Fancy Fruits - An Augmented Reality Application for Special Needs Education

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***Abstract*—Augmented Reality (AR) allows for a connection between real and virtual worlds, thus providing a high potential for Special Needs Education (SNE). We developed an educational application called *Fancy Fruits* to teach disabled children the components of regional fruits and vegetables. The app includes marker-based AR elements connecting the real situation with virtual information. To evaluate the application, a field study was conducted. Eleven children with mental disabilities took part in the study. The results show a high enjoyment of the participants. The study also validated the app's child-friendly design.**

***Index Terms*—augmented reality, special needs education, field study, children**

I. Introduction

'An apple a day keeps the doctor away' is a well-known saying. Nevertheless, not all children might keep it in mind [1, p. 52]. A healthy diet is not only relevant for adults but also for children. Acquainting them with fruits and vegetables might enhance their awareness. Since children with mental disabilities struggle to cope with daily activities [2], they need assistance to get familiar with knowledge concerning everyday life [3]. Further possible restrictions of Special Needs Education (SNE) are a limited attention span and high distractibility within the learning process [4]. The use of educational Augmented Reality (AR) applications might support the learning about phenomena of everyday life, as "the AR technology provides an object layer generated by the computer to the real physical object in real time" [5, p. 1]. The immediate presentation of knowledge in the perceived and relevant environment can facilitate the senseful acquisition of competencies [6].

Our contribution is twofold. 1) We develop an AR application called *Fancy Fruits* targeting science education for SNE. The app's design allows for a direct classroom integration. 2) We present the results of a user study conducted at a school for mentally disabled children. The study shows the application's high joy of use and validates the child-friendly design. The following section describes the app's theoretical background. Subsequently, conception and implementation will be specified. Finally, a field study concerning the application's use with special needs learners as well as a discussion of results and future work will be presented.

II. Theoretical Background

Research has already reported numerous examples of advantages of an educational use of AR. In the present case, relevant benefits are especially increased motivation, attention, concentration, satisfaction, and interactivity as well as an improved learning curve and memory [6]. Also, AR usage "can increase engagement and immersion" [5, p. 3], which could also support the attention of the learner.

Several studies have shown the potential of an educational use of AR in the context of SNE [7]–[9]. Learners with special needs take more time using this technology, but their "performance is similar" [10, p. 47] as compared to other children. Advantages are interactivity as well as the subdivision of the learning content into small separate parts [3]. Another positive aspect is that it provides disabled pupils "control over the speed of learning" [11, p. 1256]. Finally, the possibility for immediate interaction with physical objects is another advantage [10].

Following the learning paradigms of behaviorism, constructivism and cognitivism, one can derive design guidelines for applications. Cognitivist principles for information intake and memory suggest information to be directly presented and received by learners [12]. According to the binary coding theory, exchange of information of the app can occur via auditive and visual output [13]. Regarding constructivism, children should learn via exploration and self-reliant sense-making [12]. Since AR usage is combined with real objects (e.g. scanning a target), an AR app fosters authentic learning [9]. Behaviorism focuses on feedback [12]. Since positive consequences increase the possibility of behavior, immediate laudatory feedback for correct answers enhances the learning process [12]. Also, behaviorism suits mobile learning with short time frames to communicate factual knowledge [12].

III. Implementation

Resulting from the formerly discussed theoretical background, we chose to communicate contents concerning fruits and vegetables to the learners using an AR application. *Fancy Fruits* enables children to become acquainted with the components of several types of fruits and vegetables and their functions. Using the app, learners scan markers with the help of an AR camera to receive educational content. To strengthen their new knowledge, players are able to test themselves via quiz. Within the scope of the app three sorts, each representing one learning package, were implemented: apple, pumpkin, and potato. The following subsections describe the application's structure and its utilization in school context.

A. Context of Use

The app is designed for usage in the elementary grade of SNE in the subject of general knowledge and local history. The target group are pupils from second grade. The teaching concept includes different desks, where the teacher has prepared the fruits and vegetables with markers on it plus mobile devices and papery worksheets. These worksheets contain details about the fruits and vegetables, for example the country of origin or harvest time, as well as the main marker. By scanning the main marker, the respective type of fruit or vegetable is unlocked. Afterwards, the user is able to scan the corresponding fruit or vegetable. The pupils visit the desks successively.

B. System Architecture

Fancy Fruits is subdivided into four parts. Once the user has unlocked the type of fruit or vegetable, they are able to explore the application individually. The recommended workflow suggests the scanning of all respective markers, the completion of the quiz and finally the revision of the recently gained knowledge within the two-dimensional learning environment. During application usage, learners unlock achievements for the completion of tasks. The application was created using the game engine *Unity* version 2018.2.10f1 [14]. The *Vuforia Engine* 7.5 [15] was utilized to track image targets in AR.

1) Scanning: We implemented a scanning process using an AR camera to allow for a self-directed and exploratory learning (see Fig. 1). After the user has scanned a main marker on their worksheet, the AR camera is activated. Facing SNE requirements, the learning content for each fruit or vegetable in *Fancy Fruits* is also subdivided into short units. Therefore, users have to scan the little markers pinned on components of the respective fruit or vegetable separately. This two-step procedure allows the teacher to control the student's workflow. Once a marker is ticked, a virtual agent appears and plays auditive information concerning the selected part. The agent is visualized by the picture of a grey owl called *Emma*. She always appears on screen while acoustic feedback is given and constantly guides the user through the application experience.

2) Quiz: After the scanning process, the quiz can be played. According to behavioristic principles, feedback is included in the quizzes. The fruit examined in the previous scanning process is displayed as a two-dimensional picture (see Fig. 2). The virtual agent challenges the user to select a certain component of the respective fruit or vegetable via touch. Afterwards, positive and negative feedback is orally given by the virtual agent. During the quiz, a status bar provides visual feedback about the progress. Missed instructions can be repeated.

3) Achievements: To receive positive reinforcement in accordance with behaviorism, learners collect achievements by completing the quiz and scanning all markers for each fruit or vegetable. Their purpose is to increase children's motivation. A separate board provides an overview about the gathered badges.

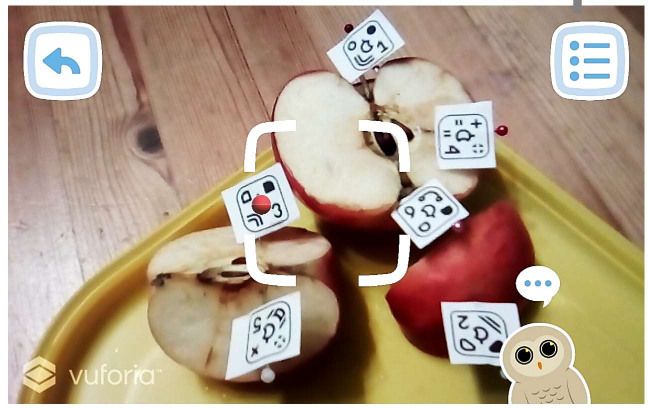

Figure 1. AR camera in the apple's scanning process with the virtual agent *Emma, the Owl* at the bottom, the 'Quiz' button at the top right corner and the button linking back to the main menu at the top left corner of the screen.

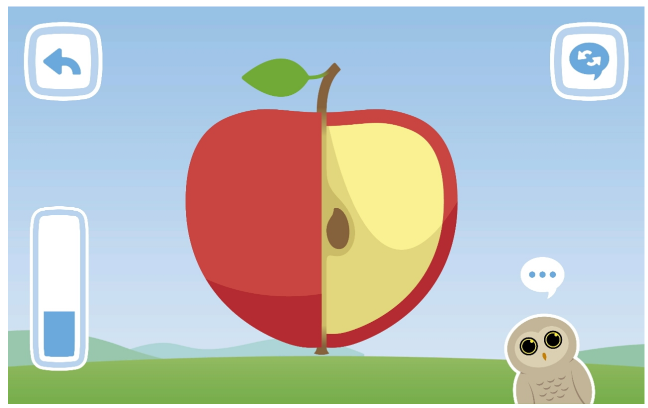

Figure 2. The apple's quiz with the 'Repeat Question' button at the top right corner and the progress bar at the left side of the screen.

4) 2D-Learning: To strengthen the recently gained knowledge, information can be repeated in accordance to cognitivist guidelines in an additional two-dimensional learning environment without the presence of real fruits and vegetables. By touching individual parts of the fruit or vegetable, information similar to the scanning process is orally given by the virtual agent. Ingredients, such as vitamins, are displayed next to the fruits and vegetables.

IV. Study

We conducted a field study to test whether children are able to handle the application on their own. Furthermore, the children's joy of use and the app's child-friendly design had been investigated.

A. Study Design

Focusing on learners with special needs, eleven pupils from a school for mentally disabled persons were recruited. The parents were informed about the study in an information letter and gave written consent in their children's participation. The responsible pedagogues checked and approved the experimental setup.

First, the children were invited to use the application for about 15 minutes. The experimental setup is represented in Fig. 3. An investigator helped the children whenever it was needed. While playing, the screen was being captured using the *DU Recorder* version 1.7.5.5 [16] for further analysis of erroneous entries and handling time. After finishing, the kids filled in their personal worksheets with the help of the investigator.

After their gameplay, they answered 13 questions in a semi-structured interview. The interview guide included questions concerning demography, fun, understanding, design, achievements and perceived learning success. We also asked the children whether they wanted to use the app again and what they thought about the papery worksheets. Lastly, they should list positive and negative details that were not covered by our questions. The interview guideline had been pretested.

Figure 3. Experimental setup with apple, pumpkin, potato, the respective worksheets and the personal summarizing worksheet.

B. Sample

Seven girls (63.64%; age: M = 7.71, SD = 0.95) and four boys (36.36%; age: M = 8.25, SD = 2.22) took part in the study, so a total of eleven children was surveyed. Their age ranged from five to ten years, M = 7.91, SD = 1.45. Most of the children attended the third class of special needs school (n = 6), four children were second graders and two participants were preschoolers.

V. Results

We used the tool *MAXQDA2018* version 18.1.1 [17] for computer-assisted qualitative text analysis to examine the children's interview data. The data gathered from the screen recordings were imported to a *Microsoft Excel* worksheet and analyzed using a coding scheme referring to the children's feelings towards the app concerning their general enjoyment, aesthetic impression, perceived learning outcomes and reuse of the application.

A. Joy of Use and Child-Friendly Design

Regarding the children's practical experience with tablets and mobile applications, eight participants had prior experience with mobile devices. Asking them whether they enjoyed their gameplay, ten kids confirmed they had fun while using the app. The child who did not have fun during the game told the interviewer that it was an exhausting process. Nine pupils wanted to use the application again in the future.

Concerning intuitive use, more than half of the participants (n = 6) needed help operating the application. Only five children stated that they fully understood the app's handling. In regard to the implemented badges, ten kids got excited about the achievements they unlocked. Also, the children liked the application's design (n = 10), with apple (n = 2) and pumpkin (n = 1) being highlighted. One child did not reply to this question.

Furthermore, the participants mentioned some positive features like immediate feedback (n = 1) and ”cool” loading screens (n = 1). One child liked the combination of tablet usage and real fruits and two kids positively referred to the quiz. There were no negative comments.

Regarding the additional teaching material, ten children liked the papery worksheets. The given reasons were nice design (n = 5), interesting information (n = 3) and autonomous editing (n = 1). One participant did not answer this question. Asking about the children's perceived learning outcomes, eight pupils stated that they learned something new during the gameplay. Mentioned topics were the apple's (n = 4), pumpkin's (n = 1), and potato's (n = 1) components as well as the worksheets' content (n = 1). One kid brought up the field of nutrition with vegetables and fruits being healthy.

B. Application Handling

Analyzing the screen recordings, we explored the children's behavior during the tutorial video, the amount of incorrect answers in the quizzes and the time they needed to finish all the tasks.

Starting with the faulty insertions that the participants entered while they were supposed to watch the tutorial video, we detected 5.18 (SD = 5.78) erroneous entries on average, ranging from one wrong entry up to 22 faulty insertions. We calculated means and standard deviations summing up the incorrect answers of each question of the quiz (see Tab. I). The potato related quiz seemed to be the hardest one, especially the eyes of the potato (M = 5.44, SD = 4.67, n = 9) and its sprouts (M = 2.44, SD = 4.80, n = 9). The fewest mistakes were recognized for the pumpkin quiz, which simultaneously was the shortest quiz on average. Tab. II shows the calculated handling time per unit. On average, participants played 14 minutes (n = 11). The range was from 7:45 up to 19:54 minutes. Since the children individually decided which fruit or vegetable they dealt with, not all of the children completed every unit.

Table I
INCORRECT ANSWERS PER FRUIT

	M	*SD*	Min	Max	*n*
Apple	3.89	1.69	1	7	9
Pumpkin	3.78	5.29	0	17	9
Potato	8.56	8.06	0	26	9

Table II
HANDLING TIME PER UNIT

	***M* in minutes**	***SD* in minutes**	***n***
Apple Scan	05:21	01:06	9
Apple Quiz	02:08	01:05	9
Pumpkin Scan	03:04	01:06	9
Pumpkin Quiz	01:17	01:11	9
Potato Scan	02:58	00:56	10
Potato Quiz	01:49	00:49	9

VI. DISCUSSION AND FUTURE WORK

Our evaluation demonstrated the applicability of *Fancy Fruits* for SNE.

A. Study Results

The pupils reported they had fun using the application. Since ”fun is the best motivator” [10, quoted from Prensky, 2001], this is an important finding. The application's design was perceived as child-friendly. Children can repeat the learning material at their own pace. Only minor problems concerning the app's handling were detected. Mainly, the tutorial must be revised. Results from our evaluation indicated that the information should be divided into shorter parts. The best solution to this problem would be an interactive tutorial to diminish erroneous entries as well as to facilitate the apps handling.

Nevertheless, we tested our application only with a small sample size at one school. Thus, a larger study would be necessary to confirm our exploratory results. A longitudinal design might indicate whether the application is able to maintain the children's motivation and interest. Additionally, there exist several types of schools for SNE, which should also be considered in future tests. Despite not having analyzed the learning outcomes, the screen recordings of the quizzes indicated a knowledge gain.

B. Lessons Learned

The lessons learned for *Fancy Fruits* might be of importance for scientists, educators and designers. Upcoming research could refer to the positive feedback regarding the achievements. Apparently, the implementation of gamified elements highly increased the motivation of learners with special needs. The graphical user interface was perceived as child-friendly and aesthetically pleasing. Other learning environments might take the design concept of *Fancy Fruits* into account.

During the field study it was eye-catching that mentally disabled children of same age strongly differ about their attention span. It may be an alternative to work on one fruit or vegetable at the beginning of a lesson instead of agglomerating the learning content. Alike, the worksheets' conceptual design should be reconsidered. Since most of the surveyed children had difficulties in reading the worksheet, the written text may be replaced with picture stories.

VII. CONCLUSION

The paper presented the development of the AR application *Fancy Fruits* which has the aim to help children with special needs to learn about the components of fruits and vegetables. Results from a field study show the app's beneficial potential: a high joy of use and a child-friendly design. Since we interviewed mentally disabled children, this paper provides relevant findings concerning the design of educational AR applications for SNE. As the project's current stage is the experimental design and construction [3], further evaluation and improvement is needed. The implementation of an interactive tutorial and the general design of the papery worksheets should be addressed. Actual learning outcomes might be investigated, especially over an extended period of time.

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