Assessing a Virtual Baby Feeding Training System

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Figure 1: *The virtual baby as seen in the simulation and viewed by a user.*

Abstract

Currently a considerable amount of time and resources are spent helping parents overcome issues related to feeding young infants. Designing interactive virtual feeding scenarios is a preventative means to reduce the adaptation process time for newly made parents, but also help new parents improve their approach to feeding their children. In this paper, we present a case study on using and assessing a virtual reality infant feeding application. Our results show that virtual training can increase the efficiency of feeding depending on the different behaviour of the child.

CR Categories: I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—; I.3.8 [Computer Graphics]: Applications—; K.3.1 [Computers and Education]: Computer Uses in Education computer-assisted instruction—;

Keywords: Virtual Reality, Infant Feeding Difficulties, Human Computer Interaction, Presence in Virtual Reality, Serious Games, Education and Computer Graphics, User Studies

1 Introduction

Problems associated with feeding infants are estimated to cost the British National Health Service (NHS) £70 million each year. The importance of studying feeding difficulties in early childhood has been increasingly recognised [Cooper and Stein 2006]. However, the body of research tends to focus on severe cases resulting in compromised growth and consequent referral for professional help. Feeding difficulties encompass a wide spectrum of behaviours sometimes manifesting in mild faddiness, which many would consider within the range of normal behaviour, through to food refusal. Parents may not seek help if they manage to accommodate their child's eating behaviours and the child's weight does not suffer. The parents may make the (possibly wrong) assumption that all is well if the child steadily gains weight. In addition, in some cases parents may fear criticism from health professionals.

We offer a VR training application as a new innovative medium to be used as a preventive strategy for parents. The VR application can provide simulated exposure to real feeding situations with possibility to explore different reactions from the baby while changing parameters of the baby's mood. VR simulations can only be considered successful if its users have learnt a desired skill set or knowledge through the game. From a developer perspective, it is crucial to evaluate the impact of the training provided in order to improve the system. It may be difficult to compare results of the training success with other results due to the lack of similar systems that could be used as a reference for comparison. In this paper we assess the results of a group of users, and provide an in-depth discussion of the results.

The remainder of the paper is organised as follows. Section 2 details the problem of feeding difficulties and presents related work in using VR as a tool to help people overcome existing real world problems. The design and framework for our application is presented in section 3. Section 4 overviews the experiment setup and how users interact in the software. Results and a discussion of their implications are detailed in section 5 and 6. Finally, conclusions and future work are presented in section 7.

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Afrigraph 2010, Franschhoek, South Africa, June 21 – 23, 2010.
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2 Background

2.1 Infant Feeding Problems

Early interaction between parents and children is significant for their upbringing. Young infants spend between a half and a third of their waking time eating, making the outcome of the feeding times considerably important, not just in terms of nutrition, but also in establishing a healthy relationship between the caregiver and the child [Reilly et al. 2006]. Feeding can therefore be argued to serve more purposes even at the earliest stages in a child's development than simply to provide nutrition. It establishes the foundation of the child's personality, abilities and knowledge for the future. It teaches them etiquette, communication skills and illustrates fine motor skills that will be necessary for the child's future. It is important to give anticipatory guidance when feeding is potentially problematic [Satter 1995]. A positive feeding relationship between parents and children allows for a healthy relationship to be established as well.

Between 25% and 40% of infants and toddlers are described by their parents as having some form of feeding problems [Claude and Bonnin 2006]. Mealtimes can become stressful, and if children fail to gain weight adequately, it is common for parents to describe them as picky eaters with poor appetites and they fear that their children are not eating enough [Rudolf 2008]. Most problems concerning feeding can be prevented by routine support and education about feeding and parenting.

If a child is growing well, but parents are uneasy with feeding their child, health professionals may often leave parents with their anxieties or otherwise may tend to be judgemental and assign blame to poor parental skills [Rudolf 2008]. Although parents must make individual decisions tailored to their own infants, guidelines provided by recommendations and advice should be followed to ascertain what to do and when. For example, a delayed introduction to solid foods may cause difficulties in weaning and may result in further feeding problems [Northstone et al. 2001].

Successful treatment of feeding and eating problems depends on the motivation of the parents and the resources available to carry out the intervention. The scope of improving the feeding includes knowledge about providing the right environmental conditions for meal times and offering foods of different tastes. There are a range of behaviour therapeutic methods that can be used to treat behaviour and oral motor problems of children [Wolke 2003]. Frequently the problem is that parental behaviour during meal times is often fixated on nutritional intake, the parents become nervous. Social behaviour, fun and play during meals can therefore be ignored [Wolke et al. 2006]. Concerns about the right amount of food intake, lack of interest in the meal and problematic feeding behaviour contribute to parental stress [Chatoor and Ganiban 2003]. While necessary knowledge can be acquired through books and courses, the training of a relaxed parent-child interaction still can be only achieved through direct interaction with the child.

2.2 Related Work

The advantage of the VR training system is its interactivity and flexibility, although it varies greatly. The main requirement is to aid the learning by supporting the wide range of different training scenarios [Bluemel et al. 2003]. Increasingly the practical applications focus on the simulation of different situations for educational purposes such as a simulator to learn driving [Lopez-Garate et al. 2008], [de Winter et al. 2008] or submarine training program [Jones 2008]. [van Wyk and de Villiers 2009] discuss requirements and constraints for VR solutions applied to safety training for the mining industry in Africa. The last paper also reports on how realism can be enhanced in simulation training systems. These applications are used for serious training purposes, where VR technology is often use to improve the immersiveness and interactivity with little emphasis on entertainment [Narayanasamy et al. 2006].

A serious game is an interactive VR simulation that has a challenging goal, is engaging to play, incorporates the aspect of assessing its user for the purpose of imparting a skill, knowledge, or attitude that can be applied in the real world [Bergeron 2006]. They enable virtual experiences created by a developer for a specific user or group of users in mind. Almost everything, which requires a knowledge base, skills or decision making, may be set in a interactive virtual environment to achieve considerably effective results [Blackman 2005]. Serious games scenarios need to be sufficiently similar to the equivalent real world situation for successful training.

Figure 2: *Example of a participant using the application.*

Our application, see Figure 2, can be regarded as both a simulation and a serious game due to the specific objectives given to the participants. The significant advantage of these virtual environments is the the level of control the developers and users have of the system, its cost-effectiveness and how the nature of interactive applications allows for unique experiences. The system can be readily modified, either to provide new challenges through adjusting levels of difficulty or to provide more descriptive text to facilitate learning. It gives an opportunity to pause training for discussion or other means of instruction, and enables the recording of a full history of the users' performance [Xiaoling et al. 2004].

A significant amount of research has been conducted on using VR as a tool to aid people with real world situations. Health and medicine games have a great impact on society and individual well-being according to Bergeron [Bergeron 2006]. Several can be found on the internet providing users with a strong user-oriented experience and encouraging them to learn how to keep healthy lifestyle, enhance self-acceptance or fight against serious illnesses. Practical training courses for learning and simulations can also be used to deal with phobias, for example social phobia [Roy et al. 2003], [Kwong et al. 2009].

Several examples of VR applications and serious games have shown promising results to treat or decrease eating disorders [Riva et al. 1998], arachnophobia [Garcia-Palacios 2002], acrophobia [Coelho 2006], fear of public speaking [Slater 2006], post traumatic stress disorder [Rizzo 2006] and fear of flying [Banos et al. 2002]. More recent examples include applications for upper limb motor rehabilitation [Burke et al. 2009] or to support triage training [Jarvis and de Freitas 2009].

3 VR Training Prototype

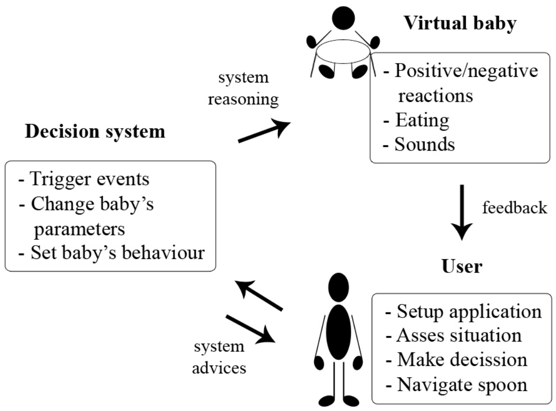

Figure 3: *VR Feeding Training System - key elements.*

The flow chart in Figure 3 illustrates the pipeline design of using the application. Interaction is done with a Nintendo Wii nunchuck controller, see Figure 2. This device has previously been shown to provide an appropriate interface to the simulation [Petrasova et al. 2009]. The initial parameters of baby's mood are set up through keyboard input. Various combinations of parameter values and user input affect the different reactions of the baby. Variables are assigned based on a simple approximation of the real world derived from heuristics and expert opinion [Petrasova et al. 2010]. The baby is not driven by an operator. The user's task is to assess the situation, learn to respond appropriately to the changing mood of the baby and feed the baby using the nunchuck controller provided. An example of baby's behaviour might be dismissive response accompanied by turning the head sideways and hand movements preventing the spoon to move closer to the baby's mouth, see Figure 4. One of the positive reactions is watching the spoon coming towards the mouth accompanied by mouth opening and hands lifting, see Figure 5. Parameters in the application defines the baby's attention, tiredness and happiness. They also determine how hungry the baby is and if he likes food and its texture or not. The range of values for each parameter is from one to five.

There are two possible outcomes of the simulation. Firstly, if the baby's hunger has decreased sufficiently, the simulation ends. In terms of value of the parameter hungry it means that its value needs to be changed from 5-very hungry to 1-not hungry at all.This is the goal of the user. On the other hand, if the user is considerably impatient, or does not pay attention to the baby, the baby will respond poorly and eventually get tired. The user can no longer feed the baby and the simulation ends. This happens when the value of the parameter tired is changed from 1-not tired to 5-very tired. The value of the happiness varies from 1-not happy to 5-very happy. The application keeps a track of the user behaviour within the virtual environment. The aim is to teach parents to learn to assess the baby feedings situation, handle stress and decrease the anxiety about the infant's poor food intake. For this case study, the user does not receive any feedback in terms of performance as we wish to assess the user's performance based on computer interaction alone.

4 The Experiment

In order to assess training success and usability of the simulation a user case study was conducted with 33 participants. Data collected

Figure 4: *Example of a negative response from the virtual baby. In this image the baby avoids the spoon.*

Figure 5: *Example of a positive response from the virtual baby. The baby smiles and is more willing to accept more food.*

during the experiment included time spent feeding and three parameters of baby at the end of each feeding. Only four participants had their own children, but 14 participants reported that they had already fed a baby, i.e. a friend's or sister's baby, younger brother etc. Seven users work in a nursery as child care professionals. 36% of users never fed a baby. Of 33 participants who took part, 13 were female and 20 were male. The average age of the participants was 27.8 years.

All participants were asked to feed the virtual baby five times. The baby could be initially either happy or unhappy, but would always start as hungry and not tired. Once during the five times, participants fed the baby in *guided mode*. In guided mode, the system displays changing values of parameters and a short text description suggesting what to do next. The user should be able to interactively accomplish the individual steps according to advised information. The content of the guidance can be diverse. In our user study, helpful comments about baby's mood and recommended movements of spoon were provided to users. The baby's happiness changed during the five feeding processes. 17 participants started feeding a happy baby, while the other 16 participants started with an unhappy baby. Both groups were split into two groups of eight (in the case of 17 participants there were groups of eight and nine). One of the two small groups experienced the guided mode in the second feeding, and second group in the fourth feeding. After the experiment, the participants were asked to complete a questionnaire. The participants were instructed how to control the virtual spoon by using the nunchuck input device and tried to pick up food from a bowl and reach the baby's mouth.

Various generic baby's reactions were presented to users during feeding. The best feelings and encouragement were invoked by positive baby's reactions, see Figure 5. The baby refusing food caused disappointment of unsuccessful feeding, see Figure 4.

Through our user case study we proposed the following hypotheses related to this training simulation:

- Feeding performance depends on the baby's initial state of happiness.
- The guided mode has a positive influence on a user's performance.
- Repeated feeding with the VR application improves the feeding performance.

5 Results

5.1 The state of the baby's mood

Considering the first hypothesis, we compared the feeding acting between the two initial states of baby's happiness (fully happy and unhappy) with respect to all data measures (hunger, tiredness, happiness and time of the simulation). For the comparisons we used the nonparametric 2-independent-samples Mann-Whitney [Siegel and Castellan 1988] test because it is optimal for data of our size (16 and 17 participants). For increased robustness of our conclusions the p-values via the exact versions of the above test were calculated. Tests were performed at the 0.05 level of significance.

The initially happy baby is significantly less hungry (p-value$<$0.001), see Figure 6 and less tired (p-values=0.001), see Figure 8 at the end of the first feeding than the unhappy baby. There is also significant difference in the baby's happiness (p-value=0.002), see Figure 9 at the end of the first trial when comparing happy with unhappy baby. Further the overall feeding time was longer in happy babies (p-value=0.026), see Figure 7 than in initially unhappy babies.

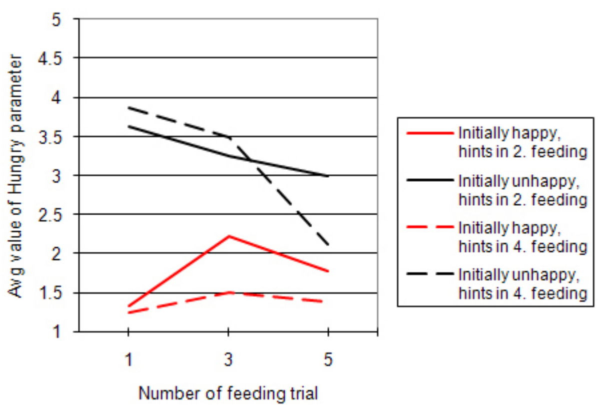

Figure 6: *Graph of Average Hunger.*

Similarly, at the end of the third feeding, the originally happy baby is significantly less hungry (p-value$<$0.020). However, the initial happiness state does not seem to make a significant difference in the final tiredness (p-value=0.445) nor in the total feeding time (p-value=0.064). When baby was very happy at the beginning the average final baby's happiness across the 17 participants was lower than in the 16 participants who started feeding unhappy baby. However, this difference was not found significant (p=0.066).

Significantly lower hunger (p-value$<$0.022) in the case of happier baby also remains at the end of the fifth feeding. However, the initial happiness state does not appear to make a important difference in the final tiredness (p-value=0.088), happiness (p-value=0.592) nor in the total feeding time (p-value=0.129).

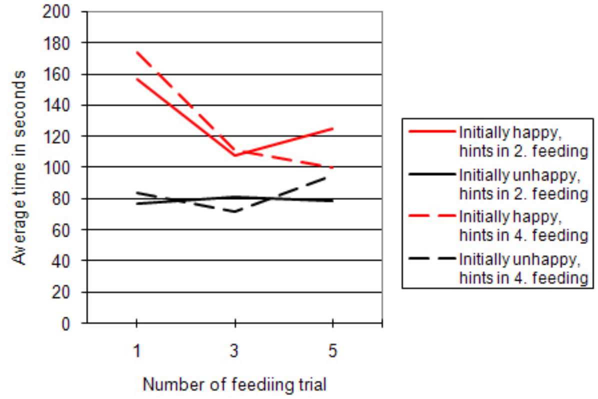

Figure 7: *Graph of Average Time.*

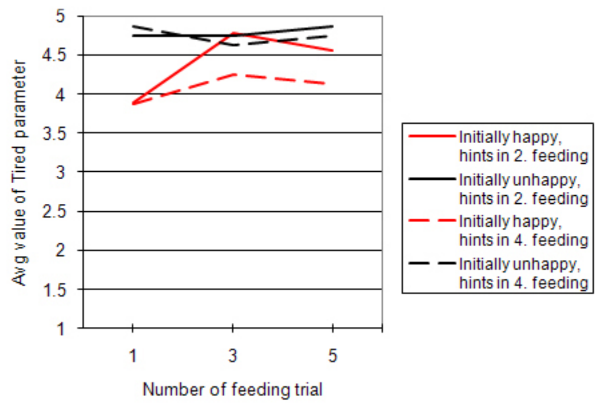

Figure 8: *Graph of Average Tiredness.*

5.2 The influence of the guided mode

In the second hypothesis, for each level of initial happiness (happy and unhappy) independent comparisons of the user performance across the timing of the guided mode were carried out. Specifically, it was tested if the users' success in the third feeding depends on whether there were hints provided in the second feeding. Similarly the user acting was compared in the fifth feeding across two conditions: the hints in second vs in fourth feeding. The nonparametric Mann-Whitney test for independent groups was used. Exact p-values were than judged at 0.05 level of significance.

The task completion in the 3rd trial was significantly similar between those who had second trial with hints or without hints (p-values=0.082, 0.086, 0.271 and 0.923 for final hungriness, tiredness, happiness and time of originally happy baby; p-values=0.821, 0.890, 0.700 and 0.636 for unhappy baby).

Similarly, carrying out of the task in the fifth trial was statistically the same between those who had hints in the second or fourth trial (p-values=0.195, 0.243, 0.916 and 0.336 for happy baby at the beginning; and p-values=0.121, 0.535, 0.659 and 0.269 for initially unhappy baby). There was no evidence that the guided mode would

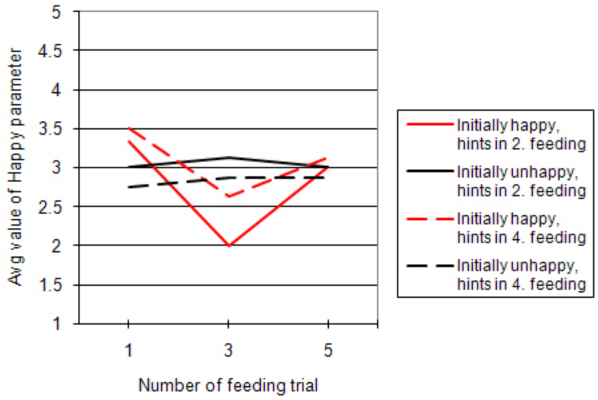

Figure 9: *Graph of Average Happiness.*

influence the performance.

It was also tested if the performance of the users in the second trial depends on whether the hints were provided in this second time. Similarly results from the fourth trial were compared depending on if the hints are provided at the same time or not.

The achieved results in the case of the happy baby in the 2nd trial were significantly better when the hints were provided. Specifically the baby was significantly less hungry (p-value=0.007), less tired (p-value=0.013) and more happy (p-value=0.046) than the baby who was fed without the hints. Time however does not depend on the hints (p-value=0.115). The user acting with the unhappy baby in the 2nd feeding remain statistically unaffected by the existence of the hints (p-values=0.617, 0.417, 0.582 and 0.923 for the hunger, tiredness, happiness and time).

There was found no statistical evidence for the observed differences in the 4th feeding trial with respect to provision of the hints. The user performance is statistically same with or without the hints (p-values=0.951, 0.777, 0.511 and 1.00 for the hunger, tiredness, happiness and time in initially happy baby; p-values=0.920, 0.778, 0.396 and 0.923 in unhappy baby).

5.3 The training effect

For each level of the initial happiness (happy and unhappy) independent comparisons of the user performance between the first and the last feeding were conducted. The non-parametric Wilcoxon test [Siegel and Castellan 1988] for 2 related samples was used, and we did not differentiate between the timing of the hints as these were found insignificant in our previous analysis. Exact p-values were then judged at the 0.05 level of significance.

The first and last feeding of the happy baby are statistically the same with respect to the final baby's hunger (p-value=0.313), to the final state of tiredness (p-value=1.79) and to the final state of the happiness (p-value=0.319). However, the total time of the last task trial is significantly shorter (by 53 seconds) than that of the first one (p-value=0.017), see Figure 7. The feeding of the initially unhappy baby also improved over repeated doing of tasks, but in a different way. Participants filled the unhappy babys tummy much better in the last trial than in the first trial (p-value= 0.05), see Figure 6. However, user performance in the last trial was statistically equal to the one in the first trial with respect to babys tiredness, final happiness and time of feeding (p-values=1.00, 0.875 and 0.782).

6 Discussion

In the first trial, the initially happy baby leads to significantly better feeding performance of the participants making happy baby happier, fuller and less tired as the initially unhappy baby. This differences in performance appear to decrease in later trials, when the performance of the participants only differs with respect to the final baby's hunger, i.e. initially happy baby is significantly more full at the end of the feeding, see Figure 6. Data also suggest that users may feel overconfident due to ease of feeding of the happier baby. By not paying sufficient attention to the baby, a decreasing of the baby's happiness even to a lower level than in the case of earlier unhappy child may occur.

Although the guided mode was not noticeably helpful according to the results users achieved, according to the questionnaire about 63% of users were convinced that the mode was better, helped them in better task performing and they preferred feeding in this mode. The users were told that baby's parameters are changing during the task, but they did not know how the baby's mood changes over the five feedings. For those who started feeding the happy baby, first feeding occurred to them as relatively easy. Confusion was caused in the second case as the user was unfamiliar with an unhappy baby. They found difficult to adapt to sudden change in behaviour of the baby during both the second and fourth feeding. The baby became too tired soon and there was not enough time to try properly the guided mode. Data suggests that the performance with the happy baby in the second trial while using the guided mode was better because the users were more relaxed and had a greater opportunity to follow and apply offered advice. The users, who did not have the hints during the second feeding and had to deal with feeding situation by themselves firstly, had even better results while additional assistance in the fourth time.

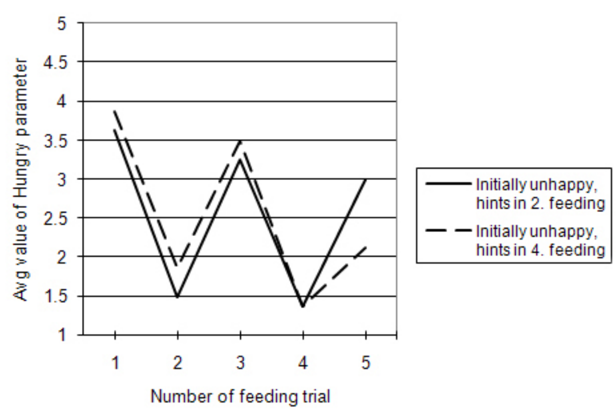

Figure 10: *Graph of Average Hunger of initially unhappy baby through all feeding trials.*

There were clear differences among individual feeding trials of those who fed initially unhappy baby more times and eventually their performance improved, see Figure 10. Users gradually made the results better in unhappy baby cases by training; first time was the worst, then better and then the best. By working with the unhappy baby more times, users experienced the guided mode in the case of happy baby feeding. These advices were not applicable to case of unhappy baby, therefore there were clear differences between feeding of happy and unhappy baby.

6.1 VR Suitability and Potential

Appropriate parent-child interaction is one of four prerequisites for successful feeding discussed by [Wolke 2003]. A multi-modal approach for training is more appropriate for severe feeding problems or when parents have some psychological problems [Wolke 2003]. However recreating a 1-to-1 experience is impossible with current technology.

VR applications employed to educate people and facilitate new skills have shown promising results in recent years. With increased realism in computer graphics and novel human computer interfaces, the benefits of using such technologies are increasing. In order to create authentic experiences, it is crucial to work with experts in the field; in our case psychologists and professional caretakers.

A concern in creating VR simulations is validating its accuracy, and the longevity of its impact on the user. To our knowledge, there are no standardised metrics that evaluate the short term and long terms effects of training VR applications other than collecting statistics on performance of the users. However, these statistics will not account for prior experience, level of engagement, the user's pre-occupation during the simulation as well as the user's previous experience with computers and human computer interaction. These factors may have an effect on the users' ability to perform that are considerably difficult to quantify and incorporate into assessment. Another concern to address is the personality of the baby the simulation aims to emulate. A baby may for instance be more inclined to be fed by a parent than a new babysitter. Babies at various ages and from different cultures interact with adults at various levels.

7 Conclusion and Future Work

This paper discussed the training success of an interactive, virtual environment developed to support training of infant feeding. VR can enhance interest and motivation of users and help acquire and maintain the necessary knowledge by interaction. The main impacts on the user's performance were discussed. It shows as well that training can increase the efficiency of feeding on various aspects depending on the behaviour of the child.

In summary, we conclude that the repeated feeding of the baby in our VR application lead to the improvement in the feeding performance, but it depends on the initial happiness state of the baby. The repeated feeding of the happy baby did not lead to a change in hungriness, tiredness or happiness, but it significantly shortened the time of the feeding by 53 seconds. Further, the initially unhappy baby became significantly more full in last feeding trials when compared to the first feeding (though still significantly less full than the initially happy).

Future development will focus on extending feeding training scenarios to more complex and varied ones. The use of speech recognition to enable parent encouraging the baby will be considered as it is also very important in a feeding relation between parent and infant. With regard to human behaviour as the object of the study there is still a high potential for further investigations involving also other human factors as the mood. Our next steps involve comparing the virtual feeding situation with a real one. The impact of each type of baby's reaction on the user needs to be evaluated as well as the correct system feedback. There is also an opportunity to investigate the system usability in terms of educational aspects, emotional correlations with the real situation and stress factors.

Acknowledgements

This research is funded by EPSRC/Warwick Innovative Manufacturing Research Centre (WIMRC), The University of Warwick, Coventry, UK, projects numbers: R.ESWM.9221, R.PSAA.9221. The authors would like to thank Mrs Debbie Castle, the manager in the University of Warwick nursery, for interesting feeding discussions and all who participated in the experiment.

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