

# E-CORE (Embodied COgnitive REhabilitation): A Cognitive Rehabilitation System Using Tangible Tabletop Interface\*

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**Abstract.** This paper presents a novel cognitive rehabilitation system with a tangible tabletop interface allowing the users to perform cognitive tasks intuitively by their hands. The system consists of a tabletop display with multi-touch function and several tangible objects working on the tabletop interface. We named the system E-CORE (Embodied COgnitive REhabilitation) since it reinforces the coupling of human body and cognition. E-CORE is designed to improve both cognitive functions and gross motor skills of older adults by practicing artificial daily life activities such as cookie making.

## 1 Introduction

Cognitive rehabilitation has become an important issue due to the rapidly increasing elderly population in South Korea. Cognitive training can improve cognitive functions and potentially slow cognitive decline, thus preventing age-related cognitive problems such as dementia [1], [2]. According to demographic research, the prevalence rate of mild cognitive impairment (MCI) was 3~19 % in people aged over 65 years [3]. A recent meta-analysis showed that approximately 5~10% this population develop dementia each year [4]. Considering the high incidence of age-related cognitive impairment, effective methods of cognitive training or rehabilitation are needed.

A majority of computer-based cognitive training has focused on specific domain effects such as memory, attention, and the executive function [5], [6]. On the other hand, the important role of body movement in cognitive rehabilitation has been relatively less highlighted. Given that human action (body) and thought (mind) are deeply incorporated [7], behavior should be considered when designing cognitive training programs. Clinical research showed that the augmented cognitive-behavior

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therapy group is more effective for maintaining and improving the cognitive level after one year of training [8]. Activity of daily living (ADL)-mediated cognitive training may have more lasting effects than categorized cognitive function training.

Tangible objects are closely related between physical activity and cognition [9], and these can serve as powerful tools to improve cognitive functions associated with ADL tasks. By utilizing tangible objects, people can directly manipulate physical objects and reduce their cognitive effort during the training period. Recently, the tangible tabletop interface (TTI) has emerged as a new application for cognitive training [10]–[12]. The TTI, composed of a multi-touch surface and tangible objects, is easier to understand, learn, and use compared to computer-based training using a mouse or keyboard. Also, the TTI is intuitive and easily accessible. It enhances motivation by various types of visual or auditory feedback. In this sense, TTI-based cognitive training is suitable for the elderly population.

Few studies were used TTI for cognitive training in elderly people, however, most of the studies used limited tangible interaction objects. Gamberini et al. [11] developed several games using tabletop platform to preserve cognitive functions in elderly people. Though this gaming platform was used real objects (pens), pens were only used to interact with tabletop as input devices. Marques et al. [12] showed the suitability of touch and gesture-based user interfaces for elderly people using Air Hockey game. This study indicated that TTI was feasible to stimulate cognitive functions and motor skills on elderly people.

In this paper, we propose a novel cognitive rehabilitation system, E-CORE (Embodied Cognitive Rehabilitation) using TTI. To reinforce the harmony between human movement and cognition and to demonstrate the training effects, we designed ADL-mediated cognitive training. Therefore, our system can bring the gap between digital contents and physical space throughout the training.

## 2 E-CORE (Embodied Cognitive Rehabilitation) System

### 2.1 Background

E-CORE is a cognitive rehabilitation system that can delay and/or prevent age-related cognitive problems through its use of tangible objects and a tabletop interface. Based on the embodied cognitive concept, which emphasizes close interaction between physical enjoyment and cognition, human activity can facilitate cognitive functions [9]. Thus, our approach targets the cooperation between physical activity and the human mind in a TTI-based single cognitive training program.

To reduce the distance between the digital space for training and one's actual daily life, this system offers an instrumental ADL task as a cognitive rehabilitation program. While participating in the ADL with tangible objects, people can train their gross motor skills [12] as well as their cognitive functions. Because our system utilizes real objects used in daily life, the elderly can intuitively manipulate them. In addition, the ADL task can reduce their cognitive load when seeking to understand

the training process due to its familiarity with their activities in real life. The tangible tabletop system can also provide quantitative and objective outcome measurements of physical and cognitive functions.

For these reasons, we developed a new approach for a cognitive rehabilitation system for the elderly population utilizing tangible objects and a tabletop interface. To develop the ADL-mediated cognitive rehabilitation system, we need to integrate tabletop platform with tangible objects and understand commonly used gestures in daily life such as grasping, squeezing, and shaking etc. After reviewing several instrumental ADL task, we designed cookie making game for the first time as a part of the E-CORE system. Cookie making task is one of the most applicable a variety of tangible objects in a simple structure. The next sections will present the prototype design and development, and will illustrate the results of its tests.

## 2.2 System Design

Our system is composed of three components: (1) the tabletop interface, (2) tangible objects, and (3) a stereo camera (Fig. 1). The tabletop interface presents digital contents and detects the participant's touch while providing information about interactive tangible objects (i.e., shape and position). We use three types of tangible tools used to make cookies – a cookie cutter, syrup, and a topping container. Various tangible objects with sensors installed detect the participant's physical manipulations (i.e., squeezing and shaking). The stereo camera is equipped to recognize movement in space.

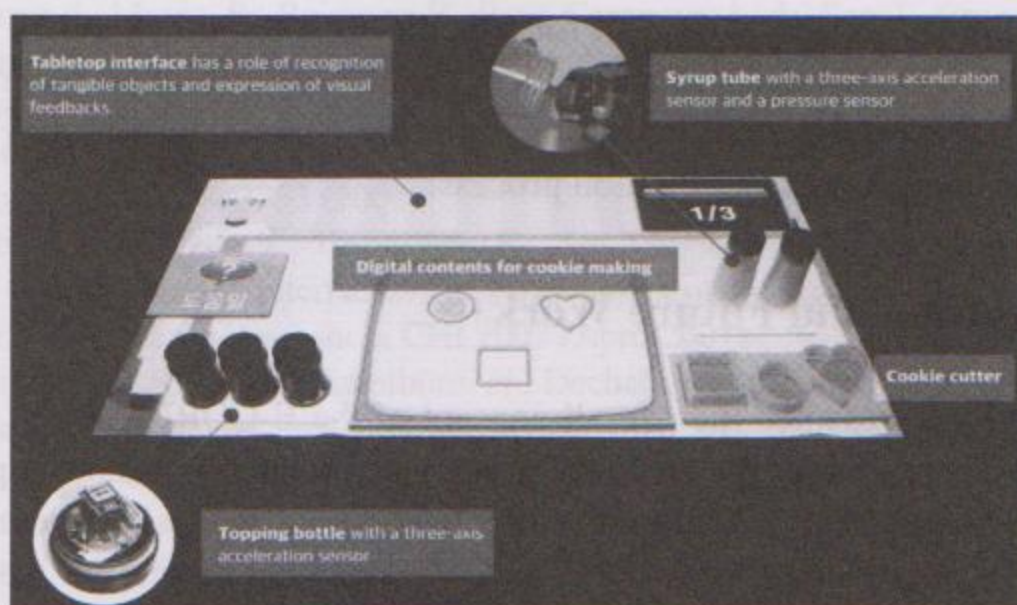


Fig. 1 E-CORE (Embodied COgnitive REhabilitation) systems

## 2.3 Digital Contents

At the beginning of the training, several cookies are presented. The users follow the cookie making process using tangible objects. The first step of this training involves creating the shape of the cookies using an adequate cutter and serving syrup by recalling the displayed cookies. Next, users should remember what they made and sprinkle toppings on the cookies. In this step, motor coordination is required to

scatter toppings over the proper place at the correct time. While participating in the entire cookie making process, people naturally train their motor and cognitive and get feedback according to their performance level.

We developed computerized performance assessment system based on the assessment of motor and process skills (AMPS) [13] and the international classification of functioning, disability and health (ICF) classification [14]. Performance assessment was conducted throughout the entire training session by measuring execution time, trial-and-error rate, and performance accuracy etc. The scoring criteria in E-CORE system include motor and process skills (i.e., reaching and grasping, choosing, and manipulating appropriate objects to perform the task) and mental function (i.e., sustaining attention, short-term memory, time management).

#### **2.4 Heuristic Evaluation**

Five experts (three doctors, one cognitive psychologist, and one cognitive rehabilitation therapist) conducted a heuristic evaluation to investigate our system. After performing two trials with E-CORE system, semi-focus group was asked guided questions including usability of our interface system, applicability to target population (elderly people), and effectiveness of cognitive rehabilitation. Some were concerned that cookie making is not common ADL task, which could make difficulty to understand the context of task. However, the general responses were positive regarding the use of the TTI for cognitive rehabilitation and on the digital contents that simulated daily life activities. Piecing together their comments, this system is suitable for the cognitive trainings on elderly population as they can easily immerse and engage the rehabilitation process.

### **3 Conclusion and Future Work**

In this paper, we presented the overall concept of the E-CORE system, utilizing a TTI for cognitive training. We are in the process of developing a more sophisticated system as a cognitive rehabilitation system. We plan to design more levels of difficulty for cognitive challenges to enhance the training effect. For the transition to the next step, we will conduct a usability test to reflect real user feedback. E-CORE is a new attempt to apply TTI-based ADL tasks to cognitive training so as to promote interconnections between human behavior and cognitive processes. We believe that our system represents a new interactive therapeutic approach toward better cognitive rehabilitation.

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