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The Planning and Execution Assistant and Trainer (PEAT)

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Introduction

Meet PEAT, the Planning and Execution Assistant and Trainer. PEAT is a new device designed to increase the independence of persons with brain injury. PEAT uses powerful new technology to help users stay focused and on task despite surprises and distractions. PEAT is a hand-held electronic calendar and address book. It features automatic cueing to start and stop daily activities and has built-in phone, fax and Internet capabilities. But it is much more. PEAT uses automatic planning software from NASA to compensate for executive function deficits. It automatically generates daily plans, monitors plan execution, and replans when the situation changes.

The challenge of impaired executive functions

A significant problem for persons with brain injury and their caregivers is the diagnosis and treatment of impaired executive functions. This includes functions such as ``anticipation, goal selection, planning, initiation, self-monitoring, and use of feedback" (Stuss and Benson, 1986). The executive functions provide flexibility that is required for autonomous action in a dynamic world. Independent living requires the ability to combine memorized routines with novel plans. For example, a routine procedure for going shopping may need to be changed if the car doesn't start. A routine procedure may not apply in a new situation, or it may become ineffective when the situation changes. When surprises occur, routine procedures may need to be replaced by planned procedure variations. The executive functions determine when and how to replace routine procedures with deliberately planned variations (Levinson, 1995b; 1994). This provides the flexibility needed to achieve goals in an uncertain and changing environment. Many people cannot regain independence in their lives after a brain injury because they have lost this mental flexibility. The executive functions mostly involve the neural circuits in the brain's frontal lobes. This work is motivated by the following observations:

Observation 1: Executive dysfunction is common due to the susceptibility of frontal lobe damage. "The frontal lobes are the most frequent site of damage as a result of head injury" (Goldman-Rakic, 1993)

Observation 2: Executive dysfunction is often the largest barrier to community reintegration after brain injury. ``Deficits in executive functions, perhaps more than any other cognitive process, determine the extent of social and vocational recovery."(Sohlberg and Mateer, 1993)

Frontal lobe damage typically impairs one's ability to predict the effects of actions, to generate plans and to execute plans. Persons with frontal lobe damage are often highly distractible due to impaired impulse control and low self-awareness. These patients may have difficulty generating and executing plans for activities of daily living (ADL) such as doing laundry, making a sandwich, orchestrating a business meeting, and planning a trip (Sohlberg and Mateer, 1989).

Our Approach

Recent advances in artificial intelligence (AI) planning technology and personal digital assistant (PDA) technology have enabled a new approach for diagnosing and treating persons with executive function deficits. PEAT uses that AI planning technology on a PDA to increase the independence of persons with brain injury. The new device is intended to serve as an ``orthotic" frontal lobe. The device uses a computer model of prefrontal cortex function to assist the user with the planning and execution of daily activities.

PEAT uses an AI planning system called PROPEL, The PROgram Planning and Execution Language (Levinson 1995a). PROPEL was developed at NASA for use in robotic systems that must operate with minimal human intervention. Thus, we were using PROPEL to increase the autonomy of machines. Now, we are applying it to increase the autonomy of people who have brain injuries

In PROPEL, users define scripts for routine action sequences such as the morning routine or going shopping. The most important feature of PROPEL is that the same script can be used for both planning and execution. Planning involves simulating the script before it is executed. Scripts can contain choice points that identify where a choice must be selected from a set of alternative resources or subroutines. Examples of choice points in a Dinner script include choosing a restaurant for dinner, and choosing between walking or driving. Without any planning a default script can be executed reactively by using heuristics to make default choice point selections. The planner first simulates the default program instance, and then it simulates program variations. The planner evaluates each simulation with respect to the goals, and it searches for program variations that maximize goal achievement. Finally, the planner generates advice rules that are used during execution to make deliberate selections at choice points. PEAT uses PROPEL to simulate prefrontal cortex function, with special focus on the executive functions.

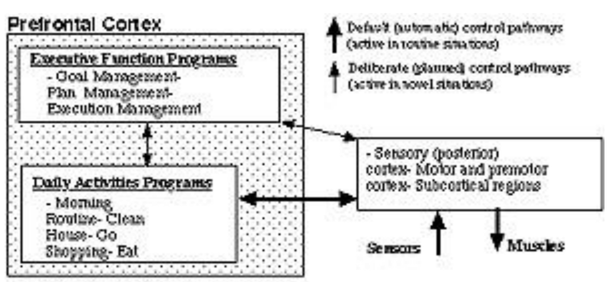

Figure 1. Our model of prefrontal cortex function

Our model of prefrontal cortex function is shown in Figure 1. In this model, the prefrontal cortex stores symbolic (linguistic) memories of conditioned action sequences called programs (also called scripts). In human brains, these programs correspond to functional neural circuits (also called pathways). The programs encode memories of long duration action sequences that remain active to direct behavior in the absence of sensory stimuli. Routine sensory conditions activate default program pathways, and novel sensory conditions activate deliberate scripts variations. Some prefrontal programs encode behaviors for daily activities such as cooking, shopping, and bathing. Other programs encode executive function behavior for self-monitoring and self-programming. The Executive Functions determine when and how to replace the automatic, default programs with deliberately planned variations. Our main focus is on simulating the following Executive Functions.

1) Goal Management programs maintain the goal structures that map external conditions into reward values. Goals can be added, removed, or changed. In our model, self-awareness is the process of relating personal reward values to current and predicted conditions. This allows a system to inhibit reactions to strong stimuli, and to generate self-directed actions in the absence of sensory stimuli. Without this type of reasoning, a system can easily get distracted by strong sensory input and get locked into the present moment.

2) Plan Management programs are responsible for starting and stopping script simulations. They detect and correct potential script errors and search for the most effective script variations. The search is guided by heuristics that evaluate each program variation with respect to the goals. The default program instance is simulated first. The simulations are analyzed to detect simulated script errors, and scripts that conflict with important goals are rejected. The simulated errors are then corrected by backtracking to a choice point that leads to a better script variation. The best plan is converted to advice rules that are used by the execution management system to override default choice point selections.

3) Execution Management programs are responsible for starting and stopping script execution. They execute the daily activity scripts in real-time. In order to guarantee quick reaction times, no search is involved during execution. Choices are selected quickly by using default heuristics or any available plan rules produced by the planner. Execution management programs detect and correct execution errors such as when the car does not start. Correcting these errors may activate the planning programs to generate a novel recovery procedure.

These executive functions provide the classic frontal lobe functions of inhibiting reactions that are irrelevant, ineffective, or interfering . They also make sure that routines are started, stopped, switched, continued and modified according to the generated plans. Impairment of these processes produces recognizable symptoms of frontal lobe damage such as distractibility, awareness deficits, and perseveration.

This computer model is a synthesis of several neuropsychological models of frontal lobe function. The primary influences were the Executive Function Behavioral Ratings Scale (Sohlberg and Mateer, 1989) and Norman and Shallice's Supervisory Attention System (Shallice and Burgess 1991) but there were several others. Please see (Levinson 1995b and 1994) for details about how our model relates to these theories of frontal lobe and executive function.

PEAT uses PROPEL to simulate the above model of prefrontal cortex function. The simulated executive functions serve two roles. For diagnosis, they can simulate a person's impaired executive functions. For treatment, they provide compensatory support for impaired functions.

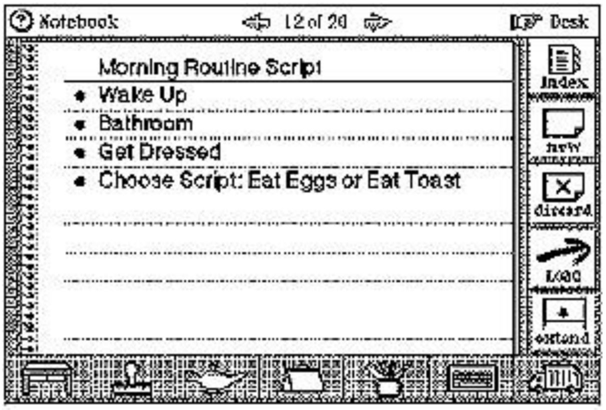

Figure 2: The Morning Routine Script

PEAT maintains a library of hierarchical programs (scripts) that describe daily living activities such as making a sandwich, paying the bills, or the Morning Routine shown in Figure 2. The scripts use choice points to specify alternative resources and subroutines. The Morning Routine is a script involving 4 subtasks: Wake Up, Bathroom, Get Dressed, and a choice of breakfast tasks.

Some users will rely on their caregivers to write and enter the scripts, while other users will be able to to that themselves. We expect most users will need less help over time. Users begin by entering appointments into the calendar as shown in Figure 3.

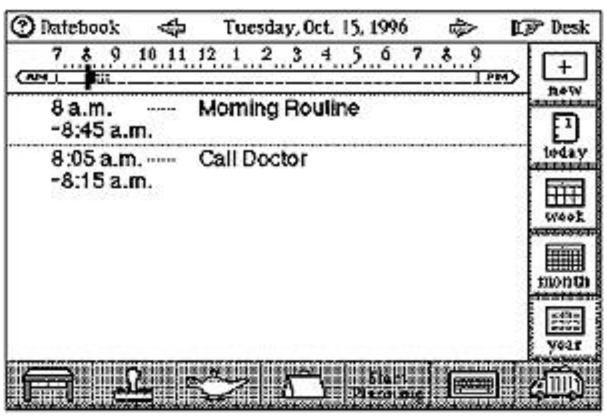

Figure 3: The calendar with two appointments

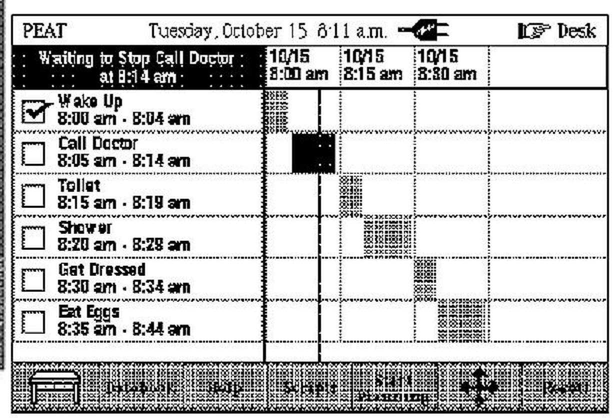

Figure 4: The results of replanning

Given the script shown in Figure 2 and the calendar appointments shown in Figure 3, PEAT's planner generates the expanded plan shown in Figure 4. The plans are evaluated and those that are ineffective due to resource conflicts are replaced with better variations. The planner finds script variations by making different choice point selections. PEAT then assists with plan execution by using visual and audible cues to prompt the user through each plan step. The visual cue to start Waking Up is shown in Figure 5.

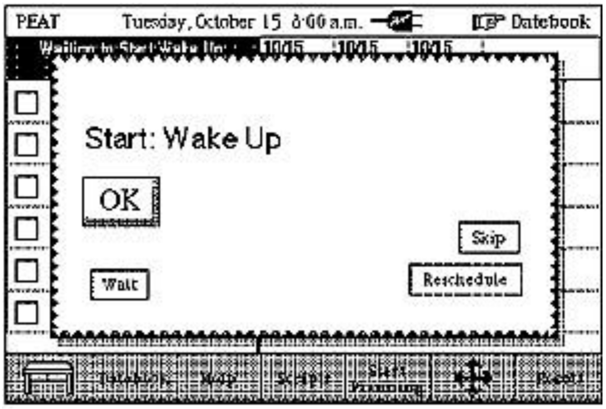

Figure 5: The cue to start waking up

For example, entering the goal "Finish the Morning Routine between 8 and 8:45 a.m." will cause the planner to simulate the Morning Routine script shown in Figure 2. On an ordinary morning, the default plan would be to start the routine at 8 am and then perform each of the routine's steps consecutively. However, suppose one day there is an additional goal to call the doctor at 8:05 a.m. Now the default plan must be deliberately modified because by default the user would be in the bathroom at 8:05. PEAT automatically searches the space of disjunctive start times for each task in the morning routine. It finds a plan that will make sure the user is not in the bathroom at 8:05. This is achieved by shifting the bathroom activities back by five minutes. It then executes the morning routine using the choice point rules that define the best plan. As a result, the user will be cued to wake up and then call the doctor before starting the bathroom activities. If the user needs more time getting out of bed or talking to the doctor, they can tap 'Wait' in response to the stop cue. Such delays may cause the planner to adjust the plan in order to finish the morning routine on time by 8:45. It may replace the 10 minute eggs breakfast with the five minute toast option or it may decrease the length of the shower.

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