COGNITIVE REHABILITATION USING REHABILITATION ROBOTICS (CR3)

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Abstract

Cognitive deficits are a well known problem associated with many disabling conditions, such a traumatic brain injury, stroke, and other neurological disorders. Their presence may be less obvious, but potentially as disabling, in conditions such as multiple sclerosis, drug and alcohol related disorders, and psychotic disorders such as schizophrenia. This paper reports work in progress with individuals with brain damage using robot aided cognitive rehabilitation.

Introduction

Traditionally, the field of rehabilitation robotics has focused on physical disabilities where robots are used as a substitute for absent or diminished motor function. More recently there has been a concern with robotic aides for motor rehabilitation [1]. For example, Krebs et al. [2], using robot-aided rehabilitation (a robotic arm) with stroke patients, demonstrated that robot-aided therapy does not have adverse effects, patients do tolerate the procedure, and brain recovery may be aided in the process. In their experimental paradigm, power assistance was used to enhance movements being made by the patient.

Cognitive Rehabilitation using Rehabilitation Robotics (CR3) is being developed to retrain diminished cognitive function following non-progressive brain injury using guided movement. It combines errorless learning, a proven method of teaching new information to individuals with memory problems, and the Active Control Stick, currently being used in the aerospace industry, that can prevent errors from being made during learning. Thus, CR3 offers a new area for rehabilitation robotics, relevant to perceptual motor skills assisted by errorless learning.

Errorless learning is a method of teaching individuals to successfully make discriminations which are otherwise difficult for them to make under conditions which ensure that few or no errors are made during learning. Research in the field of cognitive rehabilitation with memory impaired individuals has demonstrated that conscious awareness during learning is necessary for error correction to occur [3]. For most individuals with brain damage, this conscious awareness, or memory of the event, is not available to them. When errors are allowed to occur during learning, it is the incorrect response that is often unconsciously remembered and repeated. It is not surprising that errorless learning has been found to be superior to trial and error learning for memory impaired individuals [3,4,5]. The broad aim of our project is the development of clinical applications of errorless learning and evaluation of its effectiveness with cognitive problems in addition to memory.

Methods

Equipment--Active Force Field (AFF) technology, currently being used in the aeronautic and aerospace industries with an Active Control Stick, provides a force field interaction between the pilot and the aircraft or simulator control system via biodynamic feedback and proprioceptive compensation. The electric motors of the Active Control Stick can be used in shaping motor behavior. For any rehabilitation program based on the participant using movement to select the correct option from a set of alternatives, the Active Control Stick can be set to guide the individual to the correct alternative. The role of the therapist is to set the force field parameters (e.g. motor synthesized spring strengths) according to the individual's needs, while continually trying to reduce the degree of guidance with the goal being that the individual carry out the action unaided in the end.

The distinct advantages to the use of CR3 include: a time and labor saving tool for therapists while reducing the potential human error introduced when the therapist attempts to guide the patient's movement; it is possible to adapt the program to the individual needs of the patient; and it is not necessary to constrain the patient's environment, which may be possible in a protected setting but not in a real world environment, since the patient's responses are being constrained during retraining. Also, since the patient's movements are taking place in three dimensional space, this particular technique makes it possible for patients to make more realistic movements during learning.

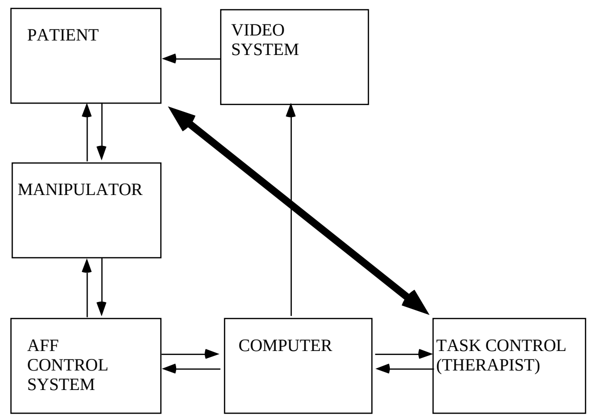

Figure: CR3 system components. The patient responds to video presented information by making movements of the manipulator. These are subject to guiding forces produced by the AFF control system whose parameters may be adaptively tuned by the therapist using both clinical observation and system measures of performance.

Proposed Study

Proposed Patient Study--Patient studies are currently underway applying errorless learning using rehabilitation robotics to deficits in executive/motor functions and attention. For example, the Active Control Stick is being used with a patient with 'action disorganization syndrome,' as a result of frontal lobe damage, who is being trained to select correct sequences of action for everyday tasks such as writing a letter, using a menu system in which the component actions in the task are listed [6]. Here the patient is constrained from making incorrect selections by the robot aid. Transfer of learning is assessed using behavioral measures of performance in everyday tasks [6,7].

In a second case, a line bisection task is being used to train a patient with unilateral neglect, as a result of stroke, to bisect stimuli at their centers. Here the Active Control Stick prevents the patient from tracking too far into the ipsilesional field, and orients his perceptual and motor responses toward the center of lines. Bisection training is applied using stimuli in different areas of the visual field, to establish generalized perceptual-motor routines linked to objects rather than to a fixed response to one location. The transfer of learning to other measures of neglect is being assessed.

Discussion

The line bisection task has been tested on normal subjects in a paradigm designed to simulate unilateral neglect in which the visual image is degraded. Preliminary results show that the robot aided errorless learning training improves both speed and accuracy of performance in the impoverished condition.

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