

Carnegie Mellon University

Annual Progress Report: 2007 Formula Grant

Reporting Period

July 1, 2010 – June 30, 2011

Formula Grant Overview

The Carnegie Mellon University received \$710,806 in formula funds for the grant award period January 1, 2008 through June 30, 2011. Accomplishments for the reporting period are described below.

Research Project 1: Project Title and Purpose

Toward Automated Collection of Falls Risk Data in Elder Care Environments - The purpose of this project is to develop an integrated system of computer-based instrumentation for collecting datasets of vital signs and biomechanical parameters in older adults. Through creation and deployment of a prototype, we will also explore usability and acceptance of such a measurement approach to older adults and clinicians who work in long term care settings. This project supports a pilot study, the goal of which is to study health reporting mechanisms of independent living campus and assisted living facility residents.

Duration of Project

5/14/2009 – 6/30/2011

Project Overview

The work plan is to investigate the viability of sensors and recording equipment for collecting data on health parameters of senior citizens in long term care (LTC) facilities. An integrated system, or “health kiosk”, consisting of an interactive console with attachments that measure weight, blood pressure, pulse rate, blood glucose and blood oxygenation, complemented with additional sensors that measure biomechanical parameters of walking and balance will create a computer-based record of all those parameters for a population of LTC residents. In this project we will design, build and evaluate the health kiosk in a real LTC environment. The interdisciplinary development team will include specialists in nursing, physical therapy, occupational therapy, biomedical engineering, human computer interaction, computer science and industrial design, as well as several older adults.

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Expected Research Outcomes and Benefits

This project addresses health management of older adults and will provide insights into their acceptance of and ability to use telehealth and related electronic means of acquiring health data. Of particular interest are data that may be related to risk of falling, which is the leading cause of injury among older adults. The expected outputs are 1) a design for a health kiosk for semi-automatic collection of vital signs and biomechanical data and 2) a fully functional prototype of the health kiosk.

In a companion project outside of this grant, acquired data will be analyzed using data mining techniques to explore relationships of parameters measured in the health kiosk and actual occurrence of falls. This research will also illuminate issues of cost, utility and fit of semi-automated health data collection into the overall schemes for health management of long term care facility residents.

We expect that this initial research will demonstrate that computerized data collection of older adults' health data is an acceptable and more cost-effective approach than current practice.

Summary of Research Completed

Based on user feedback during the last reporting period, a contemporary and intuitive user interface with some personalized capabilities was designed (Figure 1). The software's functionality was also extended. In addition to displaying metrics that have been customized by a user's clinician, other new features include messaging between users and clinicians and fingerprint authentication. Finally, this second generation application has been designed to be much more robust to withstand the demanding use cases suggested by the kiosk model and our user base. Over the course of the year, this new design and feature set was implemented and subjected user testing.

Feedback to users and clinicians about measurement results is provided, as well as graphical representation of the user's sensor readings for specific time periods. One key element of the new user interface is its visualization of measurement results. Rather than relying on an individual's interpretation of numerical results, we have added graphical and intuitively simple displays in addition to numbers (Figures 2 and 3). This same approach carries over into the user's view of their measurement history (Figure 4).

In October 2010, this new user interface was approved by our community coordinator and we had multiple elderly individuals further refine the design and suggest improvements in the lab. A brief but intense phase of community user testing occurred in March 2011, when a kiosk was stationed in each of four locations for a day while 10-12 residents evaluated the system's interface and functionality. These studies have confirmed the fundamental usability and utility of the health kiosk and have positioned us to begin long-term pilot testing in several locations.

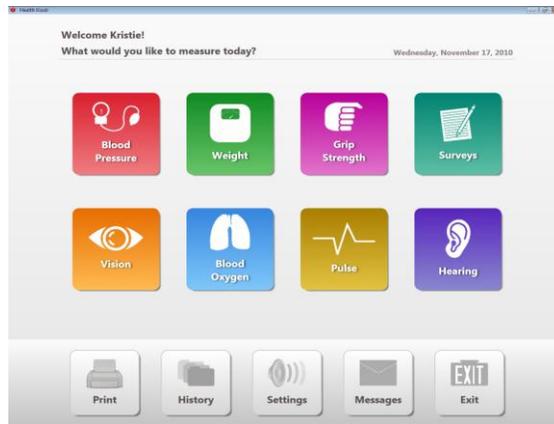


Figure 1: Main Screen

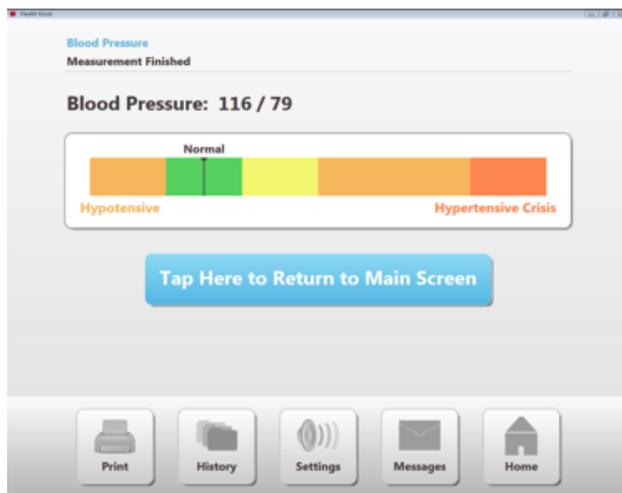


Figure 2: Blood Pressure Result

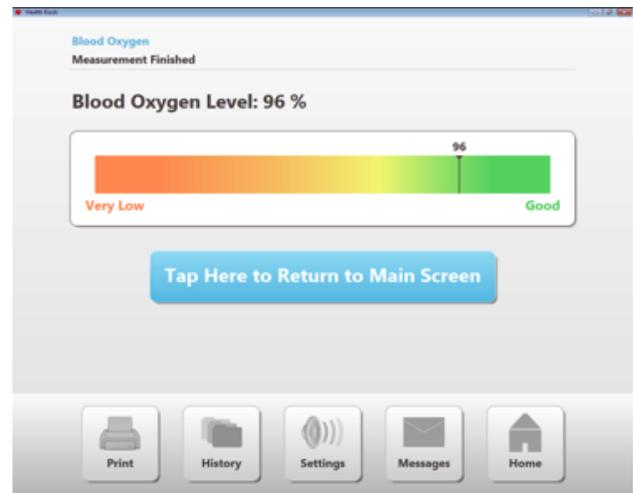


Figure 3: Blood Oxygen Result

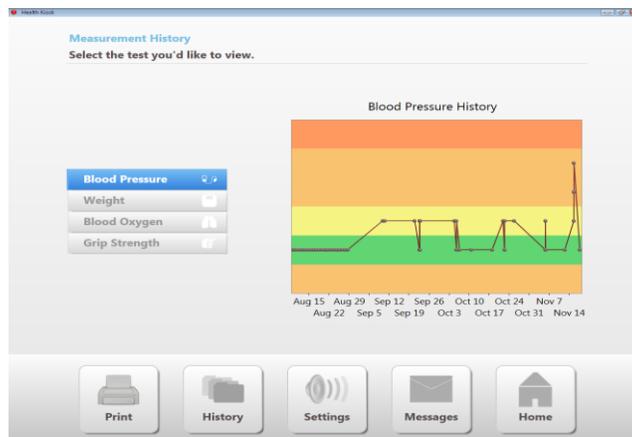


Figure 4 Blood Pressure History

Research Project 2: Project Title and Purpose

Computational and Neural Mechanisms of Lexical Processing - The purpose of this project is to use computational modeling with artificial neural networks, combined with coordinated behavioral studies, to elucidate the cognitive and neural mechanisms underlying how written and spoken words are understood and produced by the brain. The research examines and attempts to explain how reading and language skills develop in children both normally and in those failing to achieve age-appropriate skills; how they operate in neurologically intact adults and how they may be impaired as a result of brain damage; and, when impaired, how they might best be remediated. The results should lead to improvements in both educational and clinical practice.

Duration of Project

7/1/2008 – 6/30/2011

Project Overview

Words play a central role in language, and deficits in lexical processing—either in development or as a result of brain injury—can have a devastating impact on an individual's ability to lead a full, productive life. Substantial progress has been made in understanding the cognitive and neural basis of lexical processing through coordinated empirical and theoretical methodologies. Computational modeling using artificial neural networks, also called connectionist modeling, has played a key role in this process by providing a computational formalism that is sufficiently rich to capture the complexity of human behavior while also making direct contact with neural mechanisms. A central focus of the research is to work towards the development of realistic-scale, longitudinal connectionist simulations of lexical processing, spanning pre-literate phonological and lexical acquisition, reading acquisition and developmental dyslexia in children, and normal and impaired word reading and morphological processing in adults. Although existing connectionist models in these domains vary considerably in their details, they all draw on the same general computational principles whose implications dovetail nicely with common themes that run across the empirical domains. Developing comprehensive simulations of lexical processing that account for the full range of relevant findings is not only feasible but critical to capturing this commonality among domains. The computational work will be tightly coordinated with human behavioral studies to provide empirical support for various theoretical commitments, to constrain and inform design decisions in model development, and to test key predictions of the models. The project has three specific aims. The first is to develop a connectionist simulation of the core empirical phenomena related to skilled word reading, to reproduce the major forms of acquired dyslexia by damaging the simulation in ways analogous to brain damage, and to explore strategies for rehabilitation by retraining the simulation following damage. The second aim is to model how phonological development impacts normal reading acquisition and how interventions during reading acquisition might prevent or ameliorate developmental dyslexia. The third aim is to extend connectionist modeling of word reading into a more comprehensive account of lexical processing by addressing core phenomena related to inflectional and derivational morphology. The results should lead to improvements in both educational and clinical practice.

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Expected Research Outcomes and Benefits

The research is directed at providing an explicit, mechanistic account—in the form of working computer simulations—of the cognitive and neural mechanisms underlying reading and language at the single-word level, including how these mechanisms develop in children under normal circumstances and when children fail to acquire age-appropriate skills; how they operate in neurologically intact adults; how they may be impaired as a result of brain damage, and how they might best be remediated following damage. The results of the research will thus have important implications both for educational practice concerning reading acquisition and for clinical practice for remediation of cognitive deficits following brain damage. With regard to reading instruction, pedagogical practice has vacillated between "whole-word" versus "phonics" instruction without a sound theoretical foundation for understanding what each contributes to the underlying emerging cognitive processes. The current research provides an explicit, mechanistic framework for evaluating alternative reading instruction paradigms. With regard to cognitive rehabilitation, a key consideration in designing therapy is how to induce the most general degree of recovery given the necessarily limited time and resources that can be devoted to direct intervention. The current research illustrates how computational modeling of cognitive and neural processes can play a central role in exploring the implications of alternative approaches to remediation, providing firm theoretical grounding for understanding the variability in recovery among patients, and generating testable hypotheses concerning effective intervention.

Summary of Research Completed

Semantic ambiguity effects. We have continued our work on understanding the temporal dynamics of cooperation and competition in comprehending semantically ambiguous words. Past work has documented contrasting patterns of performance in different tasks: lexical decision produces an advantage for words with multiple related meanings (polysemy) whereas semantic categorization produced a disadvantage for words with multiple unrelated meanings (homonymy). Previously we have argued that these task differences can be explained in terms of the settling dynamics of semantic coding within a distributed network, supporting our account with a connectionist model of word comprehension, and a lexical decision experiment in which

the difficulty of the task was varied. The results showed that increasing the degree of semantic coding alone produces results similar to those observed in different tasks.

Follow-up analyses of our data as well as those of other researchers using more sophisticated techniques, including multilevel mixed-effects modeling, have indicated that some of the putative effects of semantic ambiguity are contaminated by confounds with lexical frequency and familiarity, and may be further weakened by poor measures of meaning and sense dominance (i.e., the relative frequencies of alternatives). We have carried out corpus-based analyses and have gathered and analyzed ratings data from subjects, and used these to develop a new stimulus set that avoids these pitfalls. In addition, the ratings analyses have revealed important limitations with commonly used existing ratings, and we are in the process of preparing a journal article for publication that reports on these analyses and comparisons.

We used the new stimulus set to replicate, clarify, and extend of our previous findings. In particular, we employed reduced contrast (stimulus quality) as a means of slowing lexical processing (thereby increasing the relative contribution of semantics). Specifically, we manipulated nonword difficulty and stimulus quality to make lexical decision difficult and attempted to produce the same homonymy disadvantage as in semantic categorization. We found that stimulus degradation succeeded to this end, and nonword difficulty only consistently slowed nonword responses. The results provide evidence both for our settling dynamics accounts of semantic ambiguity, and for interactive orthographic-to-semantic processing and the construction of more integrated models in general. Preliminary results were reported in a conference paper (Armstrong & Plaut, 2011, *Cognitive Science Conference*) and will be reported in full in a forthcoming journal submission.

In concert with these empirical studies, we are developing addition computational modeling simulations that use analogous stimulus degradation to account for these findings. The models are based on the same neurally plausible modeling framework that we have employed in the context of modeling Evoked Response Potential (ERP) data (see below). Although our modeling efforts in this domain are still ongoing, preliminary results are extremely promising, and suggest that it will be possible to provide a fully integrated, mechanistic account of how both stimulus quality and nonword difficulty impact the nature and degree of semantic contribution in lexical processing.

Adaptation of decision mechanisms. In follow-up work to our modeling of adaptive decision making, we are developing attempts to internalize the referent function by having the decision system adapt to feedback directly, without stipulating what type of information should drive the response units. The system is pre-trained with basic lexical information (corresponding to the relevant knowledge that subjects have prior to the beginning of the experiment), and then adapted on the basis of performance feedback during the experiment (using error-correcting learning). Earlier work by Ratcliff, Van Zandt, and McKoon (1999, *Psych. Review*) suggests that this approach to decision making can produce behavior very similar to their Diffusion Model account, and we are attempting to extend it to a full account of all of the relevant findings (Markey, Armstrong & Plaut, in preparation). One major advantage of this approach is that, unlike the Diffusion Model and our own models based on competing decision units, this adaptive

account potentially extends beyond N-alternative forced choice tasks to any type of response representations (e.g., phonological output during word and picture naming).

The target of our decision-making modeling work has been on experimental data from Ratcliff et al. (1999) in a numerosity judgment task, in which somewhere between 1 and 100 asterisks are displayed briefly within a 10x10 grid, and subjects must decide if the number came from a “high” (e.g., mean 60) or “low” (e.g., mean 40) distribution. However, certain aspects of Ratcliff et al.'s experimental design are problematic for properly examining adaptation (e.g., to changing stimulus distribution) and these problematic aspects likely account for putative limitations in the degree to which neural networks can account for their data. We are in the process of gathering analogous behavioral data in a way that avoids these pitfalls, and will apply our modeling framework to the resulting pattern of results in order to provide a more rigorous test of our theory.

Temporal dynamics of competition and cooperation in word comprehension. The following paper reporting on our work was submitted and accepted for publication:

Laszlo, S. and Plaut, D. C. (in press). A neurally plausible parallel distributed processing model of event-related potential reading data. *Brain and Language*.

Software for automatic selection and matching of stimuli for empirical studies. A large number of refinements and improvements have been made to both the algorithm and software over the last year, and a journal article reporting on the algorithm and its use was just submitted for publication.

Research Project 3: Project Title and Purpose

Testing the Impact of Sexual Frequency on Health and Wellbeing - This study will test whether the frequency of sexual activity in a relationship has a positive impact on self-reported health and well-being among marital partners. We propose to test two possible mechanisms by which frequency of intercourse may improve health, as measured by self-reported physical symptoms. These are 1) increased positive affect, including positive affect due to partner closeness and 2) improved health behaviors. Participants will be monogamous married couples aged 40-65 years, in good health, with no chronic illnesses and no regular medication regime. We will use a between-subjects randomized controlled trial (RCT) to evaluate the impact of sexual frequency in a monogamous relationship.

Duration of Project

7/1/2008 – 12/31/2010

Project Overview

We will conduct a prospective study to examine the causal impact of sexual frequency on self-reported health behaviors and well-being. While prior research has revealed very strong correlations between sexual frequency on the one hand, and health and subjective happiness on

the other, there are many causal chains that can lead to such a relationship. For example, good health or happiness could encourage sexual activity (reverse causality), or some external factor could influence all three variables in the observed fashion. To date, there have been no direct tests, to the best of our knowledge, of the impact of sexual frequency on health and/or happiness. Beyond testing for the existence of a causal effect running from sexual frequency to health and happiness, we also propose to test two possible mechanisms by which frequency of intercourse may improve self-reported health and wellbeing, including its impact on affect, perhaps due to greater partner closeness, and its impact on health behaviors, such as diet, sleep patterns, and exercise.

This will be a randomized controlled trial (RCT). All regularly sexually active participants (defined as once or more occurrences of intercourse per month) in the treatment group will be requested to double their current frequency of intercourse. For those not regularly sexually active, the treatment will prescribe a minimum once-per-week frequency of intercourse. In the initial study for which we seek funding, measures of physical symptoms, health behaviors, positive and negative affect, and marital satisfaction will be taken daily. All measures will be administered by a daily online survey. The control group will respond to the same measures, but will not receive any prescription for sexual intercourse frequency. The treatment and collection of measures will take place for 12 weeks.

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Expected Research Outcomes and Benefits

There are currently 77 million baby boomers in the United States. The physical and mental health of this population is critical, due not only to their representation in the population, but also to the impending health care costs of this cohort. Consequently, any research that can be applied to discovering means of improving health and longevity among this group is highly pertinent. There is substantial evidence of positive correlations between sex, happiness and health among older adults. In a nationally representative survey of 3,432 Americans, those individuals with no sex partners in the past year had the highest levels of unhappiness.

However, the studies conducted thus far have been correlational, meaning that we cannot infer causality from their results. Such correlations could arise for a number of reasons. Happier, healthier, adults might have more opportunities for sex or might be more interested in or capable

of engaging in sexual activity. Individuals in poor health may lack the impetus or interest to engage in satisfying sexual behavior. If sexual intercourse is so highly valued as a source of happiness and if it may actually confer long-term health benefits, it is crucial to determine both to what extent intercourse is actually impacting individuals and the mechanisms through which this is happening. We will test for this relationship by randomly assigning monogamous couples to conditions of either normal or increased frequency of intercourse. We expect to find that an increase in sexual frequency will result in increases in marital closeness, individual levels of happiness, and improved health behaviors. Therefore, we expect direct improvements in self-reported mental and physical health, which will immediately benefit study participants and could have long term benefits for society at large.

Summary of Research Completed

Data collection was completed during this reporting period. The final number of participants was 130 individuals (65 couples). There were 60 individuals (30 couples) in the control condition and 70 individuals (35 couples) in the treatment condition. All individuals, regardless of compliance with daily questionnaires, were asked to complete the exit questionnaire. Completion of the exit survey was a requirement to receive payment, and this, coupled with follow-up e-mails and telephone calls, led to a 100% completion rate for the exit survey for all individuals recruited during the last reporting period (92 participants).

Data cleaning was also completed during this reporting period. Data measuring alcohol and tobacco use was coded to create uniform units of measurement across alcohol and tobacco types. A standardized study day variable measuring participants' relative progress in the survey (i.e., Day 1-90) was created from the calendar dates in the survey for use in time series analyses. A large unexpected number of questionnaires with duplicate dates was discovered. (i.e., two questionnaires completed on the same day by one participant.) These instances were examined and corrected, in the case of formatting errors, or removed, in the case of genuine duplicates. Other standard data cleaning and preparation activities completed during this period include scoring scales used in the exit and entrance surveys and converting all nominal demographic variables to numeric format. Because some of the large number of records generated (1 questionnaire per person per day for 90 days) and the inability to automate some of data cleaning, data cleaning and preparation took six months, which was longer than anticipated.

After data collection for the study was complete, a follow-up survey was sent to all participants from the most recent recruitment period (92 participants). This survey asked a series of open-ended questions about participants' health habits, sexual activity and relationship with their partner during the study in order to provide insight pertinent to the analysis and its interpretation as well as explore areas for future study. 70 participants completed the survey.