

Carnegie Mellon University

Annual Progress Report: 2007 Formula Grant

Reporting Period

July 1, 2009 – June 30, 2010

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.

Anticipated 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

In the prior reporting period, we designed, constructed and evaluated the prototype unit in-house. Based on discovered shortcomings of the human-computer interaction aspects, two teams of students developed a number of enhancements, including the addition of a small touch screen interface and re-designed screen icons. Subsequent testing revealed several bugs (both software- and hardware-related) that must be fixed before the kiosk is ready for deployment. In June, we hired a software engineer to fix the bugs and generally make the system robust. Pending those changes, expected to be completed in September, acquisition and assembly of parts for a replicated unit is on hold.

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.

Anticipated 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

Noun and verb deficits in aphasic patients. Some researchers propose that lexical representations are divided both by modality (written vs. spoken) and by grammatical category (nouns vs. verbs). We are exploring an alternative and more parsimonious hypothesis – that observed selective deficits among aphasic patients to nouns or to verbs, sometimes restricted to a particular input or output modality, reflect the differential reliance of nouns and verbs on different types of semantic or modality-specific information. In particular, nouns rely more heavily on perceptual information whereas verbs rely more heavily on action-based information. We previously implemented a topographically organized model of word comprehension and production that develops graded modality-specific functional specialization within semantics as a function of differences in the statistical properties of nouns and verbs, and that, when damaged, exhibits the broad patterns of performance observed among aphasic patients. Ongoing work is directed at improving both the neuroanatomic and behavioral verisimilitude of the model.

We carried out empirical studies to test some general predictions that arose from the computational model – namely, that words with rich associated action knowledge will support faster and more accurate processing in normal and impaired speakers relative to words matched

for other characteristics but without any associated actions. However, in two studies, neither normal speakers nor stroke patients showed reliable effects of action richness on lexical decision. Because effects of action knowledge on lexical decision have previously been demonstrated for nouns in normal speakers, and because we would expect action verbs to have even stronger associated action knowledge than manipulable objects, we speculate that the lexical decision task given to the normal participants was not difficult enough to encourage deep semantic processing. Moreover, the patients we tested all performed near ceiling at a picture naming task, so therefore may have only been mildly aphasic. We are currently planning follow-up empirical studies using a task that more strongly engages semantics (semantic categorization).

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 are currently in the process of carrying out corpus-based analyses along with gathering ratings data from subjects in order to develop a new stimulus set that avoids these pitfalls, and will use this set in replications and extensions of our existing findings.

We have also carried out a pilot study using reduced contrast as a means of slowing lexical processing (thereby increasing the relative contribution of semantics), with promising results. In concert with this, we are developing additional computational modeling simulations that use analogous stimulus degradation to account for these findings.

Adaptation of decision mechanisms. An important challenge facing theories of lexical processing is how decisions are made based on lexical information, and how these decision mechanisms adapt in the face of changing circumstances (e.g., different stimuli or feedback). In earlier work, we described a theory of decision system adaptation in which yoked criteria shifts serve as a simple but powerful mechanism for rapidly minimizing errors without sacrificing speed. To support the theory, we implemented a connectionist model of lexical decision, wherein the state of a word perception network was “read” by a pair of decision units. The response criteria for these decision units were then subjected to yoked shifts to examine how, in the face of perceived errors, such a response mechanism might adjust performance. We also presented the results of a lexical decision experiment that manipulated the truthfulness of the feedback participants received so as to trigger the error correction mechanism while keeping

other task parameters constant. The results of the experiment largely parallel those of the simulation, suggesting that yoked decision shifts make an important contribution to error minimization in decision system adaptation.

In follow-up work, we are pursuing a simplification and extension of the above that accounts not only for adaptation due to error feedback but also practice effects, speed-accuracy trade-offs and trial-to-trial adaptation effects. Two variants are being developed. In the first, instead of adjusting yoked response criteria, the “referent” function (which serves as input to the “no” unit in lexical decision) is updated trial by trial on the basis of feedback. Preliminary simulations suggest that this approach can account not only for the results of our own study but also for the more general effects mentioned above. The second variant we are developing attempts to internalize this 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. 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).

Temporal dynamics of competition and cooperation in word comprehension. Particularly interesting and important data on the nature and time-course of word comprehension comes from recent work by Laszlo (now a postdoctoral fellow in Plaut's lab) measuring Evoked Response Potentials (ERPs) to different types of words and non-words. The N400 component (a negative deflection about 350-450 ms post stimulus onset) is thought to reflect processes related to semantic access. Laszlo found that, when subjects perform lexical decision to isolated words, word-like pseudowords (e.g., MAVÉ), consonant strings (e.g., KLRX) and acronyms (e.g., NASA), words and pseudowords produced equivalent and relatively large N400s, whereas consonant strings and acronyms produced smaller (and equivalent) deflections. This is interesting because words and acronyms have meanings but pseudowords and consonant strings do not, suggesting that the N400 reflects the transitive degree of semantic activation during semantic access rather than the final steady-state activation, and both words and pseudowords temporarily engage semantics to an equivalent degree in this process. (This perspective is further supported by the observation that N400 magnitude for words increases with neighborhood size---the number of other words differing by a single letter.) We are developing a neural network simulation of these data in which excitation and inhibition are handled by separate neuron populations with distinct temporal dynamics, and preliminary results look extremely promising.

Software for automatic selection and matching of stimuli for empirical studies. In the course of developing stimuli for our empirical studies we ran into severe difficulty identifying experimental and control stimuli that were matched on all relevant dimensions. In response, we have created S.O.S., an algorithm which (S)tochastically (O)ptimizes (S)ets of items from

(possibly large) populations of items based on the desired constraints of an experiment or post hoc analysis. A number of different types of experimental constraints have currently been implemented, including matching or maximizing differences on a particular dimension between sets at both group and pair-wise levels, matching or minimizing the standard deviation of different sets, and uniformly distributing items across a range of values for regression analyses. S.O.S. addresses a critical gap in the execution of an empirical research program, and that employing this procedure opens new avenues in terms of the types of theoretical questions an experiment can address, and their validity and power, all while avoiding experimenter error and saving the experimenters' time. A free, open-source software implementation of the S.O.S. algorithm is available for download for academic purposes, and pre-compiled binaries are also available for all major operating systems. A paper reporting on the algorithm and its use is currently in preparation.

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.

Anticipated 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

In the reporting period, the project completed recruitment, enrolling an additional 50 couples (100 individuals) in the past year. To obtain a sufficient sample size, all screening and enrollment procedures, such as baseline questionnaires, were moved to a telephone and Internet format. To ensure that all participants met the age and marital status eligibility requirements, all individuals were required to submit proof of age and marital status before beginning the study. Intake questionnaires were also checked for completeness before enrollment.

There are currently 67 couples (134 individuals) enrolled. Individuals range in age from 30-65 years and baseline sexual frequency ranges from a minimum of once per month to a maximum of three times per week. Of these 67 couples, 36 have been randomized to the treatment group and 33 have been randomized to the control group. Stratified randomization (by age and sexual frequency) was employed to ensure an even distribution of these two key variables across conditions. All couples in the treatment group were asked to double their sexual frequency at a minimum. Couples in the treatment group with the lowest levels of sexual frequency were prescribed a minimum sexual frequency of once-per-week.

Seventeen couples (34 individuals) have completed the 12 weeks of questionnaires; data are still being collected from the remaining 50 couples. Because of the remote nature of the study, data are reviewed on a biweekly basis throughout collection to ensure that participants are filling out questionnaires regularly and correctly.