Virtual Kitchen: Using a Touch Table for Cognitive Rehabilitation in Activities of Daily Living

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Abstract: A tool designed to assess and rehabilitate memory in patients with Mild Cognitive Impairment (MCI) or People with Dementia (PwD) is presented. This tool includes a touch table equipped with a 3D camera on top for motion capture and a 3D Virtual Kitchen application. The aim is to assess and strengthen their ability to memorize and reproduce the activity of preparing a cup of sweetened coffee with milk. An errorless learning method has been implemented to prevent the user from performing and remembering any erroneous actions while performing the task. We conducted a preliminary study with eight healthy participants to investigate the usability of the solution. The results suggest that Virtual Kitchen on Hôsea touch table is user-friendly, motivating, and requires a moderate workload. We assume that the use of the touch table to interact with the virtual objects will optimize the rehabilitation process for instrumental activities of daily living (IADLs).

1 INTRODUCTION

With virtual reality (VR), a human can be immersed in a virtual environment (VE) in which he can interact in real time using 3D techniques based on our natural abilities of action, perception and expression (Fuchs et al., 2001; Burdea and Coiffet, 2024). In the context of motor and cognitive rehabilitation, VEs allow the acquisition of a large quantity of data, minimizing errors and improving the reliability of results. Additionally, measurements can be improved, allowing the examination of parameters that are difficult to capture with traditional *"paper-and-pencil"* tasks (Chae and Lee, 2023). Virtual reality provides an ecosystem capable of dynamically adjusting the difficulty of cognitive and sensorimotor tasks for each patient. Specifically, VR devices facilitate the personalization and adaptation of therapeutic interventions. However, visualizing, selecting, and manipulating virtual objects typically relies on fully immersive setups and 3D interaction devices, which can present challenges for older adults. In fact, immersion achieved with head-mounted displays (HMDs) or Cave Automatic Virtual Environments (CAVEs) can lead to problems such as simulator sickness (Cherniack, 2011).

The main objective of the work presented in this paper is to offer an easy to use and high performance tool to reinforce the ability to carry out an activity of daily living in people with Mild Cognitive Impairment (MCI) and People with Dementia (PwD). In the following section, we present some work based on VR setup and techniques but also on some touch tables with their use in cognitive rehabilitation. In section 3, we present our experimental device called Hôsea and the Virtual Kitchen application including the task, the interaction technique, and the proposed error-free learning method. Finally, we present our preliminary usability results, and then the article ends with a conclusion and presents future work.

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2 RELATED WORK

2.1 VR Techniques

Virtual reality techniques have been used in cognitive neuropsychology since the early 2000s. In 2004, a comprehensive study was conducted by Rizzo et al., (Rizzo et al., 2004). More recently, reviews have been conducted by Smith et al., (Smith, 2023) and Catania et al. (Catania et al., 2024). In a study by Brooks et al., VE enabled an amnesic patient to learn to move around his rehabilitation center (Brooks et al., 1999). Before training, the patient was unable to navigate 10 simple routes within the real unit, all involving locations he visited regularly. Initially, the patient was unable to find simple routes in places he had previously visited. The VE training sessions sig-

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nificantly improved his ability to move around on his own.

In order to avoid the problems caused by immersion in VE, some works have proposed a non-immersive approach. This approach relies on using a simple monitor or a screen with a video projector (Allain et al., 2014; Foloppe et al., 2018; Yamaguchi et al., 2012; Richard et al., 2018; Lecouvey et al., 2019; Klinger, 2006; Cogné et al., 2017). Although these studies showed some efficacy of the proposed non-immersive setup, difficulties were mentioned for some patients regarding the use of the mouse to select or drag-and-drop the virtual objects. A study by Plechatà et al. investigated the responsiveness of a memory task based on a supermarket scenario for young and senior participants using an immersive interface with a headset and low immersion with a computer. The results suggest that the use of VR is tiring for both groups, but that seniors performed better with the computer with minimal side effects (Plechatá et al., 2019).

In a comparative study by Jin et al. on the learning of traditional art among students, the use of a touch table and a VR headset highlighted several aspects. The table proved to be beneficial for quick handling, playing on the quality of its intuitive interface. This also facilitated the dialogue between the experimenters. Conversely, VR has been shown to be more engaging and attractive in the long term (Jin et al., 2021). From these comparative studies, we see the advantages of touch tables in terms of collaboration and accessibility. The approach we promote in this research is to use a touch table that allows direct manipulation of the virtual objects and devices.

2.2 Touch Table Interfaces

Touch tables are present in several industries such as engineering (Kaya et al., 2017), exhibition (van Dijk et al., 2012), music (Cossou et al., 2018) and healthcare (Ro et al., 2023). Historically present since the 1990s, touch tables have experienced strong growth in 2010s (Bruun et al., 2017). Touch table offer an accessible solution adapted to the varied contexts of medical-social centers and is a good alternative in many situations. Different touch table devices coexist. The main differences are characterized by the display and touch interaction technologies. For the display mode, touch tables are divided into rear projection systems and integrated screen systems. Among the tables using projection, the devices vary according to whether they use an external projector or an internal projection. When it comes to screen display tables, there are also different design approaches. The most commonly used are projected capacitive, resistive, infrared, camera optics, and planar scattering on vision (Schöning et al., 2008). Each table offers unique advantages and disadvantages, but most of them offer a natural interaction interface without the need for proxies and with multi-touch interaction capture. This aspect is important for the accessibility of the interface for profiles subject to cognitive disorders and whose use of the controllers may prove difficult (Annett et al., 2012). Additionally, the robustness of the screen provide relative tolerance to sudden movements and imprecise handling (Augstein et al., 2016). Furthermore, the enlarged interaction zone offers freedom of movement and bimanual use of the interface (Augstein et al., 2015). Finally, familiarity with traditional tables and touchscreen devices makes touch tables intuitive interfaces, offering manipulation that closely resembles everyday physical interactions (Annett et al., 2012).

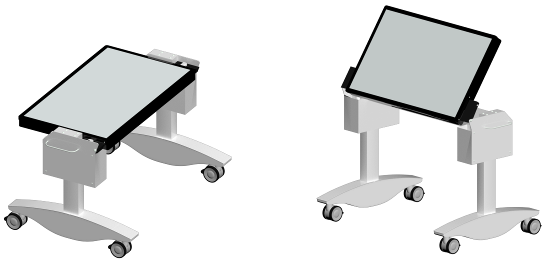
Some studies have discussed the use of touch tables with an elderly population. On a European scale, the *ElderGames* project has developed a solution to improve the quality of life of elderly people (Gamberini et al., 2009). The device was designed to preserve cognitive functions and help prevent cognitive dysfunctions associated with aging. In parallel, Mahmoud et al. identified recommendations for the design and evaluation of touch table games for older adults (Al Mahmud et al., 2008). Gundogdu et al. proposed the use of touch tables for reminiscence therapy (i.e. an intervention aimed at recalling memories in older adults) (Gündogdu et al., 2017).

3 MATERIALS

3.1 The Hôsea Table

Our touch table, called Hôsea, was designed to be used in rehabilitation centers and nursing homes. It is accessible to people with reduced mobility or for use while standing. A 3D model of our touch table is shown in Figure 1. It consists of an open-frame projected capacitive screen with a detection capacity and a display surface of 43 inches (109.22 cm). The two miniature jacks allow the screen to be positioned flat or tilted and the height to be adjusted. The table is adjustable using buttons to operate the two electric jacks. The frame is made of aluminum and includes a side handle at each end to facilitate the movement of the structure. Two columns consisting of two legs with four directional wheels allow the table to be moved.

In use, the medical brakes on each of the wheels



(a) (b)

Figure 1: 3D model of the Hôsea touch table in low position (a) and high inclined position (b).

guarantee the stability of the structure. The central unit integrated in one of the two side boxes is a compact, non-ventilated industrial computer, also designed in aluminum and used for ecological considerations of energy consumption, recycling and robustness. The operating system embedded in the central unit is Windows 10 IOT.

3.2 The Virtual Kitchen

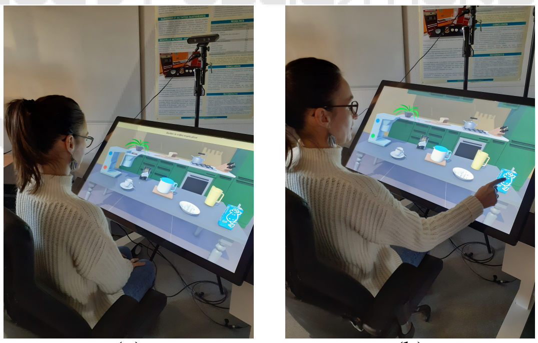
The Virtual Kitchen presented here has already been the subject of publications to which we bring new perspectives through the use of tactile interactions with the Multi-touch Table (Yamaguchi et al., 2012; Allain et al., 2014; Richard et al., 2018; Foloppe et al., 2018). Cognitive stimulation involves certain components of cognitive functions, which are higher functions of the brain: attention, memory, executive functions, visuospatial functions, and language (Lumsden et al., 2016). In this work, we study in particular the rehabilitation of memory and executive functions such as planning in instrumental activities of daily living (IADL).

Figure 2: Front view of the Virtual Kitchen.

The choice of a Virtual Kitchen is justified by the fact that a kitchen occupies an important place in people's daily life activities in their own home. The Virtual Kitchen is illustrated in Figure 2. On the Virtual Kitchen table are arranged all the elements and ingredients necessary for preparing a cup of sweetened coffee with milk. A coffee machine is also available, equipped with a water tank and a compartment for coffee filter and ground coffee. To open the compartment, the touch table allows you to simply touch it with a finger. A button (at the bottom) allows you to turn the machine *on* and *off*. This button, which is initially red, turns green to indicate that the machine is making coffee. During this preparation time, a coffee machine noise is emitted. Another button (at the top) allows you to open and close the water tank. To enhance the realism of the task, appropriate sounds are emitted when the user pours water into the compartment, puts ground coffee into the coffee filter, and pours milk into the cup. The same is true when the objects (jug, milk carton, water jug, coffee carton) are put back on the table.

3.2.1 Setup and Procedure

The setup is illustrated in Figure 3. The user sits in front of the touch table. An Orbbec Astra 3D camera (IR + RGB) is placed high behind the table. This camera can capture a wide range of behaviors to assess and support the recovery process. These behaviors are crucial for both the diagnosis of impairments and the monitoring of a patient's progress during rehabilitation. In particular, the camera makes it possible to capture the kinetics of movements in space which permits a better analysis of patient performance. For example, we can identify patients' hesitations, parasitic, compensatory, and pathological movements.



(a) (b)

Figure 3: User watching the video showing the different actions to perform (a) and selection of the milk jug (b).

The application was developed using Unity3D 2021 game Engine. A main menu allowing to enter a user ID is proposed (Fig. 4). The identifier will be used to name the backup file (CSV). The menu also allows you to specify the time at which the visual and sound signals are triggered. In this case, the application can be used for patient assessment. The menu also allows you to launch the instruction video and start or exit the application. The generated CSV file includes the 3D camera movement data, as well as all relevant events (object selection, errors, number of cues used) and their timing.

Figure 4: Main menu of the Virtual Kitchen application.

The proposed procedure is as follows. First, the user must watch a video that shows the different actions that must be memorized and reproduced (Fig. 3a). Once the video is finished, the application launches. You must then reproduce each action, one by one, in the same order. At the end of the activity, a final view allows you to see the necessary assistance as well as the omissions made. This section provides an opportunity for discussion between the elder and their caregiver on the task performed. The list of data collected during the exercise is given in table 1.

3.2.2 Interaction Techniques

The interaction technique used on the touch table is very intuitive. The user simply has to touch with any finger the object or element of the scene to be selected (Fig. 3b). The corresponding action is then executed automatically using a predefined 3D animation. For those able to perform the required arm movements, a non-automatic mode has also been implemented. In this mode, to move objects, the user must keep his finger on the table surface and perform translation movements.

3.2.3 Errorless Learning

Errorless learning could be useful for patients with cognitive impairments, such as memory disorders or learning disabilities, where making errors can lead to frustration or reinforce incorrect learning. Although this approach has many advantages, such as reducing anxiety, preventing errors, it also has limitations. For example, errorless learning provides heavy guidance and support, which can cause the patient to become dependent. This can limit the ability to transfer learned skills to real-world situations where cues are not present. In addition, for some patients, this high level of support can inhibit problem solving and independent learning, as they are not encouraged to find solutions on their own or deal with mistakes. Finally, by preventing errors, errorless learning may reduce the cognitive challenge and patient engagement.

Table 1: Descriptive list of quantitative collected data.

Data	**Type**
Time	Number (*Secondes*)
Actions	Categorical (*Click on the button; Opening the compartment; Incorrect action; Closing the water tank*)
Total number of clicks	Number
Correct action	Categorical (*Correct; Incorrect; With help*)
Number of sound cues	Number
Number of audio and visual cues	Number
Automatic movement count	Number
Total number of indices	Number
Total number of errors	Number
Waiting time before cues	Number

Keeping these advantages and drawbacks in mind, an errorless learning approach has been implemented to prevent the patient from making mistakes, such as selecting the wrong object or using the machine at the wrong time. For example, if the patient selects an object or activates the machine when he should not, the corresponding action is not performed but the error is logged. If the patient does not perform an expected action, after a while a human voice indicates the action to be performed, for example *'Place the coffee filter in the compartment'*. Then, if the patient still cannot perform the expected action after the same amount of time, the action is repeated verbally and the object to be selected flashes. Finally, if the patient still does nothing, the required action is performed automatically and the next one is moved on.

3.2.4 Task Description

The task consists of a series of 12 consecutive actions. The goal is to prepare a cup of sweetened milk coffee using the proposed ingredients and the coffee machine. The user simply places his finger on the machine's *opening/closing* and *activating/deactivating* buttons. The selected object is animated to automatically perform the associated action. Animations are also used to open and close the coffee and water compartments. The sequence of actions is described in the appendix. To perform each action and trigger the corresponding predefined animation, a simple touch is necessary.

4 PRELIMINARY STUDY

A preliminary study was conducted at the University of Angers to investigate the usability of different application on the touch table including the Virtual Kitchen application. Each healthy participant (*n* = 9) performed a Virtual Kitchen evaluation task, standing and under the supervision of an experimenter. One participant was removed because a technical interruption compromised the validity of his data. The exercise consisted of performing the task of preparing a cup of sweetened coffee with milk without having seen the explanatory video and assistance. The sound was not kept for this test to focus on visual feedback. The characteristics of the participants are available in Table 2.

4.1 Usability Scale

The usability of the Virtual Kitchen application on the touch table was measured with the F-SUS scale (French System Usability Scale) (Brooke, 1995; Gronier, 2021). The test requires answering 10 questions based on a 5-point Likert scale. The final score is given by subtracting one point from the answer for odd-numbered questions and subtracting the answer value from 5 for even-numbered questions. The sum of the questions multiplied by 2.5 gives a usability score out of 100 for each participant. Our result for all participants is 76.56 (*mean*: 76.56; *std*: 11.49) suggesting an acceptable usability of the solution despite strong variations between users. The other scale used is the raw version of the NASA-TLX measuring perceived workload (Hart, 1988; Maincent, 2001). This simplified version does not weight the importance of each subscale between participants and considers them as having equal value. The six subscales are Mental Demand, Physical Demand, Time Demand, Performance, Effort, and Frustration. One question is asked per subscale on a 20-point Likert scale. The overall score is obtained by summing the responses to the question and dividing by 6 before multiplying by 5. The results of the subscales are Mental Demand (*mean*: 7.50; *std*: 6.37), Physical Demand (*mean*: 3.25; *std*: 4.17), Temporal Demand (*mean*: 3.63; *std*: 3.20), Performance (*mean*: 16.50; *std*: 3.30), Effort (*mean*: 5.88; *std*: 6.60) and Frustration (*mean*: 15.63; *std*: 3.02). The mean score of the participants is 43.65 (*mean*: 43.65; *std*: 16.70) suggesting an activity that only requires subjectively moderate workload for an healthy population. The low Mental, Physical and Effort Demand scores for healthy participants suggest relative simplicity of actions. The Frustration score can be explained by the need for gameplay improvements, bug fixes, and the short trial period. Finally, a motivational study was carried out using the SIMS scale (Situational Intrinsic Motivation Scale) (Guay, 2000). The test consists of 16 items grouped into 4 sub-dimensions and are asked using a 7-point Likert scale. The four subscales correspond to Intrinsic Motivation (IM), Identified Regulation (IR), External Regulation (ER) and Amotivation (A). In our experiment we have as result IM (*mean*: 5.19; *std*: 1.59), IR (*mean*: 3.88; *std*: 2.23), ER (*mean*: 3.00; *std*: 1.93), A (*mean*: 2.31; *std*: 1.63). These results suggest a tendency towards personal satisfaction during the task (IM), a moderate importance of the task is considered in the motivation of the participants (IR), external factors play a minor role in the motivation of the participants to the task (ER) and a low absence of motivation is felt (A).

4.2 Qualitative Analysis

We retained the verbal remarks of the participants during the experiments. Regarding the level of difficulty of the task, the participants found it relatively simple with clearly identified problems. For many of them, it is necessary to have to explain the objectives of the task beforehand. The main cause of the misunderstanding of the scenario would be the buttons of the coffee machine. Several comments highlight a difficulty in understanding how to act with the buttons and when the coffee is ready thanks to the light feedback. Some comments are about the choice to limit interactions to a single click. This is a source of frustration when they want to drag-and-drop. The application offers a version that integrates this functionality. Another modality of interaction with step-by-step clicks starting with choosing the object and then pointing to the target was mentioned. Adding sugar and milk at the end of the sequence is also confusing. Several experimenters asked to make the choice of milk and sugar optional or not to define an order between them. Various comments suggested revisiting key aspects of the scenario. The playability of the scenario is too simple without bringing a playful aspect. Some testify that the coffee machine model must be customizable to look more like the one present in nursing homes. Others point out that the choice to make coffee discriminates against those who do not consume it. The need for assistance is also

Table 2: Participant characteristics and subjective condition (mean, standard deviation).

Baseline characteristics (n = 8)	
Age	41.63 (*10.70*)
Sex (% women)	75.00
Laterality (% right)	100.00
Education years	22.38 (*3.11*)
Years of work	15.50 (*9.50*)
Subjective condition (10-Likert scale)	
Health status	7.88 (*0.83*)
Physical status	7.38 (*1.41*)
Mental status	8.00 (*0.76*)
Digital fluency	7.75 (*1.49*)

felt at certain stages, and the differentiation between actionable objects and the decor should be more pronounced. Finally, some technical bugs were recorded during the experiments and will be corrected before interventions in nursing homes.

5 CONCLUSION AND FUTURE WORK

We presented a Virtual Kitchen application on a touch table designed for motor and cognitive rehabilitation in patients with Mild Cognitive Impairment (MCI) and People with Alzheimer (PwD). The aim is to assess and strengthen their ability to memorize and reproduce a sequence of an activity of daily living (preparing a cup of sweetened coffee with milk). The touch table is equipped with a 3D camera on top for motion capture. It specifically allows for direct interaction with virtual objects. An errorless learning method has been implemented to prevent the user from performing and remembering any erroneous actions executed during the task. In addition, visual and sound signals are displayed if the user does not remember the required action. The assumption is that the user will need fewer and fewer hints and will eventually be able to perform the task without assistance.

This tool will soon be put into practice in an experiment involving healthy elderly people, elderly people with MCI and people with Alzheimer's disease. We will use usability tests accessible for elders such as TAM and UTAUT (Davis and Davis, 1989; Venkatesh et al., 2003). We will propose the activity to two groups separately, one with a distribution method on a virtual reality headset, the other on the original touch table proposal. Subjects will first be assessed without any visual or auditory cues, then spend a number of sessions with these aids before being assessed again. A large amount of data will be collected jointly with both approaches and analyzed. This data concerns the evolution of patients during the different sessions offered. In this context, we will study the influence of visual and auditory cues as well as selection errors across different attribution modalities. To study transfer of learning, patients will be tested in a real kitchen and asked to prepare a cup of sweetened coffee with milk using the same or different ingredients and machines.

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APPENDIX

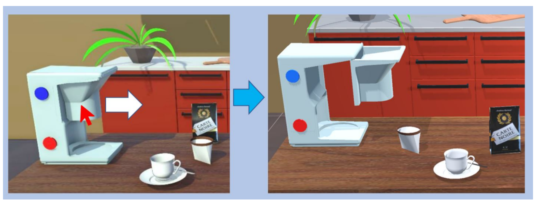

Figure 5: Opening the coffee compartment of the machine.

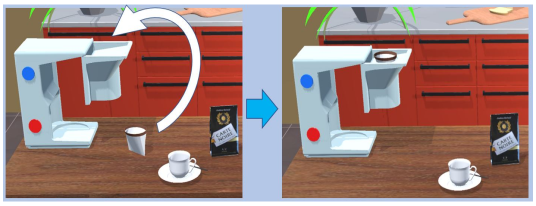

Figure 6: Place the coffee filter in the compartment.

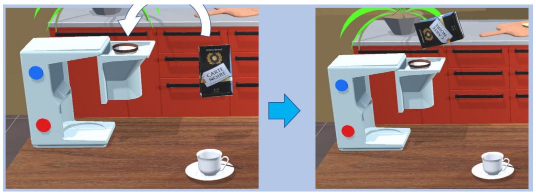

Figure 7: Pour the coffee from the bag into the filter and put it back in place.

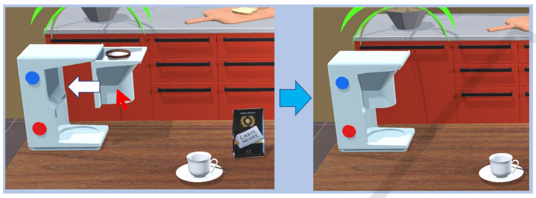

Figure 8: Closing the coffee compartment.

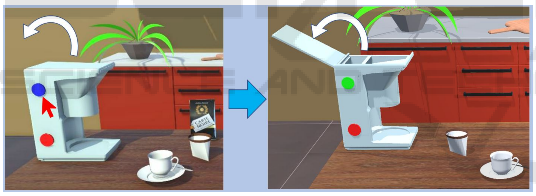

Figure 9: Opening the machine cover.

Figure 10: Pour the water from the carafe into the machine and replace it.

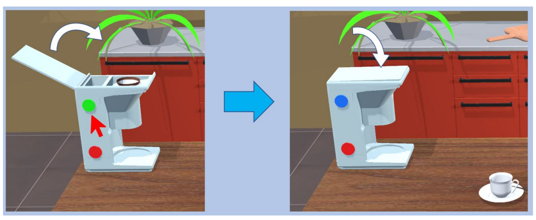

Figure 11: Closing the machine cover.

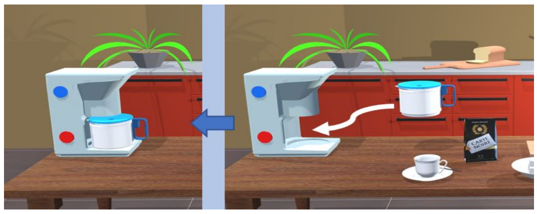

Figure 12: Place the jug in the machine.

Figure 13: Press the red button to activate the machine.

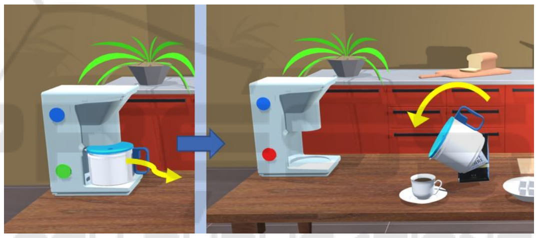

Figure 14: Pour the coffee from the carafe into the cup and return it to its original position.

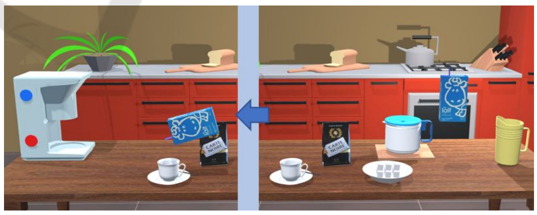

Figure 15: Pour the milk from the milk pack into the cup and replace the pack.

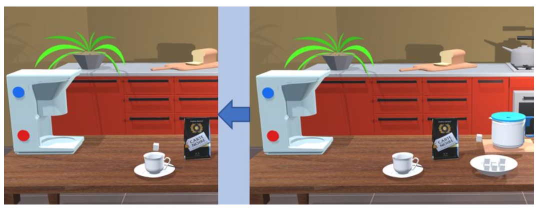

Figure 16: Place a sugar cube in the cup.