: Systems of behavioral control interact (O'Doherty)

Pavlovian cues can also be transferred to instrumental performance. Presenting a Pavlovian cue at the same time as an instrumental action results in facilitation, and the person will respond more frequently or with more vigor than without the Pavlovian cue. This effect can lead to either general or specific transfer. This is an interaction between Pavlovian and instrumental systems. For example, Pavlovian links set up through advertising could maintain maladaptive behaviors or induce "choking" due to stress, pressure, or fear. Some of the violations of rational choice can be argued to depend on Pavlovian influences on instrumental choice behavior. Framing effects and loss aversion are possibly driven by the Pavlovian system and are, in part, amygdala dependent.

The notion of parallel segregated pathways in the dorsomedial striatum and the dorsolateral striatum is a classical idea. Recent work from Haber et al. (2006) recorded connections between these aspects of the striatum and different prefrontal sites.[12] There is evidence of a huge amount of interaction between these pathways and substantial overlap between corticostriatal loops. This complex interaction makes it difficult to interpret the system as segregated.

Given all these interacting systems, there needs to be some of way of trying to control or arbitrate actions. The effects of intrusive Pavlovian learned responses need to be mitigated, and the habitual system needs to be controlled in order for the goal-directed system to guide action when appropriate. It is this arbitrator that needs to be better understood: how does control transition from goals to habits and habits to goals? What are the environmental contingencies giving rise to habitual control? What is the role of uncertainty in the response-outcome/stimulus response relationships and in state- and reward-prediction errors? The location of this arbitrator and whether there is a single arbitrator or different arbitrators for different control mechanisms is unknown.

[12] Haber, S. N., Kim, K. S., Mailly, P., & Calzavara, R. (2006). Reward-related cortical inputs define a large striatal region in primates that interface with associative cortical connections, providing a substrate for incentive-based learning. *Journal of Neuroscience, 26*, 8368-8376.

Also unknown is the role of stress in this arbitration process. Drs. Phelps and Algoe discussed the role of aversive states in promoting negative outcomes, and other work has focused on behavior by goals or habits in stressful situations. Participants of the cold presser stress task did not show devaluation sensitivity, while those in the control group clearly did. It is expected that the behavior would be goal-directed, but the stress appears to be driving behavior toward habitual control. Stress could affect the regulation of the Pavlovian system as well. If stress can be reduced (e.g., through meditation) a positive effect may be induced by giving the arbitrator(s) a better chance to work and create a state in which a person can better regulate.

Behavior change often involves transitioning behavior from maladaptive habitual control to goal-directed control. Behavioral maintenance establishes new habits leading to healthful outcomes. Stress is known to interfere directly with the balance between goal-directed and habitual control, favoring habits and thereby impeding behavior change. There may be a variety of techniques to favor engagement of goal-directed mechanisms to gain control from adverse habits: 1) meditation techniques for stress reduction that favor positive affective states (Fredrickson and Algoe); 2) explicit training and then overtraining of new behaviors (Poldrack and Schonberg); and 3) use of cognitive or regulation strategies to prime the arbitrator (Phelps). Old habits may not die; behavior maintenance likely involves both establishing new habits and inhibiting old habits. Individual differences play a large role at each stage, and it will be important to understand genetic mediators as well as the computational and neural mechanisms.

General Discussion

Critical Periods of Development

Developmental work using progressive neuroimaging of newborns has resulted in the understanding of critical periods of development. It is plausible that these systems are not present at birth and are shaped differently by supportive or maladaptive environments.

Role of Stress

Stress was characterized as inhibiting the ability to use goal-directed versus habitual control. However, certain levels of stress are instrumental in the formation and implementation of goal-directed behavior. It is clear that the arbitrator is compromised if there is too much stress or chronic stress, but that some level of stress is important for motivation. It also was noted that individual differences result in certain situations being extremely stressful for some but motivating or exhilarating for others (e.g., skydiving, public speaking).

Dr. Phelps referred to unpublished data showing less extinction retention under stress, which is consistent with the ideas presented by Dr. O'Doherty. Older literature presents an inverted U-shaped relationship between arousal and stress. However, it is unclear how to conceptualize the path to the top or the bottom of the curve. It certainly relates to individual variability and predisposition.

Behavior Maintenance

It was speculated that a different mechanism is at work for reaching the state of maintenance in the real world than for behavior change. Cognitive behavioral therapy and regulation strategies may become so practiced that they become more habitual, creating a habit of control action. Striation is not necessarily the long-term place where habits are stored. It may well be that the truly intransigent habits are in the cortex and that they take a very long time to be established. The sum of the evidence at this point supports the notion that very established habits become completely dopamine independent (e.g., Parkinson's patients who can still play the piano despite not having motor function in daily activities).

Context specificity continues to be a problem with respect to behavior modification and maintenance. Ways to induce learned behavior independent of context are not yet well developed. Therapeutic distractions have the ability to broaden attention in the moment. If new activities are paired with positive emotions, there may be similar cognitive broadening and a potential reduction of the maladaptive associations. A paired approach of extinguishing bad habits and increasing positive emotions linked to replacement habits might help put people on a trajectory toward maintenance of wellness behaviors.

Role of Motivation

Motivation plays an important role in behavior change and maintenance in the real world. A National Academy of Sciences (NAS) meeting on motivation over the life course looked at the possibility of harnessing motivation for behavior change. At mid-life there are a whole host of motivations to satisfy, but habits are ingrained and time is short to address these competing motivations. One suggestion that came out of the NAS meeting was to target the overarching motivations for why people act (i.e., their family, their overall health) to address multiple behaviors at the same time. Using a behavioral economist perspective, the way something is framed and how a person is hooked into an idea may be more productive than focusing on improving a particular health outcome or changing a bad behavior.

Some participants raised concerns about sample selection with respect to individual differences in motivation and the generalizability of findings, especially if there could be implications for policy or clinical practice. Participants in behavior change studies clearly have different levels of motivation than the general public, just by virtue of volunteering for the study. Patients who seek care in general may be highly motivated for behavior change simply because they have chosen to be patients.

Investigator Presentations (Continued)

Self-regulation as a Biological Mechanism for Excess Weight Gain in Toddlers

Alison L. Miller, PhD, Assistant Research Professor of Public Health, University of Michigan, Ann Arbor
Julie C. Lumeng, MD, Associate Professor of Pediatrics, University of Michigan, Ann Arbor

Disparities in obesity appear in early childhood. Forty percent of low-income children are overweight by the age of 36 months old, and there is an increase in overweight prevalence around 24 months. Living in a high-stress poverty environment during early development may contribute to poor physiological self-regulation, which also may increase the propensity for weight gain. The goal of this project is to examine behaviors and physiology among toddlers aged 1 to 3 years old to determine if there are predictors of obesity risk.

Toddlers are at an interesting stage developmentally for studying self-regulation. Toddlers can do some things on their own but are not highly capable of resolving conflicts independently. They may require a lot of mentoring from a parent or caregiver to learn and practice self-regulation skills. Physiological aspects do not always track behavior in toddlers, and this may change through the course of development. It is possible that food and eating can serve as a self-regulation strategy. Comfort foods are calming and reduce emotional and physiological arousal. Emotional eating and stress physiology are associated with weight gain in adults. One key question this project seeks to address is whether food and eating as a self-regulation strategy could play a role in early obesity risk in low-income children.

The conceptual model for this study includes multiple aspects of child self-regulation: food-related self-regulation, non-food-related self-regulation, and biological self-regulation. Together, the child self-regulation leads to eating behavior and diet and then weight status. The study aims to address 1) the relationship between food/non-food-related self-regulation and salivary cortisol/alpha amylase and preference for comfort food, emotional eating, and weight status at 21, 27, and 33 months; 2) the relationship between early biobehavioral self-regulation (21 months) and change in weight status from 21 to 33 months, mediated by preference for comfort foods and emotional eating; and 3) the association between behavioral self-regulation trajectories and preference for comfort food, emotional eating, and weight status at 33 months, independent of physiology, at baseline.

Study Design and Data Collection

The team currently has plans for 250 low-income toddlers to participate at 21, 27, and 33 months in a 5-day protocol that includes measures of self-regulation (observed emotions and behaviors, physiological indicators, parent-reported emotion regulation), eating behavior (observed eating in absence of hunger, parent-reported preference, parent-reported eating behavior), child weight and height/length, and demographics. The study is not designed to specifically recruit toddlers with acute stress in their life; however, about one-quarter of the participants have someone in their family incarcerated.

Data collection includes videotaped observations, saliva collection, questionnaires, and food and non-food self-regulation tasks. Saliva is collected on three separate weekdays during home visits. The child's saliva is collected three times a day before each meal and the mother's once in the morning only. The samples are assayed for cortisol and alpha-amylase (diurnal pattern).

The observational data are coded for self-regulation behavior (negative/positive affect, attentional focus, timing waiting, task success, self-regulation strategies), eating behavior (negative/positive affect, attentional focus, rate of eating, enthusiasm for comfort foods), and other behavior (parent-child interaction quality, maternal support for child self-regulation).

The current sample includes 103 21-month olds, 68 27-month olds, and 24 33-month olds. Using the Centers for Disease Control and Prevention norms for weight and length, 70 percent of the sample is at a normal weight, 12 percent is overweight, and 18 percent is obese. The sample is 56 percent Caucasian, 18 percent African American, and 25 percent biracial. Fourteen percent of the participants identified as Latino.

The team has some preliminary results from the no-touch toy non-food self-regulation test (n=60). The child is told that the adult needs to get something in a different room and that he or she is not to touch the toy until the adult returns (in 2 minutes). At 21 months, 78 percent of the toddlers touched the toy before the adult returned. The average wait time before the child touched the toy was 14.2 seconds (median=3 seconds). Heavier children waited less time to touch the toy ($r=-0.21$, $p=0.11$).

Health disparities in many areas are related to poor self-regulation skills. Eating behavior may be a model for understanding the role of self-regulation in health outcomes very early in the lifespan. The information gained from this study could lead to new strategies for obesity prevention.

Question and Answer

It was suggested that measures could be added to this study that would allow for crosswalking with larger epigenetic studies. The investigators noted that the focus of this project is problem behaviors, family process, and emotion regulation.

Some data are being collected on self-regulatory behavior of the parents, although the data are focused more on general functioning.

Capturing toddler food consumption is difficult. The parent completes a food frequency questionnaire, but it is not a perfect measure because the child may not always be with the parent (food consumption is not measured in the participants' child care, school, or other settings). Other ideas suggested included obtaining records of all food purchased, pantry inventories, and taking pre/post pictures with cell phones of a child's plate at meal time. However, each of these suggestions has drawbacks.

Determinants of Adolescent Exercise Behavior: Toward Evidence-based Intervention

Eco De Geus, PhD, Professor of Biological Psychology, University Amsterdam

This project is a collaboration among the Principal Investigator, Dr. James Hudziak, and his colleagues, Drs. Eco de Geus and Meike Bartels.

Healthy lifestyle promotion strategies are becoming a cornerstone of medical health. Regular leisure time exercise is a key target for intervention, yet there is a major drop in leisure time exercise during adolescence in both the United States and the Netherlands. At the same time, there is a sharp increase in the role of biological determinants of exercise. Understanding the biology of exercise behavior will allow for the creation of more effective interventions to engage adolescents in leisure time exercise behavior.

Causes of Individual Differences in Voluntary Exercise Behavior

The first specific aim of the study is to determine the causes of individual differences in voluntary exercise behavior from childhood to young adulthood and includes plans to quantify the sex-specific contribution of heritable and shared and non-shared environmental factors to stability and change of adolescent exercise behavior in twins, aged 7 to 18. A critical goal of the grant is to understand the relative contribution of heritable and shared/non-shared environmental factors that influence exercise behavior.

The investigators are using the Netherlands Twin Registry of 175,000 members of twin families to address aim 1. It is a population-based sample and fairly representative of the Netherlands, with the exception of some underrepresentation of low-income groups. Both identical (monozygotic) and fraternal (dizygotic) twins are included in the registry. The within pairs similarity of each type of twin is examined to determine genetic influences and shared and unique environmental influences using structural equation modeling. The trait being measured by parent and child report is the voluntary behavior of leisure time exercise.

Preliminary findings suggest that genetics plays an important role in childhood and early adolescence for determining leisure time exercise behavior. Dr. de Geus developed a model of the heritability of leisure time exercise behavior.[13] Genetics influence exercise ability and repeated acute mood effects. For some, the appetitive effects will outweigh the aversive effects, which fuels repeating the exercise behavior. For others, the aversive effects outweigh the appetitive effects and the person is unlikely to repeat the behavior. There are huge individual differences in exercise ability, and, because people like to do what they are good at, these differences in ability may lead to differences in exercise motivation. Ultimately, genetic variation influences exercise behavior and possibly indirectly influences positive affect and self-esteem.

[13] de Geus, E. J. C., & de Moor, M. H. M. (2008). A genetic perspective on the association between exercise and mental health. *Mental Health and Physical Activity, 1*, 53-61.

Individual Differences and the Psychological Response to Exercise Are Major Factors

The second specific aim of the study is to test the hypothesis that individual differences in exercise ability and the psychological response to exercise are the major factors underlying heritability of adolescent exercise behavior. Plans include using a subsample of twins to establish the heritability of the acute psychological responses during and after a standardized exercise protocol. A laboratory protocol is being used to assess this aim. Non-exercising and regularly exercising participants were deliberately included in the sample. The protocol includes lifestyle interview, resting baseline, bicycling, treadmill exercise, and an all-out test (with rest time after each activity). The all-out test records maximal oxygen consumption (VO_2max). Participants wear a monitor to ensure they do not pass an anabolic threshold and answer questions about emotions during the physical activity. Exercise ability is assessed with tests of balance, flexibility, hand grip strength, and vertical jump strength. A pilot study of 27 non-exercisers and 18 regular exercisers confirmed feasibility of the protocol. The next step is to complete the laboratory protocol with 250 twin pairs and their siblings.

The University of Vermont and the Netherlands Twin Registry also collaborate on a grant from the National Institute of Mental Health (NIMH, RC2 MH089995) that provides genome-wide SNP/CNV data and known functional variants in selected candidate genes (n=~4,700). Even without establishing heritability, the investigators can speculate about the kind of genes that involve the dopaminergic reward system. People may differ neurobiologically in that some may derive more reward from exercising than others. Combining resources from the NIMH and SOBC grants has allowed the investigators to couple functional variants in nine dopaminergic genes (COMT, DBH, MAOA, DAT1, and DRD1-5) to leisure time exercise behavior in three twin family cohorts (joint sample n=2,013). Preliminary results do not indicate an association between the variants and leisure time exercise; however, the findings may be able to inform prevention strategies.

Implications

Results from the twin studies confirm the importance of the common environment in childhood and early adolescence and suggest the viability of a family-based approach. Parents could be targeted in childhood and peers could be targeted in adolescence. For adolescents and adults, optimizing the acute affective response to exercise activities seems a viable strategy to increase exercise participation. Individual differences in optimal exercise intensity should be expected and allowed across all ages; the key is not to stress the system beyond an individual's ventilator threshold. Individual competition should be de-emphasized, especially for adolescents, and the performance of the group should be emphasized. It is possible that a gene-based prediction chip could be developed to provide information on who will feel good immediately from exercise, who will need a long time to recover, who should not exercise when stressed, etc.

Question and Answer

The team is not yet collecting temporal discounting measures, which may be relevant in terms of delayed gratification of exercise (i.e., suffer in the beginning but recognize results later). Attitudes appear to be highly correlated to behavior, but it is unclear what is driving this correlation: do attitudes change because of exercise or is exercise used to change attitudes?

Understanding what is driving the association will be addressed in a bivariate analysis of ability and attitude in a large sample of twins.

It was noted that in some ways the acute exercise test study is an intervention. If participants' attention is drawn to the affective responses immediately following the exercise, then it may highlight something they were not aware of before. The results might be affected by how the tasks and questions are framed.

Poverty, Stress, and Discounting: A Potential Micro-mechanism for Behavior Change

Johannes Haushofer, PhD, Research Associate, University of Zurich

This project is motivated by conditions in developing countries, where people have low levels of health and education and poor life expectancy. About 1 billion people worldwide exist in such conditions. Over the past 15 years there has been a new movement within the field of development economics to apply randomized controlled trials (RCTs) to social policy.

For instance, the Poverty Action Lab reports cost-effectiveness as measured by additional years of student attendance per $100 spent for various interventions (providing information, health interventions, incentives/reduced costs). The largest gains came from providing information on returns in Madagascar and deworming at a school in Kenya. Like this one, many of the most successful interventions work through behavioral mechanisms.[14] These studies demonstrate small behavioral nudges can have large welfare effects.

This project is investigating behavioral/neurobiological consequences of poverty and whether or not the consequences exacerbate poverty. The working hypothesis is that there is a link between poverty and stress, and then a link between stress and economic behavior, which leads back to poverty. The project consists of several studies conducted both in the laboratory and the field.

Poverty and Stress: Weather Shocks and Cortisol

Weather shocks to a sample of farmers in Kenya are used in one part of this study to examine the link between poverty and stress. Rainfall data and cortisol samples are part of the data collection. Alcohol, tobacco, food, caffeine, miraa, physical labor, and time of day are controlled for. Findings indicate that a lack of rain raises cortisol levels and that cortisol levels reflect worries.

Poverty and Economic Preferences

In order to investigate whether poverty causally affects economic preferences, the study examines one particular economic characteristic of poverty—income shocks. Income shocks are

[14] Duflo, E., Kremer, M., & Robinson, J. (2009). Nudging farmers to use fertilizer: Evidence from Kenya. *National Bureau of Economic Research*, Working Paper 15131. Retrieved September 25, 2012, from www.nber.org/papers/w15131.
Kremer, M., Miguel, E., Leino, J., & Zwane, A. P. (2009). Spring cleaning: Rural water impacts, valuation, and property rights institutions. Working paper retrieved September 25, 2012, from http://www.econ.as.nyu.edu/docs/IO/11958/Kremer_20091103.pdf.

usually difficult to measure because of reverse causality and income effects. In a laboratory paradigm, negative income shocks can be randomly assigned while holding absolute income constant.

Before the experiment, participants are told that they may gain or lose points during the experiment, they cannot influence this, and that it will happen at most once. The participants engage in an effort task for 15 periods (counting 1s and 0s for an hour). After period 15, half of the participants either gain or lose points and a new income is given to them. The other half receives no message. The participants engage in a time preference task after period 17. Findings indicate that participants who experience negative income shocks have greater present bias. No difference was detected among participants who received positive income shocks. These findings suggest that negative income shocks—a typical feature of poverty—lead to present bias, thereby potentially further exacerbating poverty.

Poverty and Stress: Unconditional Cash Transfers

Increases in income and its impact on stress were examined in a separate RCT of unconditional cash transfers in Kenya. The RCT design included 500 control and 500 treatment households within 50 control and 50 treatment villages. There were four arms of the treatment. Half of the treatment households received a lump-sum cash transfer (half to male, half to female), and the other half of treatment households received a stream of payments over nine months (again half to male, half to female). Preliminary findings indicate a large effect on food security and expenditures. Those reporting having enough food in the house for tomorrow increased 30 percent. There were also large consumption effects. Next steps include examining the cortisol and psychological data.

Busara Center for Behavioral Economics

The goals of the Busara Center for Behavioral Economics, a laboratory being built in Nairobi, Kenya, in collaboration with Innovations for Poverty Action, is twofold: 1) from a behavioral economics perspective, the center will provide insights into behavior and preferences of participants who are not from Westernized, educated, industrialized, rich, democratic (WEIRD) backgrounds and 2) from a development economics perspective, the center will inform design before RCTs and identify channels after RCTs. Shifting the laboratory work from Switzerland to Kenya will make the behavioral economic findings more applicable to developing countries and ecologically valid.

The Busara Center uses text messages (there is a 95 percent penetration rate for cell phones in this area) to prompt the participant to visit the lab where they are identified via fingerprinting (effectively zero percent error rate). Participants are given a card that tells them where to go, receive a briefing, and participate in computer-based tasks using a touch screen. No reading skills are required. Work in the center is ongoing.

Question and Answer

The original variable used in the first poverty and stress study was the number of livestock that died due to drought. The measure of weather shocks was changed because of the potential endogeneity of the livestock death measure (e.g., a farmer may not be very good at taking care

of animals because he is stressed). Due to this endogeneity concern, it was determined that that rainfall would be a better measure.

There is very little causal data on cortisol and poverty. Some evidence from a conditional cash transfer program in Mexico suggests lower cortisol levels in children 2 years after the program. There is correlational evidence from the United States and other places but there are many inconsistencies. Results often depend on the time of day that the cortisol is collected. The results will need to be replicated.

No differences in alcohol consumption have been found between the men and women who receive the unconditional cash transfers.

Spillover effects between control and treatment villages in the unconditional cash transfers study are quantified in different ways. There is a village questionnaire, and other data are collected on the villages. The investigators will identify a few dimensions a priori for analyses of heterogeneous treatment effects (e.g., income, education).

Comparative Efficacy, Acceptance, and Effectiveness of Health Incentive Structures

Kathryn Saulsgiver, PhD, Research Project Manager, Center for Health Incentives and Behavioral Economics, University of Pennsylvania

Roughly 20 percent of Americans (46 million) smoke, and 75 percent of these smokers wish to quit. In a given year, 45 percent of smokers quit for at least one day. Despite the abundance of new pharmaceuticals, anti-smoking policies, and behavior modification programs, only 2 to 3 percent of smokers achieve sustained abstinence annually.

This project (PI: Dr. Scott Halpern) focuses on work-based cessation programs because they generally result in higher sustained abstinence rates, minimize start-up costs by building on existing infrastructure, are more sustainable than community-based programs, and are preferred by both smokers and non-smokers. The specific aims of this study are to 1) compare the efficacy and effectiveness of four financial incentive structures for improving "quit rates" (rates of prolonged smoking abstinence for 6 months); 2) compare smokers' acceptance of these four financial incentive structures for smoking cessation; and 3) identify individual characteristics that modify incentive structures' efficacy and acceptance.

Study Design

Beginning June 15, 2011, the team launched a pilot RCT among Walgreens employees at six sites comparing usual care with four incentive arms; the pilot was completed in May 2012. A full RCT among 2,185 CVS/Caremark employees was launched in February 2012 also comparing usual care with four incentive arms with equal expected value. A web-based research infrastructure, *Way to Health*, is being used for study coordination. Eligible participants are 18 years or older, smoke at least five cigarettes per day on most days, show some interest in learning about new ways to quit, are not using other forms of tobacco (cessation aids are

accepted), have access to the Internet, and must be an employee of CVS or a friend/family member of a CVS employee.

The usual care control arm is a *WebMD* smoking cessation program run through CVS in which participants can receive up to $160 in reimbursements for completing study-related tasks. The incentive structures are provided in addition to the incentives provided through the usual care arm (i.e., in addition to the $160 that can be received for completing tasks). The treatment arms include individual contingencies (individual rewards and fixed deposit) and group contingencies (collaborative rewards and competitive deposit). The payout schemes are as follows:

1. Individual rewards: incentive payments of up to $800 in addition to the $160 if smoking cessation is sustained for 12 months.
2. Fixed deposit: submit $150 deposit, opportunity to earn back the deposit and gain up to $650 reward in addition to the $160 if smoking cessation is sustained for 12 months.
3. Collaborative rewards: earn $100 for each member of your group who quits smoking, up to $2,000, in addition to the $160; opportunity to encourage group members via social media.
4. Competitive deposit: six group members submit $150 deposit ($3,600 total) and those who quit will share the $3,600 equally in addition to the $160; no interaction among group members.

Exposure measures to be collected at intake and some throughout the study include demographics, smoking behaviors, use of pharmacologic aids, smoking history, retail versus distribution center, stage of change, substitute reinforcers, complementary reinforcers, and time-discounting function. Outcome variables include incentive acceptance, reported smoking cessation, and cotinine/anatabine/anabasine.

Pilot Study Results

During the pilot study the investigators were able to validate testing and collection/shipment procedures for saliva cotinine test strips, and ambulatory urine collection. They also were able to identify ways to improve recruitment. Changes to the recruitment strategy included using a comprehensive rather than targeted recruitment pool with random pre-testing to confirm smoking status, reducing the deposit amount from $250 to $150, increasing the baseline survey payment to $50, and extending the time frame in which participants can select a quit date. The recruitment strategy includes 16 methods of contact over nine weeks.

Adaptive Randomization

The refined recruitment strategies have resulted in 3,060 accounts being created on the recruitment website. Of those, 922 participants are enrolled in the control or treatment groups, 690 participants rejected the intervention offered to them and are enrolled in the dropout arm (identical to usual care control arm), and 1,111 participants have not completed enrollment. The remaining 337 individuals were deemed ineligible.

In order to assess and compare smokers' acceptance of the four financial incentive structures (aim 2), an adaptive randomization system is being used to assign participants to treatment groups. The study is designed to examine incentive programs' comparative acceptance without undermining the study efficacy through loss of power. The probability of being assigned to one of the incentive arms changes based on how many people accept or reject assignment (i.e., if fewer people say yes to fixed deposit, more participants are randomly offered fixed deposit in the next round). The adaptive randomization has been revised to minimize the dropout rate. There is an 80 percent chance of being assigned to control or reward arms and a 20 percent chance of being assigned to one of the deposit arms; within each of these groups, there is adaptive randomization.

The differences in acceptance rates were highly significant and confirmed the hypothesis that deposit contracts are not as desirable as incentives in the form of pure rewards: 96 percent accepted individual rewards, 87 percent accepted collaborative rewards, 22 percent accepted fixed deposit, and 27 percent accepted competitive deposit.

Question and Answer

Any of these incentive structures would be fairly expensive for a workplace to support. The idea is that the company would recoup substantial savings in health insurance costs. The goal of this project is to identify the incentive structure that works best (deposit versus rewards) and then identify ways to scale it down for a particular employer.

Using Media to Explore Mechanisms of Behavior Change among College Students

Megan Moreno, MD, MPH, Assistant Professor of Pediatrics, University of Wisconsin-Madison

Social media provides an opportunity to learn more about adolescent health behaviors and to explore the possibility that social media can be used as a medium for healthful messages. More than 90 percent of college students use Facebook, and they frequently reference and display alcohol and substance abuse online. Alcohol and substance use are among the top causes of morbidity and mortality in college students. In a previous R21 study funded by the National Institute on Alcohol Abuse and Alcoholism (NIAAA), Dr. Moreno found that display of intoxication or problem drinking references on Facebook was positively associated with self-reported problem drinking behaviors through clinical screening. Facebook might present new opportunities for investigation, screening, and prevention.

The specific aims of this project are to 1) test the predictive value of references to alcohol, drugs, and tobacco displayed on Facebook profiles for identifying substance use intention, use, and misuse; 2) test a provisional model of Facebook as a mediator of behavior change; and 3) as an exploratory aim, investigate methods by which Facebook can be used as an intervention tool among college students. Updates on aims 1 and 2 were presented.

Predictive Validity of Displayed References to Alcohol and Substance Use

The objective of aim 1 is to determine the predictive validity of displayed references to alcohol and substance use on college students' Facebook profiles throughout their college experience.

Participants from the freshman 2011 cohort were drawn from two college campuses using registrar lists from both schools. Recruitment was completed in the summer of 2011.

The data collection is intended to measure attitudes, intentions, and behaviors. Data collection includes a baseline telephone interview and an initial Facebook profile coding. Ongoing data collection includes monthly Facebook profile evaluations, summer interviews of all participants, and change interviews conducted over the phone that are triggered by Facebook content (e.g., increase in reference to alcohol) and completed within 28 days of the change.

The Facebook profile evaluation includes coding displays of alcohol use and intoxication or problem drinking behavior. The evaluation also codes for the top 10 substances used by college students including marijuana, tobacco, hallucinogens, and prescription drugs. References to drinking alcohol in the past, present, or plans to do so in the future and pictures showing the student drinking from a clearly labeled alcoholic beverage are coded as alcohol displays. Intoxication is coded when there are references to being drunk, wasted, or hung over. Problem drinking references are coded using the CRAFFT Screening Test (car, relax, alone, forget, friends, trouble) and includes references to drinking alone, drinking and driving, forgetting/blacking out, getting into trouble, or getting arrested.

The baseline data were collected before the students arrived to campus. At baseline, 20 percent of the students displayed alcohol and 10 percent displayed substance use (most commonly marijuana, prescription drugs, cocaine, LSD, and ecstasy) on Facebook. By the end of finals week of freshman year (year 1), displays of alcohol use more than doubled and displays of substance use doubled. One of the two college campuses accounted for 80 percent of the increase. There was a lot of variability in the substance use data.

Attrition and missing data have been minimal. One participant permanently deleted the Facebook account, and seven others deactivated their accounts. The investigators conducted an interview about why the accounts were deactivated; most were done so temporarily. The investigators have had a 95 percent success rate in conducting change interviews within the 28-day period and have used 28-day timeline follow back and other questions to assess the role of Facebook in behavior change and decision making. Preliminary results suggest that students use Facebook to make comparisons to high school peers and participate in the college community. A strong theme in the interviews has been the concern of missing out. Facebook and alcohol are part of the college experience, as they perceive it, and this prompts students to constantly check social media to ensure they are not missing a party or other social gathering.

Preliminary results suggest a few early conclusions. Facebook profiles from both colleges looked similar at baseline. The students from one college outpaced the other in displays of alcohol throughout freshman year. Vignettes presented to the students during the change interviews suggest peer pressure is initially most prominent in person (as opposed to through social media) and there is a higher susceptibility by males and toward alcohol.

The team is conducting summer interviews and will soon have one year of data for pre-college, Facebook data for the freshman year, and the summer interview data. Half of the participants have had a change interview during their freshman year. At this point there are few data on the students who choose not to display alcohol or substance use on Facebook. Next steps include evaluating the changes between baseline attitudes, intentions, and behaviors as well as the distribution of Facebook references across the freshman year.

Provisional Model of Facebook as a Mediator of Behavior Change

The development of a provisional model of Facebook and its role as a mediator of behavior change started with a qualitative assessment including a concept mapping exercise with a purposeful sample of participants selected from across a wide range of student organizations. The focus groups were tasked with brainstorming a list of things on Facebook they think would influence someone. This process generated 600 unique aspects of Facebook. Another focus group was recruited to sort and rank these items, which resulted in a refined list of 150 items. Participants then created a conceptual map by ranking what they felt were most influential. Several themes emerged from the focus group data such as identity development, comparisons to others, connection to past and current groups, and use of Facebook as a unique experience. It appears that students at different stages in college use it in different ways. The investigators are between the analysis and interpretation stages of this part of the project.

Question and Answer

It was noted that one of the colleges studied is known for its drinking culture, and it seemed somewhat surprising to see such an increase in alcohol displays among students at this college during the freshman year. Dr. Moreno clarified that the baseline measures were not of reported alcohol use, but only Facebook displays of use. There appears to be something about the college experience that induces students to display alcohol use via social media more. She has added some questions to the interviews about first drinking experiences to try to collect some information about exposure and attitudes. In the state where this college is located, children under the age of 21 are allowed to drink with their parents.

Participants were asked at baseline about their security and privacy settings on Facebook. The investigators have found that the students are often confused about privacy settings. Typical actions found in previous studies include blocking ex-girlfriends and boyfriends and blocking or removing pictures as they move closer to graduation.

Facebook advertising may be an inexpensive untapped resource for providing positive cues. It is not clear at this point how social media could frame a message about alcohol given the level of social acceptance in the same way that applications have been designed around encouraging fitness and sharing the results (e.g., Nike Plus). It was noted that there are a lot of applications available for fitness promotion but not for deterring substance abuse; it does not appear as though the effectiveness of these types of applications is being evaluated.

The investigators gain access to the participant profiles by friending potential participants through a research assistant's account. Part of the agreement includes that the research

assistant will not post anything on the participants' walls. Analysis of the participants' networks might be something to pursue in the future.

Behavioral Economics and the Demand for Alcohol

Henry Saffer, PhD, Research Associate, National Bureau of Economic Research

Prior economic studies of alcohol advertising have measured an average population effect of advertising with mixed results. Industry has used these weak or mixed effects findings to resist change in policies on advertising. The empirical model used in this study is based on a blend of neuroeconomic theory, behavioral economics, and neoclassical economics. The model poses that higher past alcohol consumption will decrease the effect of price and increase the effect of cues on behavior. Cues refer to alcohol advertising on television and in retail outlets. A key underlying construct in this model is that the effect of an addictive substance on the forecast of hedonic pleasure, rather than on hedonic pleasure itself, holds the key to understanding the role of cues on alcohol consumption.

The theory asserts that a consumption decision is a result of a balance between two neurological systems (dual agent model): the heuristic system and the rational system. The heuristic system is fast and efficient at learning simple action-reward correlations but can only incorporate a limited range of near-term consequences. The heuristic system learns about the desirability (reward) of a good from the consumption experience. The heuristic system is based on behavioral economics. The rational system, in contrast, develops causal models of the world and reasons out the implications of different choices but requires time and effort to make a choice. The rational system is based on neoclassical economic theory.

The Effect of Cues

The key to understanding the role of cues on alcohol consumption is that the effect of an addictive substance is on the forecast of the reward, not the actual reward. When a participant is presented with a cue followed by a reward in laboratory experiments, a reinforcing dopamine process occurs in response to the reward. However, as the experience with the reward continues, the dopamine process occurs in response to the cue rather than the reward. The dopamine response to the cue gradually increases when the reward is increased but the cue remains constant. The implication of this phenomenon is that the heuristic system forecasts a reward proportional to past consumption rather than proportional to the level of the cue. The same cue will produce a greater response in heavy consumers than light consumers. The rational system can be engaged to exercise self-regulation to override the heuristic system.

A simplified econometric model was created to predict the effect of price on consumption as a function of the weight given to the heuristic and rational systems based on cues, past consumption, self-regulation, and price. The equations predict that an increase in past consumption will offset the negative effect of price on consumption, an increase in past consumption will increase the effect of cues on consumption, and the higher levels of past consumption will increase the negative effect of self-regulation.

Estimation of the Model

Data from 2002-2009 taken from National Longitudinal Survey of Youth 1997 (NLSY97) were used to estimate the model. Data from national local television advertising and alcohol prices by time frame and geographic location also were used. Education is used as a proxy for self-regulation because individuals who are better able to self-regulate have been shown to achieve higher levels of education.

Different methods were used to address estimation issues. Past consumption cannot be used as an independent variable because it would result in bias. However, current consumption is highly correlated with past consumption and thus an adequate ordinal proxy for past consumption. Therefore, the effects of cues and prices are measured at different levels of current consumption. The estimation models used included finite mixture models and quantile estimation. Finite mixture models allow for more than one underlying distribution and heterogeneous groups in the population. Quantile estimation is a variation of ordinary least squares and can estimate parameters at different points of the distribution. Both methods bypass endogenous selection problems because the overall sample does not need to be portioned.

The preliminary results of the estimation model are consistent with previous studies of alcohol price. The finite mixture model produced two components: heavy drinkers and moderate drinkers. Findings indicate that heavy drinkers are more responsive to advertising and less responsive to price than moderate drinkers. There is a larger negative effect of education for heavy drinkers, which suggests that education is a good proxy for self-regulation. When state dummy variables were added to the model the state effects wash out the price variable. This occurs because the price data have little time variation and are aggregated to the state level.

Implications and Next Steps

Restrictions on alcohol advertising are an underused public policy tool. Because heavy drinkers are more responsive to cues and less responsive to price, policies that limit external cues, such as TV advertising, are targeted at heavy drinkers, while price and excise tax policies are targeted at moderate drinkers. Education has a negative effect on consumption, and this effect is greater at higher levels of past consumption. These results support the novel assertion that education is a proxy for self-regulation.

Next steps include estimating the model using data from the National Longitudinal Survey of Youth 1979. This dataset includes additional data on television watching and personality, including measures of locus of control, self-esteem, and depression. These data may allow for better control of heterogeneity and effects of self-regulation.

Question and Answer

The effect of price drops out when fixed effects (state and time dummies) are added to the model. Dr. Saffer noted that prior studies have shown that price exclusive of tax tends to be the same across states, but the state taxes vary. State tax is determined by local policy, and the

assumption is that the taxes are driving the price variation. This approach has been used in many prior studies of alcohol demand.

Dr. Saffer has conducted cross-national work on this topic as well on 21 Organisation for Economic Co-operation and Development (OECD) countries to look at advertising bans and price measures. The results indicate the usual negative price effects. Countries with higher tax rates have low alcohol consumption, holding other variables constant.

Integrating Keynote: Looking Forward

James Hudziak, MD, Professor of Psychiatry, Medicine, and Pediatrics, University of Vermont

Dr. Hudziak presented a philosophy of thinking that puts behavioral change at the center of health care and health care reform. All health emerges from behavioral health. Programs such as the SOBC and OppNet should be viewed as driving health care reform. The basic science of behavior change should be closely linked to planning policy. Advocacy, policy, and education serve as the vehicles for healthy behavior maintenance. The projects presented during the meeting address various aspects of behavior change at various stages.

"New" sciences of behavior change offer multiple opportunities to advance knowledge in this area. Advances in neuroimaging show that behavior change is linked to reductionist changes in the brain function and form. Advances in genomics provide opportunities for personalized medicine, which can be informed by the evidence base being built by these projects. Neuroimaging and genomics technology should be used to develop evidence-based arguments that support the critical role of behavior change in health care. These new scientific strategies should be used to test models across phenotypes in the laboratory, through epigenetics, and among extreme populations; assess the role and implications of individual differences; and develop economic models.

Translation

There is too great a time lag between building the evidence base and translating the information into education, action, and interventions. Behavioral change can be taught through a developmental approach to education. New information, approaches, and technologies can be used to demonstrate and teach about behavioral change across a wide range of settings (e.g., K-12 education, college, medical school, residencies, and continuing education for health care professionals).

Individual Differences

Individual differences may play a much larger role in behavior change than previously thought. The methodologies used by researchers working on behavior change must complement each other in order to advance a unified science of behavior change and understand individual differences (e.g., high-risk studies, population-based studies, imaging studies).

For example, neuroimaging studies of monozygotic (identical) twins can inform the biological basis of individual differences. Despite Attention Deficit Hyperactivity Disorder (ADHD) being highly heritable, it is not perfectly concordant between monozygotic twins and brain scans show subtle differences between them. Multiple phenotypes can emerge from a common genotype. Researchers should collaborate across the United States and internationally to develop massive samples and ask common questions across cultures to contribute to a unified science of behavior change.

Learning from Others

There are many lessons on behavior change to be learned from other cultures and programs. The El Sistema program in Venezuela was instituted by the government beginning in 1977. This National System of Youth and Children's Orchestras has provided more than 2 million children ages 3 to 19 with training in music. Studies have shown that 63 percent of participants have good or excellent achievement in school compared to 50 percent of students not in the program. The program also has resulted in decreased rates of school dropouts and crime, leading to savings for the government. The program has been modified and adopted in South Dakota, Vermont, and Scotland. Other wellness program examples include those targeting obesity through diet and exercise at school.

Funding and Policy

Basic science and behavior change intervention research needs to be better funded. Strategies could include partnering with economists; partnering with well-affiliated hospitals; increasing research and training grant awards; tapping into projects such as Clinical Translational Science Awards (CTSAs) by writing applications focused on behavior change approaches; focusing on advancing science of personalized medicine; and contracting with outside funding agencies.

Behavior change scientists need to be more involved in influencing policy by participating in committees and working with government agencies to translate and inform others about the growing knowledge base. Health care reform is about health promotion, illness prevention, and behavior change as interventions. NIH and programs such as the SOBC and OppNet could create shared databases of behavior change science across a range of topical areas and populations to inform others and influence policy.

Collaboration Is the Key

To build a unified science of behavior change and create an evidence base that will inform interventions and policy, researchers across multiple disciplines need to be highly collaborative in research, teaching, and patient care: neurosciences; psychology; public health, nursing and primary care; economics; genomics/neuroimaging; and patient and family perspectives.

Question and Answer

Dr. Hudziak described how cooperation was obtained by the participating school systems in Vermont and South Dakota for the wellness programs modeled, in part, after El Sistema. The investigators sought cooperation from school boards and principals and focused on the most disadvantaged student populations. The program uses family wellness coaches and gains buy-in and participation from parents by first helping their children.

Economic analysis was used to model effectiveness and engender support from school systems. For example, work by Dr. James Heckman models savings based on early education dollars spent and the reduction of crime-related and other social costs.[15] In Dr. Hudziak's experience, school systems want programs with evidence of effectiveness. It was noted that the choice of violin is particularly effective because it involves self-regulation, emotion regulation, and other important processes.

General Discussion

It was suggested that alternate meeting formats be explored for future SOBC annual meetings of investigators. Suggestions included a more active agenda involving problem solving, brainstorming, focus groups, or other collaborative discussion sessions; engaging other stakeholders such as policymakers, agencies, or schools; and joining the annual meeting with the grantees of another RFA such as OppNet's *Basic Research on Self-Regulation* (RFA-AG-11-010).

Strategies for optimizing the multidisciplinary nature of the SOBC grantee projects also were discussed. For example, outside presenters could be invited to provide overview talks about the state of the field (similar to what invited speakers did during the first annual meeting of investigators); participants could be provided background reading prior to the meeting; or panels of discussants could address translation needs following groups of grantee presentations. Most were in agreement that there is something to be gained from the breadth as well as the depth of the work presented. Others noted that presenting research content in such a way that educated lay people can understand is a desirable skill and the annual meeting provides a good forum in which to practice.

The next SOBC Annual Meeting of Investigators is scheduled for June 20-21, 2013, in Bethesda, Maryland, on the NIH main campus. The SOBC Working Group and Annual Meeting organizers welcome further input from the grantees on the format of the next meeting via email or future conversations.

[15] Heckman, J. J. (2008). The economics of inequality: The value of early childhood education. *American Educator*, *35*, 31-35, 47. Retrieved August 27, 2012, from http://www.aft.org/pdfs/americaneducator/spring2011/Heckman.pdf.

Agenda

Annual Meeting of Investigators
Science of Behavior Change Common Fund and OppNet
National Institutes of Health
June 20-21, 2012

June 20 (Wednesday)

8:00 a.m.	**REGISTRATION CHECK-IN**	
8:30 a.m.	**WELCOME REMARKS**	Patricia Grady, Richard Hodes, Richard Suzman
	SCIENCE OF BEHAVIOR CHANGE I Moderator, Jonathan King	
8:45 a.m.	*Emotions and choice: Mechanisms of behavior change*	Elizabeth Phelps
9:10 a.m.	*Affective and genomic mediators of sustained behavior change*	Sara Algoe
9:35 a.m.	**Question and Answer**	
9:50 a.m.	**BREAK**	
	BASIC MECHANISMS INFLUENCING BEHAVIORAL MAINTENANCE I Moderator, Minda Lynch	
10:10 a.m.	*Characterizing habitual and goal-directed behavioral control systems in the human brain using computational and multivariate fMRI*	John O'Doherty
10:40 a.m.	*Overcoming the persistence of first-learned habits to maintain behavioral change*	Tom Schonberg
11:10 a.m.	**Question and Answer**	
11:30 a.m.	**LUNCH** *Neuroscience Center Building Cafeteria*	

BASIC MECHANISMS INFLUENCING BEHAVIORAL MAINTENANCE II
Moderator, Minda Lynch

12:45 p.m.	*Neural mechanisms of habit formation and maintenance*	Henry Yin
1:15 p.m.	*Goals versus habits in the human brain: Cognitive and computational mechanisms*	Daphna Shohamy
1:45 a.m.	**Question and Answer**	

INTEGRATION

2:00 p.m.	*Linking mechanisms of behavioral change and long-term behavioral maintenance*	John O'Doherty
2:30 p.m.	**Discussion**	
3:00 p.m.	**BREAK**	

SCIENCE OF BEHAVIOR CHANGE II
Moderator, Lois Tully

3:30 p.m.	*Self-regulation as a biological mechanism for excess weight gain in toddlers*	Julie Lumeng and Alison Miller
3:55 p.m.	*Determinants of adolescent exercise behavior: Toward evidence-based intervention*	Eco de Geus
4:20 p.m.	**Question and Answer/Discussion**	
5:00 p.m.	**ADJOURN**	
6:00 p.m.	**NETWORKING DINNER** *The Meritage Restaurant, Bethesda North Marriott Hotel & Conference Center*	

June 21 (Thursday)

8:30 a.m.	**INTRODUCTION**	Jonathan King
	SCIENCE OF BEHAVIOR CHANGE III Moderator, Lisa Onken	
8:45 a.m.	*Poverty, stress, and discounting: A potential micro-mechanism for behavior change*	Johannes Haushofer
9:10 a.m.	*Comparative efficacy, acceptance, and effectiveness of health incentive structures*	Kathryn Saulsgiver
9:35 a.m.	**BREAK**	
9:55 a.m.	*Using media to explore mechanisms of behavior change among college students*	Megan Moreno
10:20 a.m.	*Neuroeconomics and alcohol control policy*	Henry Saffer
10:45 a.m.	**Question and Answer**	
	INTEGRATION	
11:00 a.m.	*Looking forward*	James Hudziak
11:30 a.m.	**Discussion**	
12:15 p.m.	**ADJOURN**	

Participant List

Annual Meeting of Investigators
Science of Behavior Change Common Fund and OppNet
National Institutes of Health
June 20-21, 2012

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