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Procedia Computer Science 198 (2022) 77–85

Procedia Computer Science

www.elsevier.com/locate/procedia

The 12th International Conference on Emerging Ubiquitous Systems and Pervasive Networks (EUSPN 2021)
November 1-4, 2021, Leuven, Belgium

Empowering Reality: The Development of an ICT4Injury Prevention System to Educate Parents While Staying at Home

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Abstract

Injury at living spaces accounts for over 70% of injuries among children under the age of 5 years and its prevention is essentially important in terms of children's health. This paper proposes an effective method of integrating knowledge graphs along with object recognition to determine the dangerous situations for infants and provide preventive measures to avoid such situations. This also leads to the proposal of a new system called "Empowering Reality (ER)" that enables a lecturer to educate parents on preventing childhood unintentional injuries at home while communicating with the parents using Augmented Reality (AR) technology. The proposed ER system consists of knowledge graphs for explaining dangerous situations, an online video capturing part, and a situation recognition part. This paper describes major advantages of knowledge graphs that takes into consideration of not only relation between objects and injuries but also dangerous layouts with the help of "inclusion" and "collocation" features. The feasibility and effectiveness of the system was evaluated through tests among 11 parents. The system allows the lecturer to conduct in-situ suggestion on specific preventive measures adapted to the home environment via online learning.

Keywords: Injury Prevention, Online Education, Augumented Reality, Empowerment, Knowledge Graphs, Situation Recognition

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Peer-review under responsibility of the Conference Program Chairs
10.1016/j.procs.2021.12.213

1. Introduction

Preventable injuries are the leading cause of death in children around the world. Globally, approximately 2000 children under the age of 14 years die because of injuries every day [1], and this has become an important and critical theme in the United Nations Sustainable Development Goals (SDGs) [2]. In 2019, 13,582 children aged 0–12 years in Tokyo, Japan were transported to an emergency room [3]. About 70% of these injuries occur in children under the age of 5 years, with the top five leading causes of injury-related emergency transport being falls, suffocations, collisions, burns, and pinches [3]. A safe home environment is crucial to prevent injury, especially among children under the age of 5 years, who spend most of their time at home. Some studies estimate that 90% of injuries in young children occur in and around the home under caregiver supervision [4]. Although child supervision is not scientifically proven as effective to protect injuries [4], there is no doubt that caregivers are responsible to create a safe environment for their children. Therefore, empowering parents and caregivers is the key to injury prevention.

When we apply the degree of empowerment as proposed by World Bank [5] to childhood injury prevention, we can assess the degree of a parent's empowerment for prevention by analyzing 1) whether he/she has sufficient knowledge and skills for prevention (existence of choice). If yes, 2) does he/she have an intention to take the necessary preventive actions (use of choice)? If yes, 3) does he/she actually takes the necessary preventive actions (achievement of choice)? Education plays a huge role in enhancing empowerment of parents. Home visitation is a traditional way to educate parents, and it has a positive impact on reducing the risk of injury [6,7]. However, due to COVID-19, it becomes difficult to visit families with small children. The development of virtual education systems has rapidly and inevitably progressed in response to community needs. For instance, *Charile's House* [8] opened an interactive virtual house that demonstrates the types of injury risks at home. Safe Kids Worldwide, a global leading organization working on childhood injury prevention, also developed a new system using Virtual Reality technology to educate parents [9]. These virtual education systems increase opportunities to reach more parents and spread the word about the importance of injury prevention. But these systems are oftentimes a one-way system and cannot answer questions that parents have in real time. In addition, the information provided by these systems are highly generalized, which makes it even more difficult for many parents to apply it to their own home environment. In some cases, parents cannot install safety devices because of the layout of their home or rules in a rental agreement. Thus, a two-way system is important for injury prevention education.

To overcome these challenges, we proposed a new system for home injury prevention education called "Empowering Reality (ER)". This system enables a lecturer to educate parents at home through real time communication utilizing augmented reality (AR) technology. This study aimed to achieve the following:

1. identify possible actions parents can take to increase home safety while also discussing challenges or other reasons for not being able to take actions.
2. explore the potential in achieving empowerment of parents using the proposed system.

In this paper, we provide an overview of the ER system and then discuss the results of a feasibility study conducted to evaluate its implementation.

2. Development of Empowering Reality: System Overview

2.1. Overview of the proposed in-situ support system.

Fig.1 shows the outline of the system proposed in this study. Online information presentation means using Face-to-Face communication apps such as Zoom or Skype to diagnose the living environment on the spot and present necessary information on injury prevention. First, we use the learner's device (Parent's PC) while taking part in the online learning and get a picture of the indoor environment (like living room, bedroom, kitchen etc.) with a webcam or a smartphone. The live data is then received at the instructor's end (Instructor's PC). Then, the captured image is processed to identify (potentially) dangerous objects which can henceforth, lead to a dangerous situation. The recognition result and the information on measures to prevent the potential accident/injury are displayed by virtue of screen share with the parents.

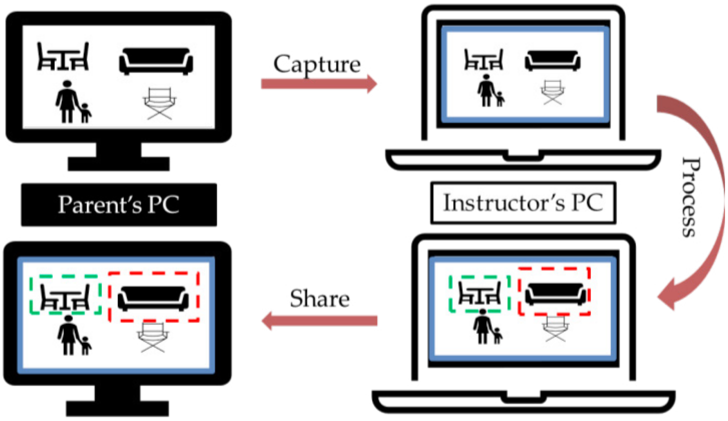

Fig. 1. An image describing the process of presentation system.

2.2. Implementation of basic functions of the in-situ support system.

There are two main underlying technologies used in the proposed system. Firstly, "Knowledge Graphs" help us organize bigdata in the form of attributes and relationships that makes it easier to visualize the information flow and extract required data effectively [10]. "Object Detection or Image Recognition" is one of the important techniques used in the field of computer vision to detect multiple objects in an image or video especially for real time surveillance [11].

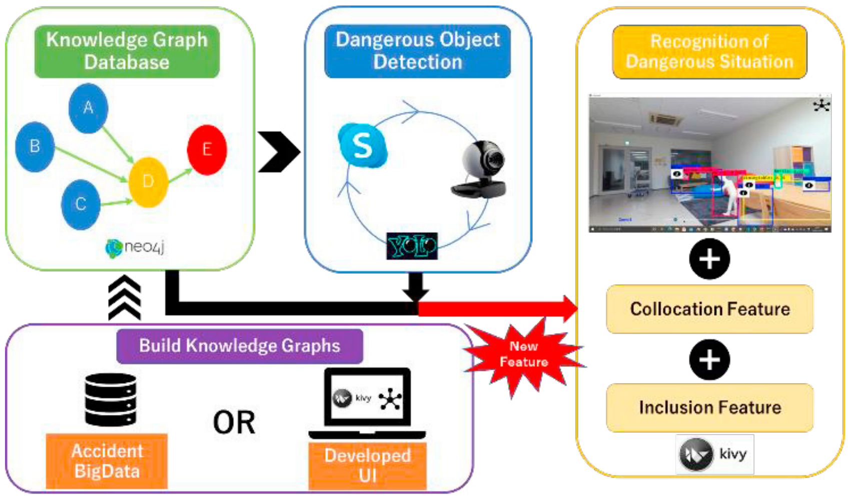

Fig. 2. System configuration for the detection of dangerous situations.

Fig.2 shows the detailed configuration of the presentation system proposed in this study. First, the image of the home obtained from the Web camera is acquired via online communication tool like Skype or Zoom, and dangerous objects are recognized. Then, system refers to the knowledge graph database, that not only helps in recognizing dangerous objects but also the dangerous situations caused due to relative position of the detected objects. Information on the detected dangerous situations and preventive measures are presented to the parents. The developed system also provides a support for creating and registering knowledge graphs on dangerous situations in the database that consists of various details on the relationship between an accident and an object (No. of Injuries, Age group prone to such injuries etc.). Kivy, a python-based GUI tool is used for the application development.

2.2.1 Knowledge representation technology related to dangerous situations.

As for the accident situations, we created an ontology regarding the relative arrangement of dangerous objects and the relationship between objects and accidents as shown in Fig. 3 using Neo4j [12]. Fig. 3(left) shows how knowledge graphs can be used in this study. A "Node" represents a dangerous object(blue) or accident(red) that occurs in a general household, and by connecting these nodes, it represents the "Relationship" between the objects and the accidents. The relationship here is the relative position between the objects, the causal relationship with the object or accident, and so on. As shown in Fig. 3(right), the positional relationship is considered dangerous when a window is above the sofa or blinds that may have cords lead to suffocation if strangulated on the neck. In this way, using knowledge graphs not only helps identify the danger due to a single object but also define the potentially dangerous situations arising due to the positional relations of multiple objects, and deduce from the larger part of the main object, about the possibility of having small parts such as cords which are difficult to identify even with the help of image processing techniques.

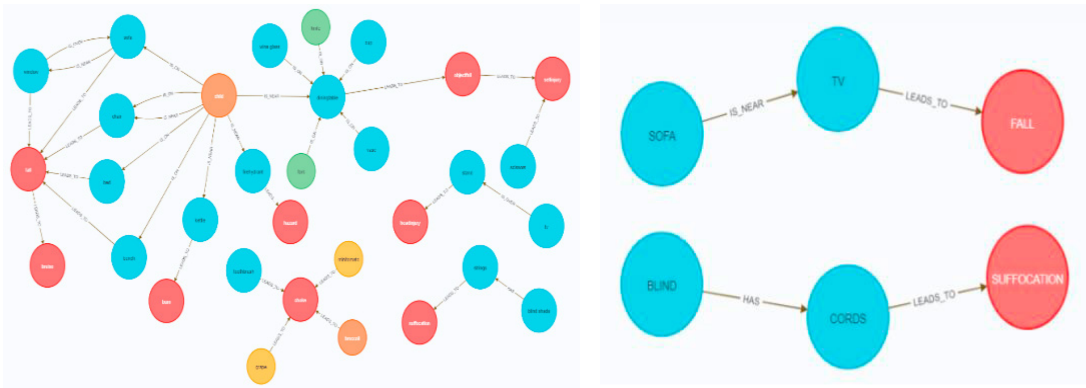

Fig. 3. An example of knowledge graph showing the dangerous relative positions between the objects and the accidents that can occur due to such positions(left). A specific example of dangerous situation implemented using knowledge graphs(right).

Although accident situations vary widely, the accident information data bank system of the National Consumer Affairs Centre of Japan [13] and the Kids Design Circle, Japan [14], provides a possible way to define the actual accident situation occurring within indoors by referring to their open dataset. In that case, as shown in Fig.4, we also implemented an interface to define dangerous positional relationships using an image. When an image is input, objects are recognized, and by selecting the suitable objects and drop-down menus available, one can easily create a knowledge graph. It is then accumulated in a database and can be used for recognizing dangerous situations.

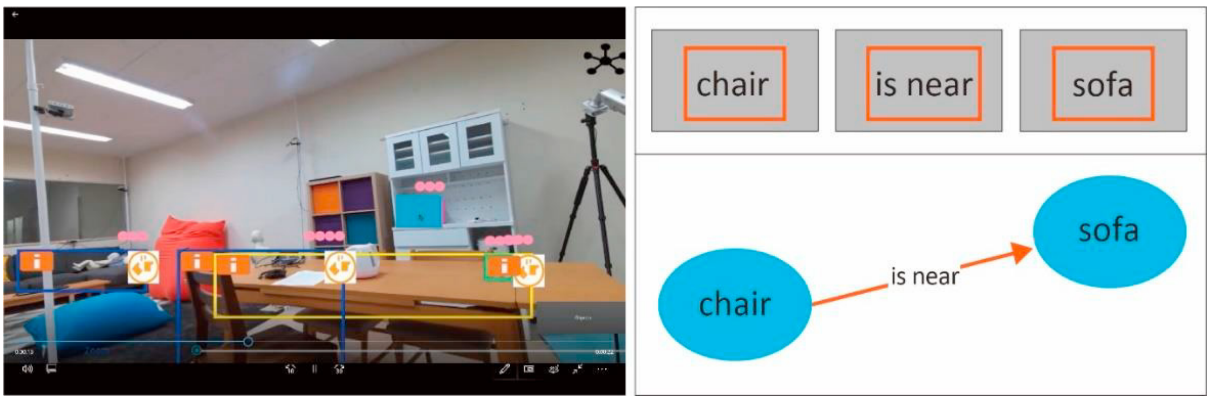

Fig. 4. An interface to create knowledge graphs using object recognition.

2.2.2 Dangerous situation recognition technology using image processing.

For object recognition based on indoor environmental images, we used a pre-trained neural network called YOLOv3 [15]. Recognition of dangerous situation is achieved by combining the use knowledge graphs proposed in this study along with the object recognition. Fig. 5(left) shows how the system performs the situation recognition in a simulated living space environment constructed within our laboratory. To validate the study, we considered 15 types of common dangerous objects that are present in the general households. Our system detects these predefined dangerous objects along with dangerous arrangements and details of the situation is presented when lecturer clicks the "i-buttons". Currently, we are also developing on presenting the severity of the injury (pink circles). On a scale of 1-5, “1” indicates “least priority” and “5” indicates “highest priority”. Prioritization of these risks are based on multiple factors like child’s age, no. of. past accident cases, relative position of objects etc. This will help parents understand which risk is more dangerous and suitable actions that needs to be taken as soon as possible. On clicking the “i-button”, a detailed information about dangerous objects will be displayed as shown in Fig.5(right). The details include: 1) An illustration showing how exactly is the situation dangerous, 2) Preventive measures that can avoid such situations 3) Details on what and how safety goods can be bought (QR code etc).

Fig. 5. An example showing how the system provides information related to a dangerous situation.

2.3. Verification of dangerous situation recognition (Inclusion & Collocation feature) using knowledge graphs.

Fig. 6. An example of inclusion knowledge graph, where window blind is considered a dangerous object that may have small parts like cords(left). An example showing how the system identifies the dangerous layout(right).

In this research, we created knowledge graphs that contains the inclusion relationship of dangerous parts (Inclusion Graph) along with the recognition of dangerous objects. Using Inclusion Graphs, it is possible to assume certain dangerous parts that may be present in a relatively larger part of the identified object in an image, because such small parts are not actually visible from the image itself. Fig.6 (left) shows the recognition result of the window blind, which is one of the objects containing such dangerous parts. Blinds that are commonly found in ordinary households, may contain cords (circled in green) that can lead to strangulation on the neck causing suffocation among infants. In this case, presence of cords is assumed upon blind detection. The current image recognition technology depends on the image resolution and is often difficult to recognize small parts. By creating a knowledge graph that can consider the possibility of existence of small parts that are difficult to recognize using images alone, we can provide much more useful information regarding the dangerous situations.

We also created knowledge graphs that help detect dangerous layouts not just due to a single object but due to the positional relations of multiple objects (Collocation Graph). This is not possible to accomplish with mere image recognition. The collocation graph is implemented by defining the positional relations of the objects such as "Is-Above, Is-Below, Is-Near". The steps for the estimation of dangerous situations is as follows. Firstly, the system recognizes the dangerous objects in the input 2D image based on the knowledge graph database. Once recognized, the center point of each object is calculated, after which positional relations of the objects are estimated. If the obtained relationship and the relationship information in the knowledge graph database match, it is recognized as a collocation-based dangerous situation. As shown in Fig.6 (right), "sofa" and "window" are recognized as dangerous objects at first. Then, positional relation is estimated as: "window" "Is-Above" "sofa". Since this relation is found to match exactly with the information in the knowledge graph database, it is identified as a dangerous situation.

2.3.1 Detailed positional relationship calculation.

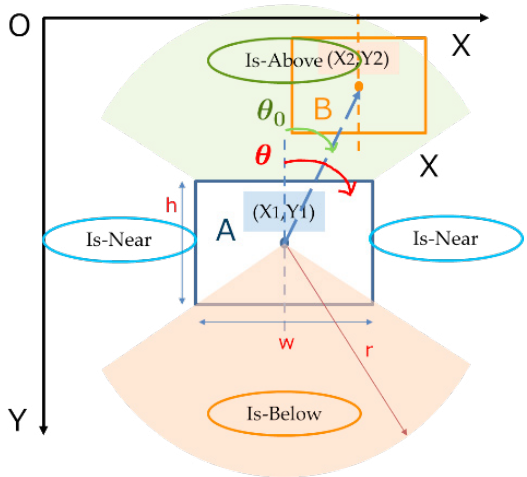

Fig. 7. A diagram showing the estimation of positional relation among multiple objects.

Fig.7 shows a method for calculating the positional relation between dangerous object **A** and **B**. When a dangerous object is recognized, the centre position ***(X1, Y1)*** and ***(X2, Y2)*** of each object and the height **h** and width **w** of the box surrounding the objects are known. The method for finding the positional relation of object **B** with respect to object **A** is as follows. First, the position of object B is estimated as "above" or "below" object A from the Y-component as shown in (Eq. 1).

$$\begin{cases} Y2 < Y1 \;\; \text{Above} \\ Y2 > Y1 \;\; \text{Below} \end{cases} \tag{1}$$

In case of Fig.7, position of object **B** is estimated as "above" object **A**. Next, we calculate $\boldsymbol{\theta_0}$ **,** which is the angle between line joining the center of both objects and the vertical line passing through center of object **A** (Eq.2).

$$\theta_0 = \tan^{-1}\frac{X2-X1}{Y1-Y2} \tag{2}$$

If **Y1=Y2**, the objects are placed side by side parallel to the x-axis ($\theta_0 = 90°$). In that case, the relation becomes "Is-Near". Otherwise, the range of "Is-Above" or "Is-Below" region is calculated accordingly which is determined by $\boldsymbol{\theta}$ (Eq.3).

$$\theta = \tan^{-1}\frac{w/2}{h/2} \tag{3}$$

Using Eq.2 and Eq.3, if $\boldsymbol{\theta_0} \in [-\boldsymbol{\theta}, \boldsymbol{\theta}]$ is satisfied, the relation becomes "Is-Above". If the conditions are not met, the relation becomes "Is-Near". For example, in Fig.7, $\boldsymbol{\theta_0} \in [-\boldsymbol{\theta}, \boldsymbol{\theta}]$ and hence the positional relation of dangerous object **B** is considered as "Is-Above". Similarly, it is possible to deduce the positional relation as "Is-Below" by the same approach, if object **B** was placed below object **A**.

3. Feasibility Study of the Developed System

3.1. Methods

We used snowball sampling to recruit participants for this study. The online education proceeded as follows: 1) each participant accessed a provided URL by using his or her smartphone or tablet computer; 2) the participant watched a 15-minute lecture on home safety; 3) the living space of the participant, such as his or her living room or kitchen, was shown on video as a virtual home visit; and 4) the risks detected by the ER system during the virtual home visit were discussed. All online education sessions were conducted one-on-one. The participant and the lecturer used information provided by the system to discuss what preventive measures could be taken to prevent injuries and, in some cases, the reasons for not taking action. When the participant explained difficulties to the lecturer regarding taking preventive measures, the lecturer suggested possible alternatives that would reduce the risk of injury and help create a safer home environment. The online education session took 30–45 minutes depending on each participant's home environment. All participants were then asked to take a survey for evaluating the feasibility and effectiveness of the developed ER system, with responses given on a six-point scale. The survey questions are listed in Table 1.

Table 1. Survey Questions

1	Do you think there is anything that you can do to prevent serious injury or death? If yes, please specify.
2	How important do parents and caregivers learn about injury prevention? [1] = Not very important, [6] = highly important
3	How confident are you to take preventive actions for injury risks detected by the system? [1] = not very confident, [6] = highly confident
4	Please let us know some challenges you face in taking preventive actions (e.g., Safety goods are expensive, do not know which ideas are good, it is just bothersome etc.)
5	Were you previously unaware of any of the risks detected by the system?
6	How useful do you think was the ER system in preventing injuries at home? [1] = not very useful, [6] = highly useful
7	How effective was the ER system in motivating you to create a safer home environment? [1] = not very effective, [6] = very effective

3.2. Results

In total, 11 parents participated in this feasibility study. All participants answered "yes" in response to question 1, and examples of specific actions included learning the types of most frequent injuries, knowing what to do to prevent injury and change their behaviors, using door guards to prevent fingers from being jammed, and rearranging furniture. When asked about the importance of learning about injury prevention for parents and caregivers, all the participants responded that it was very important. In response to question 3, four participants indicated a confidence level of 3 or 4, and seven participants indicated a confidence level of 5 or 6. In relation to question 3, examples of challenges that participants faced in taking action included the following: the appropriate timing to take action was unclear, they were too busy to find safety goods, they were unsure which safety standards should be followed, they could not install safety goods because of their home layout, and they did not know which action needs a higher priority. In response to question 6, 54.5% of the participants said that they had learned new injury risks. Regarding the usefulness of the proposed ER system, 36.4% indicated level 3 or 4, and 63.7% indicated level 5 or 6 (Figure 8, left). When asked about how effective the ER system was for motivating parents to create a safer home environment, all participants indicated level 5 or 6 (Figure 8, right).

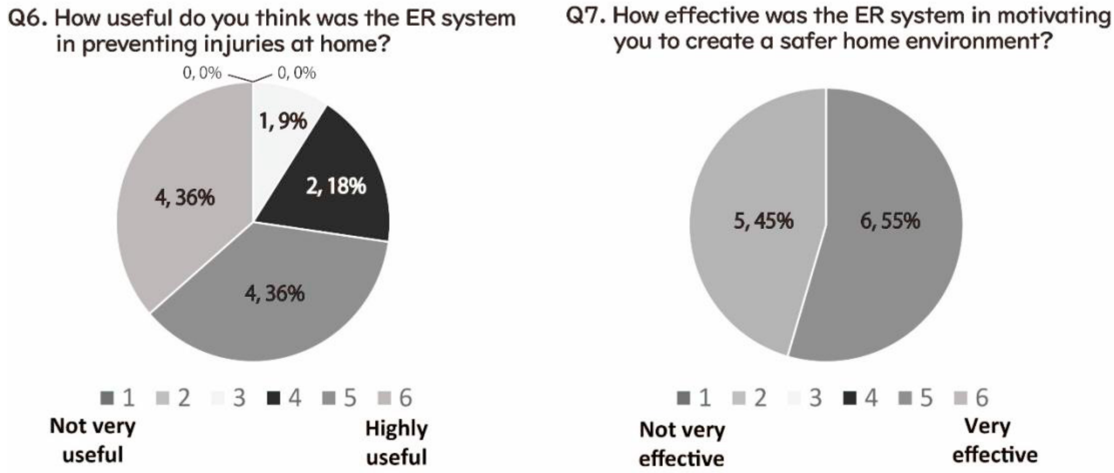

Fig. 8. Response to question 6 and 7.

4. Discussion

In this study, we developed the ER system, which enables a lecturer to educate parents on childhood injury prevention at home while communicating using AR technology. Our newly developed ER system allows lecturers to discuss injury risks with parents and find possible actions together, which was one of its primary objectives. We strongly believe that human–AI collaboration is critical for maximizing the ability of parents to overcome optimistic biases and hectic daily routines, which is also the reason for developing this system. ER should not only indicate injury risks and instruct parents about what to do, but also accept parents' beliefs and lifestyles; this cannot be achieved by AI alone. The survey results indicated that all parents understood the importance of learning about injury prevention and creating a safer environment for their children, but most of them faced challenges in taking all necessary actions. These challenges were caused by the difficulties associated with finding time to search for safety goods and understand safety standards. An ER function that provides a Quick Response (QR) code to parents could resolve this problem. Providing a QR code could save time for parents and allow them to spend more time carrying out actions. As previously mentioned, according to the World Bank, empowerment can be measured by three factors: existence of choice, use of choice, and achievement of choice. Regarding existence of choice, the ER system helped parents recognize the existence of choice. The lecturer verbally explained the injury risks and suggested various types of preventive measures suited to each parent's living situation. In addition to the lecturer's explanation, the ER system helped parents identify risks in their living space visually and indicated available choices for prevention. Regarding use of choice, discussing reasons for unable to take actions and finding alternatives for common actions increased the chances of changing the parents' behaviors. Dialogues between the lecturer and parents also promoted the degree of use of choice. Regarding the achievement of choice, parents possibly took the necessary actions immediately during the online sessions. The ER system clearly indicated where to pay attention at home, and the lecturer tailored information specifically for each participant. This human–AI hybrid support could contribute to achievement of choice by promoting parents' perceived susceptibility and injury severity. In fact, some parents took the actions recommended by the ER system during the feasibility study. From the perspective of the lecturer, the ER system is a very useful tool for remembering how to educate parents because it is sometimes difficult for even professional educators to notice injury risks that are very different from home to home. Moreover, knowing parents' various reasons for not taking the preventive actions could help lecturers understand how to improve their education provision. Although this study is an ongoing work, our ER system has shown great potential for achieving empowerment of both parents and lecturers.

5. Conclusion

In this study, we focused on parents' empowerment to prevent childhood injuries at home. We proposed and developed a new online education system that is one step ahead of AR. In the current era of the 100-year lifespan, empowerment could be one of the most important themes in our society. Our newly developed ER system provides an unprecedented opportunity for researchers, practitioners, educators, and parents to move the field of injury prevention education forward. The same system could be applied to various fields of education such as safety education for children and people with disabilities. Moreover, we believe that improving our ER system could help meet the SDGs by enabling parents to access education (SGD 4), reduce social inequalities (SDG 10), promote healthy lives (SDG 3), and create strong ties between researchers and community members (SDG 17).

Acknowledgements

This work was supported by the New Energy and Industrial Technology Development Organization (NEDO) and JSPS KAKENHI Grant No. JP 20K21052 and JP21K13566.

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