Full-Body Interaction-based Learning Support to Enhance Immersion in Zoos
Evaluating an Electrodermal Activity Response Support System

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Abstract: We are developing a learning support system for zoos that enables children to learn through body movements. For children, the zoo is an important place for science education outside of school. However, learning methods in zoos are mainly limited to observing exhibits and explanations. In addition, when children want to observe animals that are hiding, they can neither touch nor observe them. Therefore, in this study, we develop a body-experience-based learning support system that can be applied in zoos. The system measures the learners' body movements using a sensor, and provides a sense of immersion in the environment where animals live by adapting the surroundings based on these movements. In the first stage of this project, we have developed a prototype that allows learners to jump with animals, and enables children to efficiently learn animals' physical characteristics. In this paper, we describe the results of our experimental evaluation of by measuring physiological responses.

1 INTRODUCTION

Hundreds of millions of visitors worldwide, most of whom are children, experience zoos each year (Wagoner, 2010). For these children, the zoo is a very important place for science learning outside of the classroom (National Research Council, 2009); observing and touching animals motivates children to learn more about the animals and their ecology in detail (Braund, 2006). However, learning methods in zoos are mainly limited to observing exhibits and listening to explanations. Furthermore, children can neither touch nor observe animals that are hiding, making it impossible to make contact with the animals; it is very difficult for children to imagine the ecology of animals by themselves, which reduces their motivation to study. To solve these problems, conventional research has proposed learning support, including providing video content and using tablets (Zarzuela, 2013; Webber, 2015; Tanaka, 2017). However, these studies lack active mass and children's experiences; they are far different from the actual experience of making contact with animals, presenting a fundamental problem. Solving these problems requires a system that enables children to observe animals and have an authentic experience.

Children think hard while playing (Dau, 1999; Levin, 1996). When children use gestures and movements, the learning environment becomes more natural (Grandhi, 2011; Nielsen, 2004; Villaroman, 2011) and children can retain more of the knowledge being taught (Edge, 2013; Antle, 2009). Therefore, we focus on playing while moving the body; by using body movements, we can provide real experiences and impart knowledge.

We are developing a learning support system for zoos that enables children to learn through body movements. In this system, body movement information is acquired by a sensor, and the content operates based on this information. We attempt to provide realistic experiences of animals that are more difficult to contact directly. Furthermore, by reflecting the learners' body movements in virtual space as an observation behavior, the learner feels immersed, and their experience approaches

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authenticity; we therefore expect that they can learn sufficiently about the ecology of animals.

In this paper, we describe the results of evaluating the usefulness of this system by developing and evaluating prototypes as a first step in realizing a system to support learning about animals in the zoo. We quantitatively evaluate interest by measuring electrodermal activity (EDA), which is physiological response that indicates whether children are interested in the animals and motivated by the system.

Figure 1: System concept.

2 LEARNING SUPPORT IN ZOOS

2.1 System

We are developing a learning support system for zoos that enables children to learn through body movements. We use the example of the wildcat, which is a felid belonging to the class *Mammalia*. Wildcats are shy and do not commonly interact with people. However, wildcats can jump high. In zoos, wildcats hide, because they are not good at connecting with people; therefore, they are difficult for children to observe. Our proposed system supports learning about wildcats by using various sensors to measure a learner's position, attitude and movement, and operating a learning system based on these data. Figure 1 shows a schematic of the system; in the space displayed onscreen, the object to be learned changes in conjunction with body movement. The system provides learners with the feeling of being in the environment where the animals live. In addition, real observations of behavior—approaching animals, jumping, etc.—are incorporated to give learners a more realistic experience than just watching exhibits or videos. It is thus possible to increase their motivation to learn and the knowledge obtained. As the animals move according to the children's body movements, the learners identify the animals as realistic, rather than just virtual creatures.

2.2 System Configuration

To implement our zoo learning support system, we are developing a system that lets children learn about ecology of the wildcat while projecting them to an onscreen grassland to jump with a wildcat.

In this system, when a student stands in front of the screen, the region containing a person is extracted, and the learner's body is projected

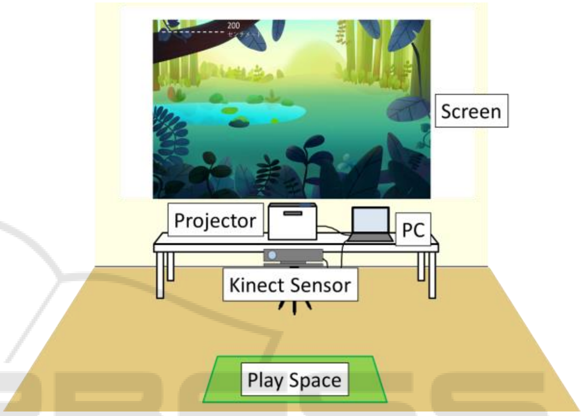

Figure 2: System setup.

with a wildcat by operating the system using body movements.

The height of the learner's jump is measured by a sensor, and the learner also jumps along with a wildcat on the screen; in this way, learners acquire knowledge of the wildcat's jumping ability.

Figure 2 shows that this system consists of a Microsoft Kinect sensor, control PC, and projector. The Kinect is a range-image sensor originally developed as a home videogame device. Although it is inexpensive, the sensor can record sophisticated user location measurements. Additionally, this sensor can recognize humans and the human skeleton using a library in its Windows software development kit. The Kinect can measure the location of human body parts such as hands and legs, and can identify the user's pose with this function and its location information. The Kinect can measure the three-dimensional coordinates of the skeletons of 25 human beings. To ascertain the height of a jump, we measure the coordinates of the learner's ankle. Next, we extract the image region containing a human. In Kinect's human body database, various human body posture patterns

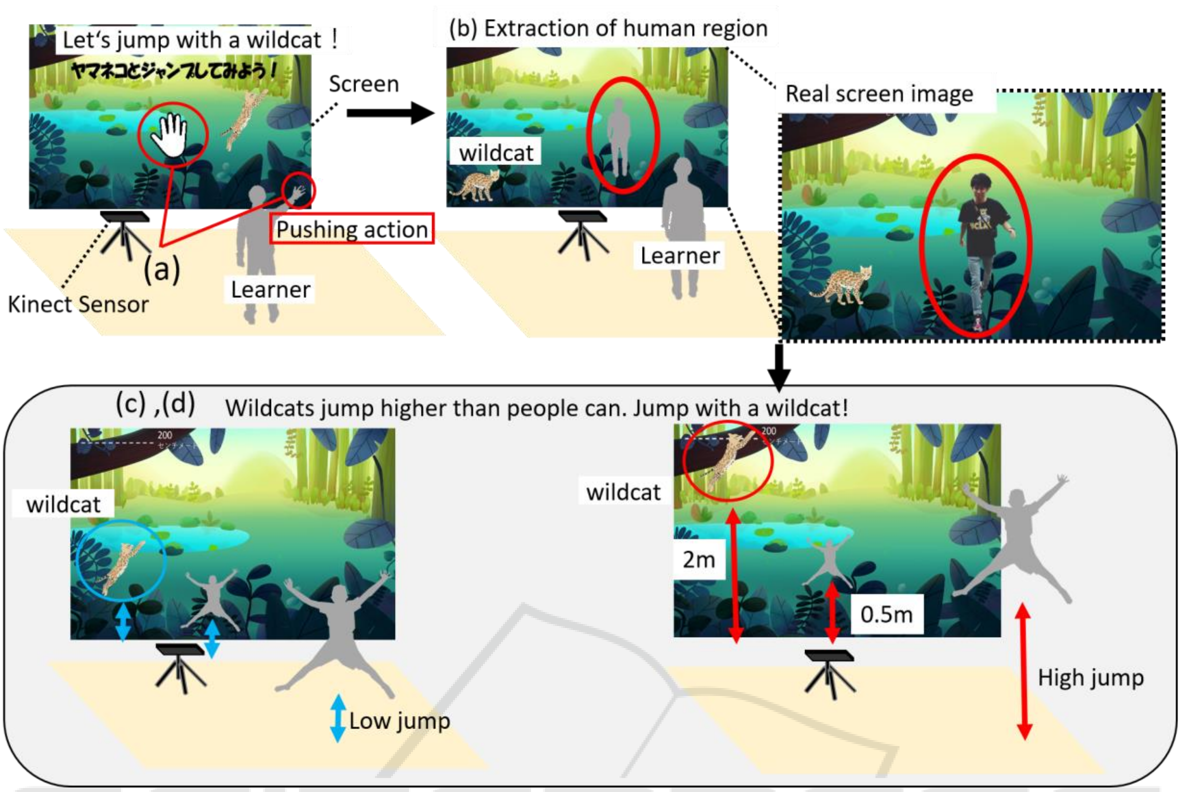

Figure 3: System flow.

are machine learned and the parts of the body are identified using this database.

The functions and flow of the system are shown below:

(a) Operates using the learner's body movement
(b) Projects a person onto the screen
(c) Interlocks body movements and the screen
(d) Teaches animal characteristics.

Function (a) allows the system to operate as directed by the user's hand movements. A learner can click a button by pushing their hand toward the Kinect sensor; the learner starts the game with this action. Clicking the start button brings up a screen for jumping with a wildcat. The learner can start the game with their body as an interface. Function (b) displays the user on the screen by recognizing the sensor region the learner is in. Learners can immerse themselves in the world of a wildcat on the screen. Function (c) allows the user to jump with a wildcat on the screen. The wildcat on the screen mimics the height at which the learner jumps. Learners would be unable to interact in this way with a real wildcat in the zoo, but our jumping system enables learners to develop familiarity with the wildcat. Function (d) gives learners the experience that wildcats are good at jumping. The system digitizes the actual jump heights of the learner and the wildcat. When the learner jumps with all their power, the wildcat is shown at its impressive jump height of around 2 m. Therefore, the learner can experience the fact that wildcats are good at jumping. Figure 3 shows the system flow and its state while performing Functions (a), (b), (c) and (d).

3 EVALUATION

3.1 Objective

In this study, we used the method of immersing the learner in a virtual environment and jumping with a wildcat to learn about the ecology of wildcats. We hypothesized that learners' interests would be piqued by this environment and activity. However, it is possible that children are simply interested in jumping. Therefore, we examined whether children are more interested when jumping with a wildcat or jumping alone. We evaluated interested quantitatively using electrodermal activity (EDA) which is a physiological response. We thus aimed to evaluate the usefulness of our system.

3.2 Evaluation by EDA

3.2.1 EDA

We used EDA to confirm the presence or absence of children's interest. EDA is the change in the electrical properties of the skin's surface due to sweating caused by excitation or tension. The method of measuring apparent resistance by passing electricity through the skin is referred to as the energization method. The sustained activity measured thereby is referred to as skin conductance level (SCL). Transient activity is referred to as the skin conductance response (SCR).

The brain's limbic system is comprised of the cingulate gyrus, hippocampus, and amygdala. Recent studies have demonstrated that the limbic system is activated when a person is interested. In addition, this system is known to have a close relationship with emotion (Boucsein, 2012). When people are visually interested in a subject, they experience a pleasant feeling and an increase in arousal, which changes the electrical activity of the skin and produces an SCR (Yoshida, 2014). Figure 4 shows that if interest is generated, the SCL and SCR reaction values can be measured from variations over relatively long and short periods, respectively. When interest occurs, a reaction appears. By contrast, no reaction appears when there is no interest. Therefore, we judge the presence or absence of interest in the proposed system using EDA.

3.2.2 Method

Twelve fifth- and sixth-grade students (7 boys and 5 girls) from elementary schools attached to the national university corporation participated in an experiment at the Hyogo Prefectural Museum of Natural History on October 27–29, 2017.

We attached an electrode that measures EDA to a fingertip on each subject's right hand, as shown in Figure 5. The participants each experienced the system individually.

First, children experienced the proposed system for jumping with a wildcat. Next, they simply jumped. We measured fluctuations in EDA with each experience.

3.3 Result

First, we examine representative experimental results from one user. Figure 6 shows a graph of the change in EDA when experiencing the proposed system, whereas Figure 7 shows a graph of the change in EDA when simply jumping in front of the screen. The horizontal axis of the graph is time

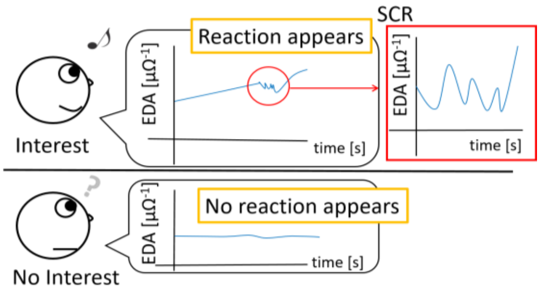

Figure 4: EDA.

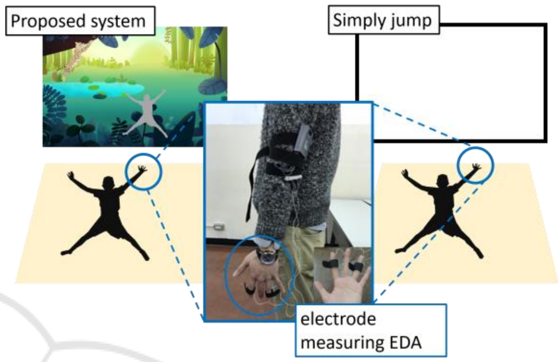

Figure 5: Experimental environment.

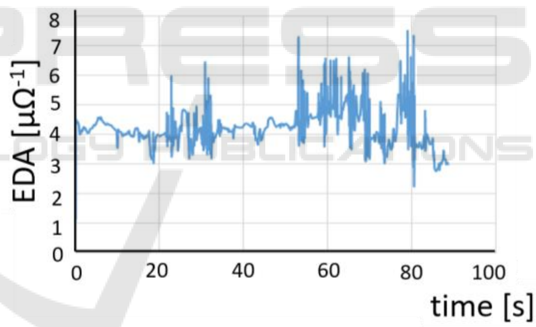

Figure 6: EDA in the proposed system experience.

variation and the vertical axis is the degree of change. From Figures 6 and 7, we see that interest occurs when users experience the proposed system.

We evaluated our results by calculating the number of occurrences of interest in each result compared to the number of trials. When jumping with a wildcat, interest occurred 29 times. However, when simply jumping, interest was demonstrated 6 times. This result quantitatively confirmed that learners are not interested in jumping, but that they are interested in jumping with a wildcat. Thus, it was possible to quantitatively evaluate the number of occurrences of interest.

Next, we considered the experimental results of all the subjects, which are listed in Table 1. Statistical tests were conducted on the EDA results in the two scenarios, and a t-test analyzing the difference between the average EDAs produced a result of $p < 0.01$, which corresponds to a significant difference.

With this result, we have demonstrated quantitatively that children are interested in the wildcat and motivated to learning about the wildcat after experiencing the proposed system. Figure 8 shows children experiencing the proposed system.

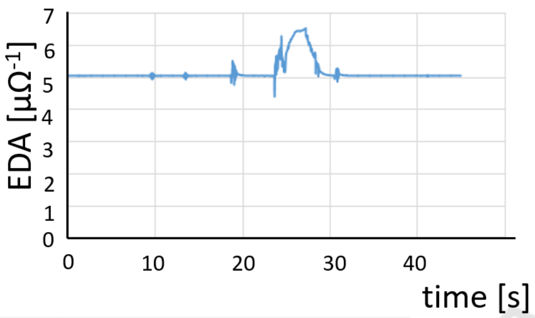

Figure 7: EDA when simply jumping.

Table 1: Results of all subjects.

	number of EDAs	
Subject	Proposed system	Jumping only
1	29	6
2	15	10
3	34	8
4	16	2
5	15	7
6	25	19
7	23	21
8	40	22
9	24	8
10	35	18
11	21	18
12	23	12

Figure 8: Learner in the system experience.

4 CONCLUSIONS

In this paper, as a first step in implementing a learning support system for children visiting zoos, we proposed a system that allows children to jump together with a wildcat using a Kinect sensor. We also described the quantitative evaluation results of measuring EDA, which is physiological response, as a metric of whether children are motivated by and interested in virtual contact with animals.

From our experiment, it became quantitatively clear that learners can be interested in animals and motivated by the proposed system experience, which enables them to jump with virtual animals on a screen following their body movement. This result demonstrated that the proposed system effectively provides a platform for observation of and learning about the wildcat, an animal that is difficult to observe directly in a zoo.

In the future, it will be necessary to evaluate knowledge acquisition and conduct experiments at real zoos. First, children observe the system after observing a rooster at the zoo. Then, we will evaluate the acquisition interests and knowledge, which with further the system's development. This experiment is already scheduled.

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