Let's Cook: An Augmented Reality System Towards Developing Cooking Skills for Children with Cognitive Impairments

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Abstract. Although activities of daily living are often difficult for individuals with cognitive impairments, their autonomy and independence can be fostered through interactive technologies. The use of traditional computer interfaces has however proved to be difficult for these users, bringing to the surface the need for novel interaction methods. This paper proposes *Let's Cook*, an innovative Augmented Reality game, designed to teach children with cognitive impairments how to prepare simple meals, following a playful approach. *Let's Cook* supports multimodal interaction techniques utilizing tangible objects on a tabletop surface, as well as multimedia output. Additionally, it can be personalized to accommodate the diverse needs of children with cognitive impairments by employing individual user profiling. The system is currently installed in the kitchen of the Rehabilitation Centre for Children with Disabilities in Heraklion, Crete where it was evaluated by the students.

Keywords: Augmented reality · Multimodal interaction · Adaptability
Cognitive impairments · Meal preparation · Cooking

1 Introduction

Cognitive impairment is a broad term encompassing various intellectual or cognitive deficits and may vary from severe cognitive disability to mild impairment. A typical limitation among people with cognitive impairments is carrying out activities of daily living, such as cooking. To that end, assistive technologies have been developed, aiming to help individuals with cognitive disabilities to become more independent and enhance their quality of life [1]. The use of traditional computer interfaces has however proved to be difficult for these users [2], bringing to the surface the need for novel interaction methods.

Play is an important activity of life, in all its contemporary and digital forms, such as video games, applications on smartphones, interactive toys etc. [3]. Game-based methods, technologies, and concepts are employed by serious games with the aim to teach, exercise, and change users' behavior [4]. Playing and cognition are deeply

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interconnected since learning "how to play" a computer game implies various cognitive skills [5]. Technologies like Augmented Reality (AR) have the ability to blend a fictional narrative with the real and familiar physical environment and to provide a high engaging learning environment [6].

Focusing on meal preparation, which is considered an important skill to teach to individuals with cognitive disabilities in order to increase their independence, this paper describes *Let's Cook*, an educational AR game, aiming to familiarize children with cognitive impairments with elementary meal preparation notions and simple recipes, in a playful way. Taking into account the need for novel interaction methods, the system supports multimodal input, utilizing tangible objects on a table-top surface and multimedia output available in textual, auditory and pictorial form.

Let's Cook is one of the five games comprising *CocinAR*, an educational system, which aims to instruct children: (i) which meals are appropriate for breakfast, lunch, and dinner, (ii) how to cook simple meals and (iii) fundamental rules of safety and hygiene that should be applied during the food preparation process [7]. Profiling functionality is supported, allowing the system to adapt to each individual student with respect to the preferred output modalities, providing at the same time teachers with statistic information on the progress of each student. *CocinAR* is installed in the kitchen of the Rehabilitation Centre (RC) for Children with Disabilities in Heraklion, Crete, where it is used by the educators in the context of their "Independent living" program, in which children are trained to execute simple recipes. Being *CocinAR*'s central game, *Let's Cook* incorporates the system's main functionality, allowing the user to "cook" a simple recipe in a virtual kitchen, following a step-by-step approach.

The remaining of this paper is structured as follows: Sect. 2 discusses related work, Sect. 3 provides an overview of the *CocinAR* system, Sect. 4 describes the *Let's Cook* game in detail, and Sect. 5 reports the results of an evaluation that was carried out with children with disabilities. Finally, the paper concludes with discussion and future work in Sect. 6.

2 Related Work

Activities of daily living (ADL) such as eating and taking a bath, are routine self-maintenance tasks. Regarding the promotion of ADL, technology has been claimed to improve performance of individuals with disabilities in comparison to more traditional means, such as plain pictorial or auditory prompts [8, 9]. Typical assistive technologies include software for reminding and prompting, task guidance, computer assisted learning and communication [1, 2, 10].

On the other hand, several serious games have emerged as a means of increasing the efficiency of learning methods. An AR application developed to assist children with autism spectrum disorders to recognize and acquire emotions is GameBook [11], which can be played on any mobile device, such as a tablet, a smartphone or a laptop. AR systems often involve interaction on an augmented table surface. For example, PAR [12] is a multiuser collaborative game for people with autism, which supports multi-touch tabletop interaction. However, touch-based interaction may prove to be challenging for very young children or children with physical and cognitive disabilities, on the grounds

that their fine motor skills may not be sufficiently developed [14, 15]. Alternatives have appeared combining physical artifacts and computer-augmented surfaces, such as Beantable [17], a system developed to support preschool children's development and combines interaction via touch, augmented objects and physical cards.

Regarding the meal preparation process, portable devices have been proposed involving pictorial instructions, auditory and vibratory feedback [20], or multi-step tasks in a self-prompting approach using video, picture and auditory prompts [21]. Another step-by-step approach for guiding individuals with cognitive impairments through a food preparation recipe is the ARCoach system [13]. ARCoach uses computer vision to recognize the various ingredients on a table and the user's actions, so appropriate feedback is provided when there is an abnormality in a step execution. An assistive system which addresses people with higher brain dysfunction and aims to support the meal preparation process focuses on assisting their memory and planning ability through multimedia recipe presentation [22]. Targeted at meal preparation, with the aim to assist the better comprehension and use of cooking recipes *CounterActive*, is an interactive cookbook that is projected on the user's kitchen counter and can be interacted with via touch [23]. An interesting AR cooking system, which provides a first cooking experience with recipes to young children, employs a tabletop screen and a miniature kitchen to simulate cooking activities [16]. Interaction is accomplished via markers, which correspond to cooking elements on the miniature kitchen, and specific touch gestures on the tabletop display, which indicate the various commands (e.g., break egg, turn on fire etc.).

In summary, efforts in the domain of cultivating cooking skills in individuals with cognitive impairments have focused on multimedia information presentation, step-by-step presentation of the instructions, as well as simulation of the cooking activities or live assistance during the cooking process. *Let's Cook* addresses children who are in the process of learning how to cook and adopts the multimedia information presentation and step-by-step guidance approaches. Furthermore, it combines the benefits of immersive experience and blending familiar environments with virtual objects brought by AR, and the playful learning approach of serious games. Progress beyond the current approaches lies in the multimodal interaction it features, the adoption of a novel interaction style, the incorporation of symbol-based language, combined with the adaptability of the system to the needs of each individual child, through profiling mechanisms. The input and output mechanisms were carefully designed, aiming to achieve an intuitive and comfortable interaction with the system, while the various modalities can be provided concurrently, personalized to support different levels of cognition.

3 The *CocinAR* System

CocinAR has been implemented following an iterative process with the active participation of UX experts and educators of the RC, who provided the target user characteristics and the specific educational goals that the system should serve in the context of their "Independent Living" training program [7]. In summary, the system should be able to accommodate a large variety of skills, by: (i) supporting information

presentation through text, audio, images and symbols, concurrently available if needed, (ii) allowing customization of font size, (iii) employing a minimalistic approach towards graphic design, (iv) providing context-sensitive help in each individual exercise, and (v) supporting two levels of content, a simple one for students with severe cognitive problems and a more advanced one, allowing teachers to switch to any of the two levels at runtime. In terms of functionality, *CocinAR* features four multiple choice games (meal appropriateness, collect the ingredients, collect the utensils, safety and hygiene rules) and *Let's Cook*, a cooking simulation game asking students to follow step-by-step instructions in order to prepare simple recipes [7].

CocinAR consists of a computer, a high-resolution projector, a simple wooden table, an infrared camera and a high-resolution camera. The system is designed to "camouflage" itself in a way that none of the equipment used is visible to the users. This is achieved by hiding the hardware equipment inside a kitchen board, leaving visible only the plain wooden table, with the aim to support an immersive user experience (Fig. 1). The interaction with the system is accomplished via simple printed cards, while any infrared device can be used to produce mouse-click equivalent functionality when pressed against the table. In order to facilitate an easier and more comfortable interaction, a custom infrared pointing device was designed for children with motor difficulties, which supports three different handles to accommodate different grip sizes [7].

Fig. 1. (a) Representation of the system setup (b) The actual setup at the RC (c) Physical cards and pointing device

4 The *Let's Cook* Game

Let's Cook simulates the cooking of a given recipe, following a step-by-step approach. All the recipes incorporated in the system were provided by the RC's educators who categorized them under three levels of difficulty. Based on the student's level, which is retrieved by the profiling module, *Let's Cook* suggests the appropriate recipe difficulty

level. The recipe selection process is facilitated by statistics on each student's performance for each recipe as shown in Fig. 2, whereby the teacher can view at a glance the date that the recipe was last played and the score achieved.

Fig. 2. First level recipes with statistics

Once the recipe is selected, the game starts in a virtual kitchen, which visually resembles the actual RC kitchen where children are trained. The virtual kitchen contains points of interest (POIs), which are deliberately confined at the bottom half of the physical table, so that they are easily reachable by children. These interactive POIs, called slots, are the positions where the virtual ingredients and utensils appear and can be manipulated using the pointing devices.

The recipe steps appear sequentially at the top right corner of the virtual kitchen, as regular text or symbolic language, which replaces text words with explanatory images (Fig. 3). The instruction visualization depends on the student's current level and can be changed at runtime by the teacher through the game settings in the menu (target symbol at the top right corner of the virtual environment). Recipe step representation is accompanied by game-flow options addressing educators' requirements, allowing them to skip a step (e.g., create a sandwich without lettuce), to indicate that a step has been executed correctly by the student (e.g., when the teacher believes that the step was completed successfully in relation to the current session's goal), as well as to navigate back and forth in the recipe steps.

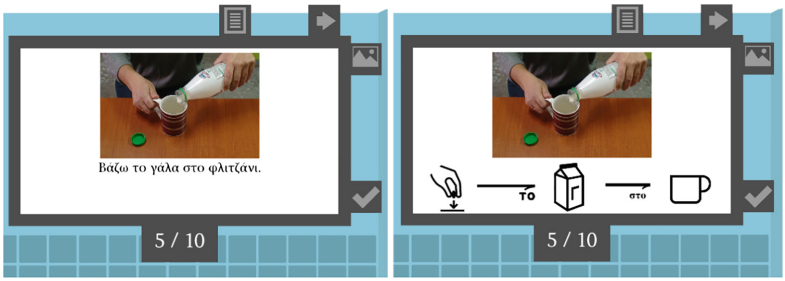

Fig. 3. (a) Question provided through text (b) symbol language activated

Prior to the system's implementation, the various recipe steps were analyzed and categorized according to their interaction style. In a typical recipe, the student would first gather the ingredients and utensils necessary, then mix them together or with kitchen appliances, or just interact with the kitchen appliances. A total of 32 recipes provided by the RC educators, were studied and analyzed. Based on this dataset, the steps of a recipe have been classified as follows:

- card retrieval (e.g., "Take the cutting board and the knife"), where the student is expected to pick a card depicting a recipe material or utensil and place it on the table
- move of an element to another slot (e.g., "Put the colander in the sink"), where a virtual element should be selected through the pointing device and placed in an interactive slot, by pointing device selection
- the combination of elements (e.g., "Put the milk in the cup"), during which two virtual elements are expected to be combined by first selecting the one and then the other via the pointing device
- setting of a specific value to an appliance (e.g., "Set the timer to 10"), where the student selects the appliance and interacts with the UI that appears
- plug or unplug a device (e.g., "Plug the toaster"), by selecting it
- turn a device on and off (e.g., "Turn on the toaster"), by selecting it, and
- wait for a process to end (e.g., "Wait for the water to boil"), where no interaction is expected.

In some cases, a step may have a repetitive nature (e.g., "Put 5 glasses of water in the pot", where the student is expected to select the faucet, the glass and the pot, five times). This kind of step can be deducted into five "combination" type steps, while repetition is assisted by a bar with the appropriate number of slots, being filled with color as the student advances with the repetition.

At the beginning of a recipe's step, a text-to-speech service announces the related instruction. If the step asks for the retrieval of some ingredients or utensils, a placeholder element appears on the table signifying that cards placed there will be recognized by the system. The student must find and place the correct cards on the placeholder (Fig. 4(a)) and then confirm the answer by selecting the arrow button at the bottom right corner. Before continuing to the next step, each card's virtual counter-part appears on the system's virtual table, which can be manipulated with the pointing device. An example

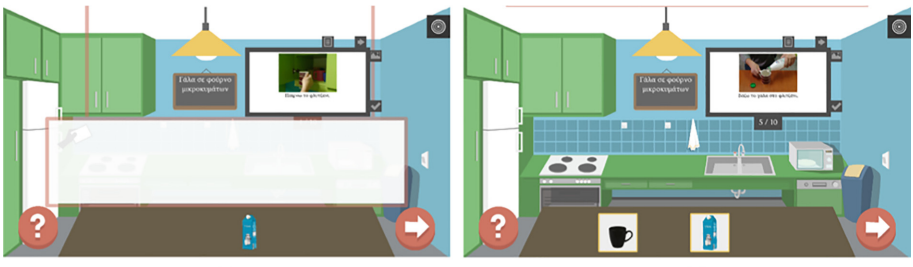

Fig. 4. The *Let's Cook* game (a) "Take the cup" step and (b) "Put milk in the cup" step

shown in Fig. 4(b) depicts a combination step, the "Put milk in the cup", in which the student has selected the milk and the cup, and is ready to confirm the answer.

Context-aware help is available to the student in each step, by tapping on the question-mark button at the bottom left corner. If help is asked, the elements to be selected are highlighted, indicating the slots that the student must select. When the student indicates that they are ready, the answer is assessed by the system and appropriate feedback is provided. In case of wrong answer, the system provides auditory advice about the step and encourages the student to try again. On the other hand, if the step was completed successfully, a clapping sound rewards the student and a video of an actual execution of this step in the real kitchen of the RC is played in a pop up window. Once the recipe is completed, the entire video is played, while a review of all the steps as they were executed by the student is readily available for the teacher.

An important feature of *Let's Cook*, is the adaptability it supports based on the profiling mechanisms implemented for the *CocinAR* system. More specifically, students are registered by their teachers, creating a simple user profile, with the child's name and functionality level, as it has been assessed by the RC educators. Once a user is logged in, additional settings can be defined referring to the content representation modalities that should be employed (text, images, speech, symbols), font size, audio volume, and sound effects activation. Speech instructions are provided using text-to-speech, which is also customizable and supports three different speech speed rates, allowing volume adaptation and complete deactivation. The most recent settings used by a particular student are retrieved and applied for every new interaction, thus personalizing the system according to the students' current needs. Furthermore, through the profiling mechanism, the teacher can have access to game history information, facilitating recognition of each student's strengths and weaknesses and planning of interventions. Game history information includes the number of times a game was played, the number and description of all the wrong answers in each game session, the number of times a student has asked for help, as well as the score achieved.

Finally, one of the most important aspects of the game is that it supports configurable interface and dynamic content retrieval, making its functionality completely context free and reusable. In more details, all word phrases and multimedia are externally defined so they can be easily replaced, while the graphics interface is customizable. All recipe related content is dynamically retrieved from a design studio, the *ConstrAct* editor [18]. This provided configurability allows the system to be repurposed for exercises with different content, preserving its functionality and interaction methods.

5 Evaluation

The evaluation of the *Let's Cook* game was conducted at the RC kitchen area, where children are taught to prepare simple meals, with the goal to identify any interaction problems, and to draw general conclusions about the system and the user experience.

Twelve children (Table 1) and their educator participated in the evaluation. Children were selected to participate in collaboration with the educator, so as to cover an as-wide-as-possible range of developmental disabilities. Their functionality level varied

from 3-5 in a 1-5 scale, with 5 being the most functional. Regarding the demographic data of the participants, the user sample consisted of six boys and six girls, aged from 9 to 17 years old. Because of their age, their guardians were requested to sign a consensus form, indicating their consent regarding their child's participation.

Table 1. Participants of the evaluation

Disability	Children	Functionality level	Reading skills
Autism spectrum disorders	2	4, 5	Yes, Yes
Down syndrome	3	3, 4, 5	Somewhat, Somewhat, Yes
Psychomotor impairment	2	4, 4	Yes, No
Mental retardation	2	4, 5	No, No
Cerebral palsy	3	3, 4, 4	Somewhat, Somewhat, Yes

The evaluation method used was that of user observation. For this purpose, two usability experts were present during each session and were situated at a distance from the child and the teacher to avoid distracting the child. During each session, the experts paid close attention to the way both the child and the teacher interacted with the system. The observation sessions were spread along a five days' interval, keeping each session's duration the same as in their usual class. At the end of each session, the teacher was asked clarifying questions by the evaluator, about specific actions or errors of the current participant. At the end of all the sessions, the educator was queried with more general questions, concerning the students' overall interaction with the system, their likes and dislikes and the system's value for the teachers, following the semi-structured interview method [19]. The observation results and the answers collected during the experiment were recorded, kept and analyzed following an anonymity protocol by the same two evaluators, who were responsible for the evaluation sessions.

Analysis of the results[1] highlighted that the participants had no problem comprehending the layout of the game and the overall style of interaction. They knew where to expect the various elements to appear and what they had to do in order to check their answer and move to the next step. Additionally, the graphic elements were appropriate for all the participating children and they could clearly understand whether an item was selected or not. Regarding the input multimodality, it was observed that all children could switch between the two interaction styles with remarkable ease. They comprehended immediately the "fetch" paradigm of the card retrieval steps and could recognize the ones that required interaction via the pointing device. The multimedia output was verified as a necessary part of the system, facilitating a personalized content provision, able to meet the students' diverse needs and dexterities. Moreover, the multimedia output allowed the practice of additional, apart from cooking, skills, such as reading and listening comprehension, granting a multi-purpose character to the system.

[1] The detailed evaluation questions and their statistical analysis will be reported elsewhere due to space limitations.

However, a difficulty in the comprehension of long sentences was observed, leading to the suggestion that the system should be able to present long instructions gradually, pausing after each requested item until it is successfully selected to reveal the next part of the sentence. Another issue related to instructions' presentation was observed in the steps where the medium necessary for the step was implied rather than clearly stated (e.g., "Put cereal in the bowl", where the spoon to be used as a medium was omitted), so the students were likely not to select it. To address this issue, the system could help the student by asking an indicative question, currently asked by the teacher.

The fundamental question of whether the children actually liked the system was answered both by the teacher and also by the observed behavior of the children. According to the educators, the system is appealing to their students, keeping them focused to the task at hand, while at the same time it facilitates the better cognitive comprehension of the recipe, bringing students closer to their educational goal, i.e., its complete memorization.

6 Conclusions and Future Work

This paper has presented *Let's Cook*, an educational game which aims to get children with cognitive impairments acquainted with elementary meal preparation notions, while employing novel input methods through cards and pointing devices on a tabletop surface. The system supports multimedia output, personalized according to each individual child's needs and preferences. The usability evaluation conducted after the final installation of the system, which involved children with cognitive impairments, indicated that the interaction with *Let's Cook* enriches the user experience, making it more engaging for children and thus facilitates the educational purpose of their teachers. Since this technology is completely new to both sets of users, questions were raised in concern to whether the teachers would find it conducive and supportive to their learning model. To address this question future work will involve a longitudinal study, involving participants over a longer period of time, in order to draw more concrete conclusions about the educational value of the system.

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