Reduction of Dental Anxiety and Pain in Children using Robots

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***Abstract*—In this study, we aim to use humanoid robots to implement a techno-psychological distraction technique for children between 4-10 years of age in order to reduce their anxiety and stress-related pain during their dental treatment. A multi-modal system supporting audio-based dialogues, videos, gestures and expressions based on face, head, arm, body movements have been developed for a robot. We have employed the Wizard-of-Oz technique, a popular approach in human robot interaction research. The effectiveness of the system is shown by carrying out experiments on two groups of children; one group whose treatment is conducted by the dentist's own skills alone, the other whose treatment is conducted by a dentist with the assistance of the robot. In order to evaluate the robot's effect on the anxiety and fear of children during these experiments, procedures with no anesthesia (not requiring the use of needles) have been carried out. The system has been evaluated subjectively by applying a variety of questionnaires to patients, and dentists as well as objectively by measuring patient's heart rates.**

***Keywords*—Robotics, dental treatment, WoZ experimentation, human robot interaction, multi-modal interaction, healthcare robotics.**

I. Introduction

Dental treatment-related anxiety is a common case in dentistry, especially affecting children and causing problems during their dental treatment. It is commmon that some children having oral/dental pathology do not comply to have a treatment. Some general methods preferred by healthcare workers are wearing colored and patterned clothes, and using clown doctors to encourage children, to distract their mind and to make medical procedures more fun [1]. Listening to music or watching cartoons are common procedures to relieve the pain and anxiety in children [2]. The goal of all these approach is to reduce unpleasant perceptions, to avoid negative behaviors and escaping from the treatment. In this way, completion of treatment without the need of such advanced medical techniques like sedation and general anesthesia is targeted. These systems may not always be effective enough to distract a child's attention away from pain. According to these analyses, there is obviously a need of a more comprehensive system to enable a child to engage more deeply during medical procedures. Nowadays, combining visual, auditory and tactile stimuli by making use of multi-sensory strategies is believed to provide a greater impact on pain than using a single stimulus. In this study, we aim to direct a child's attention from a painful stimulus to a more entertaining and amusing direction during their dental treatment using a humanoid robot and by making the therapy session less problematic and more comfortable in order to provide much cozier treatment environment to the dentist.

Moreover, instead of the pediatric dentists communicating with their patients by asking standard questions before treatment, the computer technologies (animation or robot), can take over these repetitive tasks. As a result, the dentist's chair time and energy loss can be minimized. It is targeted to develop positive behavior and increase treatment success.

For the past several years, robotics has been applied in the field of healthcare in various ways. Social and medical robots in this domain aim to motivate and encourage humans to keep up with the medical routine and to provide psychological therapies. The aim of this study is to provide an entertaining, and relaxing environment to the children patients with the help of robots in order to develop positive behaviors in children resulting to an increase in the success of dental treatment and to the circumvention of the high cost and risk of complications such as sedation and general anesthesia. Therefore, to the knowledge of the authors, our work is the first study in our country and in the world, which investigates the effect of child-robot interaction in reducing pain and stress during dental treatment.

II. Literature Review

Dental fear is an emotional reaction against the frightening stimulus during dental treatment. *Dental anxiety* is defined as unease about the fearful events that occur during dental treatment and as a feeling of loss of control accordingly. Negative expectations due to earlier experiences, negative behavior within the family, a feeling of anxiety about the pain, failed and painful experiences that occurred in earlier treatments were reported as the most important factors in feeling fear [3]. Factors associated with dental fear include age, the attitude of parents towards dental treatment, the bad experiences transmitted by those close to the child, concern about sensation of pain and past experiences of the child [3], [4], [5]. In various research works carried out on the human test subjects, the incidence of dental fear, anxiety and behavior management problems in children have been reported to range between 20-74% in several countries (74% in Brazil [6], 30.6% in Singapore [7], 27.02% in Croatia [8], 25.6% in Turkey [9], 23.1% in Sweden [10], 22.2% in Finland [11], 20.6% in Taiwan [12]).

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Management of pain during dental procedures is crucial to the success of treatment. Prevention of pain is made possible by a healthy relationship between dentist and patient, establishing trust, elimination of fear and anxiety, and the creation of a positive attitude for future visits. However, the subjective nature of pain perception may alter the patients' response to treatment and prevent the correct diagnosis and treatment approaches of physicians by affecting the accurate assessment scale against painful stimuli [13].

A variety of approaches have been proposed to prevent or completely eliminate children's dental fear. The purpose of directing behaviors of the child during treatment is escaping from unpleasant and failed experiences and to ensure that the child accepts the treatment easier. The physician treating the child should be knowledgeable about the various behavior management techniques and be able to predict the child's response to treatment by properly evaluating the data regarding child's developmental level, temperament and attitude during the operation. In this sense, the behavior of dentists and accompanying dental staff plays an active role in determining children's attitudes to the treatment [14].

Several techniques have been developed to perform dental care in children with success by applying basic behavioral methods including tell-show-apply technique, self control, positive orientation and diverting attention [15]. Especially recently, unusual stimuli and technological equipments started to be utilized in the process of attracting attention to another point. In this case, the attempt is to prevent negative behavior or escaping from treatment by reducing the unpleasant perception. In this way, it is planned to complete the treatment without the need for advanced behavioral techniques such as sedation, general anesthesia.

Although there are studies indicating that listening to music and watching cartoons reduce pain and anxiety in children exposed to medical treatment [1], [2], [16], [17], such systems deprived of interactivity. Stimulating the child as just listener/viewer is not always sufficient to be effective to divert the child's attention away from the pain.

Today, it is believed that combining multisensorial strategies with visual, auditory, and tactile stimuli (e.g. using robots) provide a greater impact on pain than the effect of a single stimulus. Beran et al. have first used robots in distraction during vaccination for a study performed on 57 children between 4-9 years of age [18]. While nurses were vaccinating, it was planned that the robot interacted with the child. Compared with control group, it has been shown that children with the robots next to them during vaccination smiled more. After this experience, parents have noticed that their children remembered the robot more than the needle and they wanted the robot to be present for the next vaccinations. Robots have been found quite fun, and helpful for diversion of a child's attention and also useful for enabling children to feel less pain and anxiety during painful medical procedures [19].

In another study, in the bilateral meetings held on 21 children between 7-9 years of age, the mechanisms of communication with humans and robots were compared [20]. Talking with children has been performed by an adult in the first group and by a robot in the other group. As a result of analysis of child behavior during the bilateral talks, it has been observed that children in robot group have made eye contact more and talked for longer. Researchers have reported that robot technology can be utilized in the field of social services and healthcare applications, where robots are superior to people in contact with children.

There is also a study aimed at increasing children's health information using robots, in which children with Type-I diabetes between 8 and 12 years of age have been subjected to quizzes via robots [21]. The study has shown that children have been motivated, had fun while answering questions and their level of knowledge about diabetes was increased in this way.

Wizard-of-Oz (WoZ) is an approach whereby a human operator, unknown to the participants, operates a robot. This method, used for full teleoperation or for partial control, enables simulating and modeling the interaction and allows the collection of data and experimenting without relying on specific system components. In child-robot interaction studies which use this method, the wizard speaks with the children through the robot [22].

Based on these findings, it is observed that there is a need of more comprehensive and robust system that can make a child busy during medical procedures. Our goals in this study are, to divert child's attention to a more entertaining direction and to provide more comfortable environment to the dentist during dental treatment.

III. Experiments

A. Participants

33 children (21 boys, 12 girls) were recruited for this study, ranging in age from 4 to 10 years old. The tests were run at a clinic in the Department of Pediatric Dentistry, Faculty of Dentistry in Istanbul University.

The inclusion criteria of the children into the experiment were the following:

- First time patients to the clinic.
- Lacking of dental treatment experience before.
- Not having pyhsical or mental disabilities.
- Not having long term bleeding or pain in teeth.
- Being given restorative or endodontic treatment plan by a dentist.
- Being accompanied by at least one parent.
- Not having any genetic syndrome or a serious systemic disease.
- Agreeing to fill out the questionnaire (both by the children or parents).

B. Hardware and Software

The robot selected for this study was IRobi, shown in Figure 1. IRobi has been developed by Yujin Robot company. It is equipped with a tablet computer, which can play videos and animations on the front panel. It can move its head, arms, and wheels, but does not change its position despite of having

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this ability thanks to its wheels. It has 3 DOFs (Degree of Freedom) on its head and 1 DOF on each arm. The robot has facial LEDS as a part of its own hardware system and can display five types of facial expressions: shy, disappointed, neutral, happy, and surprised. It can express various emotions with two LCD eyes and LED dot matrices on its mouth and cheeks, and react to human touch by five kinds of sensor.

Fig. 1. IRobiQ

There are many studies that IRobi helps children accelerate their learning language and speaking education [23], [24]. In this study, the robot was programmed to motivate the patient during the treatment and support the interaction with the child by performing short-time movements such as face, head and arm gestures or using audio and videos. Irobi asks children questions, gets responses and allows them to make choices on LCD screen.

The robot behaviors as well as dentistry animations and songs have been integrated to the robot by using ROCOS Studio. We have also prepared multimedia content in Adobe Flash to strengthen the interaction between the children and the robot.

C. Measures

Ethical committee approval for this study was taken from Faculty of Medicine, Istanbul University. A set of questionnaires measuring levels of pain and anxiety are applied in both pre and post session to each participant and their parents in order to assess the effects of robot assistance and basic intervention methods. Some questionnaires were administered to explore the feelings of the child during the interactions, how they perceived the robot as well as their mood during the interaction [25].

Before the procedure, it is required to fill the questionnaire to measure the child's anxiety levels. Thus, an experimenter explains the research protocol in detail to the children and their parents admitted to clinics and ask them to complete the consent forms. The consent was filled by the children and their accompanying parent in the waiting room of the clinic. After the consent was granted, parents were asked to primarily answer demographic questions, then the questions related to their children's familiarity to robots and computer technologies.

After the child entered the room, the Facial Image Scale (FIS) was administered [26]. The FIS is a measure to assess the state of children's dental anxiety and comprises a row of five faces ranging from very happy to very unhappy as given in Fig. 2. This scale is scored by giving a value of 1 to the most positive affect and 5 to the most negative affect face. The children were asked "How do you feel right now?" and were guided to show their response by pointing one of the faces. Approval studies have shown that it is a suitable measure for assessing the children's strongest expression of pain and fear sensation during the dental procedure, i.e. both in the waiting room and while sitting on the dental chair. Each child gave his/her own response independently although their parents or researchers help them in reading the instructions for children when necessary [18].

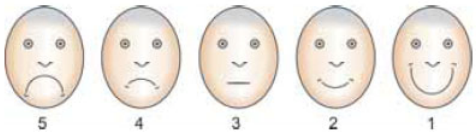

Fig. 2. Facial Image Scale (FIS) and the questionnaire used to assess dental fear and anxiety

Before beginning treatment, the dentist rated the child's behaviour on Frankl's Behaviour Rating Scale (FBRS), which is one of the more reliable and frequently used behavior rating systems in both clinical dentistry and research [27]. The FBRS categorises the child's behaviour as either one of the following: definitely positive (4), positive (3), negative (2) or definitely negative (1). This evaluation was also completed by the dentist at the end of the treatment session. Definitely negative (1) represents refusal of treatment, negative (2) means reluctance to accept treatment, positive (3) shows that the child accepted the treatment but he/she was cautious and definitely positive (4) corresponds to good rapport with dentist, the child was enjoying the dental procedure.

Anxiety level was also recorded before, during and after treatment in terms of physiological pulse rate (bpm) by using a finger type pulse measuring device (Pulse Oximeter). In the robot group, apart from measuring the children's anxiety and behaviour, we administered the question, "Would you want to have the robot in your next treatment session?", to the children. Responses were given on a 5-point scale from "not at all (1)" to "very much (5)" [18].

D. Procedure

The children's treatment plans were determined based on the first inspection carried out by specialist dentists. All children are exposed to the same dental treatment in the same clinic environment. While first patient group has been treated only by the dentist (control group, n=17), the second group has been treated by a robot accompanied by the dentist (robot group, n=16). Both groups will be subject to previously determined standard dental treatment. After clinical setting is introduced in both groups, the treatment phase starts.

Children's treatment type is divided into subgroups, according to predetermined treatment needs: 1) dental treatment of first group will be carried out without local anesthesia

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(restorative treatment), 2) dental treatment of second group will be applied local anesthesia (endodontic treatment). Although the prescribed average duration of treatment is 15 minutes for restorative treatment, endodontic treatment is set to 30 minutes. Treatments are planned to be completed in a single session. According to routine clinical procedures, parents were not allowed near children during treatment. In addition, all sessions will be videotaped with cameras fixed at two different locations.

Treatment of first group also called control group in the study, was performed in the routine clinical procedure. The dentist provided information about the clinic setting, equipments and processes. As a result of feedback received from the child, dentist applied the corresponding therapy using basic behavior techniques as appropriate. In the second group, or robot group, the robot was seated on a platform near the dentist at the child's eye level as in Fig. 3. The robot chatted with the child, instructed the child before and during the treatment, distracted, encouraged her/him, and played animations favoured by the children.

Fig. 3. IRobi performs some body movements with face expressions during a child's dental treatment.

In this context, the robot appeared acting naturally even in the lack of autonomy. For this purpose, we have used Wizard of Oz (WoZ) method, widely used in robot assisted studies to conduct our experiments. WoZ is an approach whereby a human operator, unknown to the participants, operates a robot. This method, used for full teleoperation or for partial control, enables simulating and modeling the interaction and allows the collection of data and experimenting without relying on specific system components [22].

WoZ method allows freedom in interaction and provides flexibility to make children involved in the interaction. The WoZ setup of the system is shown in Figure 4. First camera, placed in front of the child, recorded the face and body expressions and behaviors of the child. Second camera was placed in a spot with a view of the dentist, robot and child interaction. A web camera together with a microphone transmitted audio and video to the "WoZ" room. The WoZ room was away from the clinic setup. As part of the WoZ setup, an expressive verbal interaction is thought to be able to easily involve children in communication. Based on the analysis of captured videos, the majority of the children started to show more natural and expressive behavior after the wizard presented some feelings and emotions in the interaction. Because the wizard's communication skills also affect the children's behavior, we got help from a child psychiatrist about chatting with children [22].

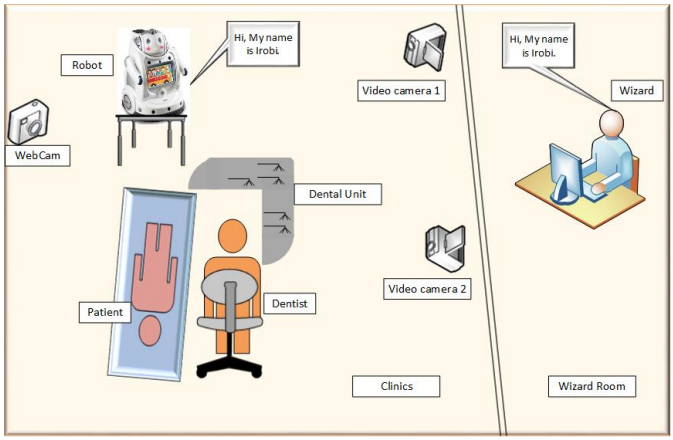

Fig. 4. WoZ setup of the system.

IRobi was programmed to help the wizard to execute the commands as distraction strategies (shaking head, swinging arms, face expressions) during the treatment. Once the WoZ system was installed, the wizard did not need to make any adjustment such as re-activate the robot for each phase. Fig. 1 shows some body movements with different face expressions performed by the robot. This way, the robot played a role as a member of both the welcoming and the treatment team.

IV. Results

Fig. 5 shows the change of children's average levels of heart rate for each group. We have observed that based on the outcomes of heart rates of the children in control group as well as the video analyses, these children were more anxious and stressful during the treatment than before the treatment. As expected, after the treatment finished, they became calmer and their heart rates reached even lower than the pre-treatment levels. On the other hand, the patients in the robot group had similar pulse rates before and during the dental procedure, which indicates that the robots were effective in the reduction of the patients' anxiety. Additionally, after the treatment has been completed, these rates have returned to lower levels compared to the pre-treatment heart rates.

By investigating the quantitative heart rate changes of individual patients, we observed that 70.58% of the participants in the control group suffered from increased heart rate in the time interval between pre-treatment and during treatment, defined as *Phase 1*, whereas only 23.52% of the patients had decreased pulse rate. If the change of pulse rate stayed within a limit of $\pm 3\%$ of the original pulse rate during the phase, we defined this case as *No change*, and only 5.88% of the patients in the control group experienced this effect. The transition from the treatment time to the post-treatment is defined as *Phase 2* and 64.70% of the patients were relieved from their dental stress, while the pulse rate of the 29.41% of the patients did not

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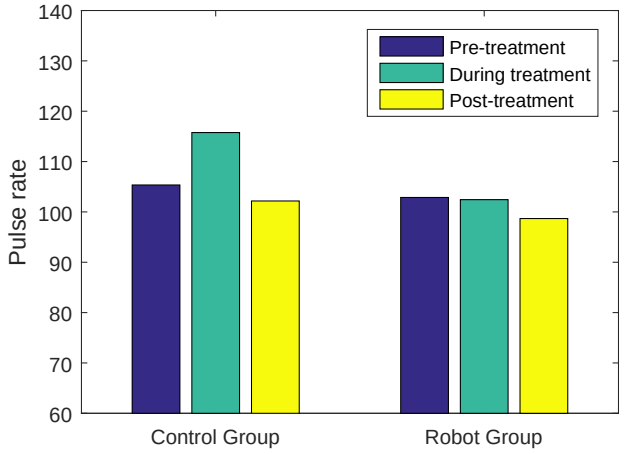

Fig. 5. Children's pulse rates before, during and after dental treatment.

change. However, the results of the robot group indicate an important trend of reduction in dental anxiety both in *Phase 1* and *Phase 2*. The total percentage of the patients having either no change or decrease in their pulse rate was 68.75% compared to 29.40% in the control group. Furthermore, the relaxation from stress after the treatment continued: a total of 87.00% of the patients had lower or equal pulse rates.

TABLE I
THE CHANGE IN THE CHILDREN'S PULSE RATE.

		Increased(%)	*Decreased(%)*	*No change(%)*
Control Group	*Phase 1*	70.58	23.52	5.88
	Phase 2	5.88	64.70	29.41
Robot Group	*Phase 1*	31.25	43.75	25.00
	Phase 2	12.5	43.75	43.75

According to the Facial Image Scale scores in Fig. 6 from pre- and post-treatment session, the percentage of children in control group having a negative or equal affect (indicating dental fear and anxiety) after the treatment (35.29%) was drastically higher than the percentage of children feeling the same way in the robot group (6.25%). %93.75 of the patients in the robot group have indicated that they felt better after the procedure. Based on these results, it is apparent that the level of anxiety of the children increased in control group, though conversely the children in robot group feel less anxiety after the procedure. Moreover, there is a remarkable difference between the levels of both groups.

Fig. 7 shows the change of the children's behavior towards dental treatment with respect to Frankl's Behavior Rating Scale. Comparing the children's treatment willingness, which was evaluated by the dentist, it can be seen that the half of the control group (50%) showed more positive attitude between the pre- and post-treatment relatively. However, the children in the robot group had more positive attitude after the treatment than they did have before the treatment (93.75%).

Tab. II shows the mean scores given by the dentists to the patients in both groups. Whereas the decrease in the average score of the patients in the control group shows a tendency of non-cooperative behavior, the increase in the willingness

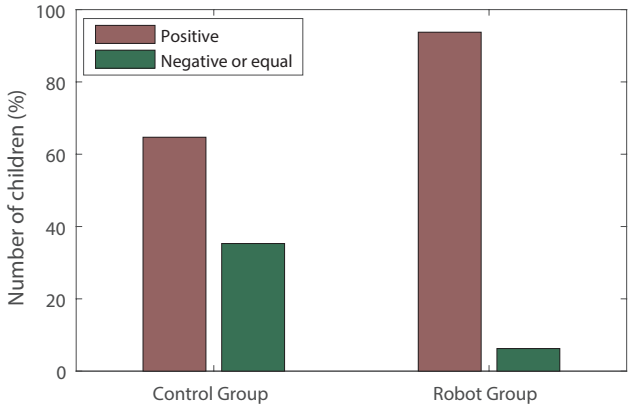

Fig. 6. The change of children's affect in Facial Image Scale.

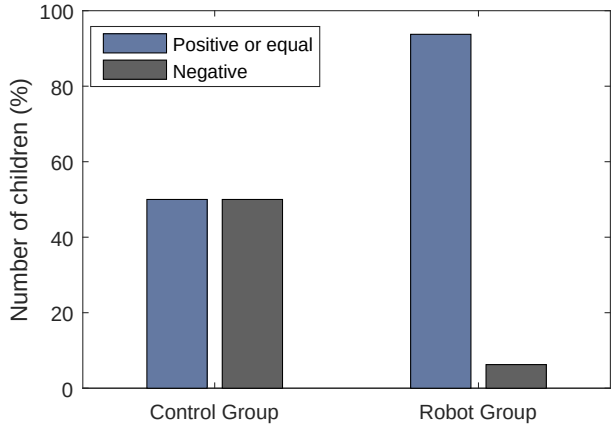

Fig. 7. The change of willingness of treatment according to Frankl's Behavior Rating Scale.

of the patients in the robot group demonstrates the promising positive effect of the usage of robots in dental treatment.

TABLE II
FRANKL BEHAVIOR RATING SCALE SCORES.

	Pre-treatment	**Post-treatment**
Control Group	*2.64*	*2.21*
Robot Group	*2.87*	*3.18*

Another assessment made using the answers from the children in robot group to the question "Would you want to have the robot in your next treatment session?" using the same terminology and notations as in the study of Beran et al. [18], show that the children liked and enjoyed the presence of the robot during their dental procedure. The distribution of the children's answers is given in Fig. 8: "very much" (%81 n = 13), "a lot" (%13, n = 2), "somewhat" (%6, n = 1).

Thus, all these improvements measured using objective and subjective evaluation criteria demonstrate the fact that the robots may have long-term positive effects on children's behavior in future treatments.

V. CONCLUSION

In this paper, we have described a preliminary study, which showed that children's pain and anxiety can be reduced in

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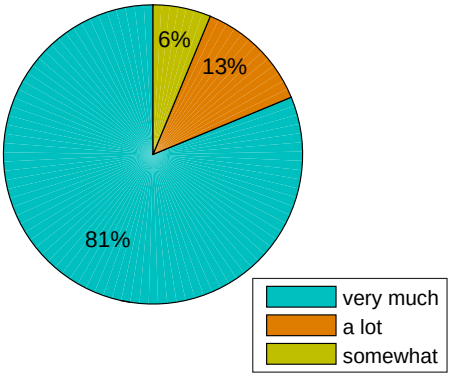

Fig. 8. Children's responses to have the robot in next treatment as well.

their dental treatment using robots. We believe that a robot can socially and emotionally aid child patients in their dental procedures to cope with stress and anxiety better than other conventional intervention methods. Furthermore, robots have advantages that they are programmable in content and level according children's age, and their usage is simple and eases the work load of health care workers [19].

In the future, we will continue to recruit more participants and present much quantitative measures relating to patient anxiety and pain. In that sense, the most urgent future work is to analyze the data obtained from all the sessions, i.e. the answers from all questionnaires, and video recordings. Furthermore, our next plan is to explore the effects of another robot Nao [28], developed by Aldebaran Robotics, to see whether there will be any differences due to the more human-like appearance and embodiment of this robot.

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