Proposal and Evaluation of the Toilet Timing Suggestion Method for the Elderly

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Abstract—We are researching and developing the toilet timing suggestion method for the elderly in order to support their comfortable outing because the elderly are likely to experience frequent urination and often encounter the difficult situation of searching for a restroom with holding their water. Our proposed system calculates the toilet timing in consideration with both their outing schedule and the amount of body water of them, and recommends going to a restroom sufficiently before they feel the need of urinating. In order to implement the system, we’ve come up with the physiological formula for non-invasive estimation of the amount of body water, and based on the estimation, the toilet timing is calculated. Also, we’ve devised the suggestion method of the toilet timing to the elderly in order both not to interfere their things to do while their outing and not to be ignored by them. In this paper, we describe our proposed system, and show the experimental result for evaluating both the toilet timing calculation and the suggestion method.

I. INTRODUCTION

For healthy elderly people, going out is one of the most important activity to keep their cognitive and physical abilities and gives them good stimulation and pleasure in daily-life [1]. Promoting barrier-free environments in public spaces in Japan encourages the elderly to go out independently. However, going out is likely to become their pain for some elderly people with aging especially due to a matter of restroom. Because elderly people have a weak bladder, they are likely to experience frequent urination and often encounter the difficult situation of searching for a restroom with holding their water. If the caregiver accompanies the elderly, the caregiver can suggest going to the restroom sufficiently before the elderly wants to go to restroom, or can look for the nearest restroom for the elderly. However, the number of the elderly living alone rapidly increases in Japan, and they cannot receive such support. Consequently, they often tend not to drink water enough while their outing due to the anxiety to go to a restroom. It is likely to be the cause of getting dehydrated especially in summer [2]. Aiming for elderly’s comfortable and independent outing, we are researching and developing the toilet timing suggestion system according to their outing schedule, their surrounding environment, and their activities like eating and drinking [3]. In order to implement the system, we’ve come up with the simplistic physiological formula for non-invasive estimation of the amount of body water, and based on the estimation, the toilet timing is calculated. This formula considers the surrounding environment of the elderly like air temperature and their activities like eating and drinking, and rearranges the toilet timing according to changes in the environment and activities. Also, we’ve devised the suggestion method of the toilet timing to the elderly in order both not to interfere their things to do while their outing and not to be ignored by them. In this paper, we describe our proposed system, and show the experimental result for evaluating both the toilet timing calculation and the suggestion method.

II. SYSTEM ARCHITECTURE

A. System Overview

Fig.1 shows our proposed system overview. The detailed implementations are described as follows.

1) The initial schedule generating unit calculates the initial toilet timing according to outing plan and current air temperature.

2) Suggestion unit recommends restroom based on the generated schedule.
3) Rescheduling unit rearranges the toilet timing based on user's activities and also the air temperature around the user that changes according to the time and the place.
4) The system notifies the user the toilet timing rearranged by Rescheduling unit.

B. Initial Toilet Timing Calculation.

Before going out, the user inputs outing plans of the day such as the departure time, the time to go home and the time of the appointment. At first, the system recommends the user to go to a restroom before five minutes in departure time. At the same time, the system measures current temperature and makes the initial toilet timing based on the obtained temperature and the user's outing plan.

Estimating personal toilet timing of the user exactly is practically impossible, because it depends on the health condition of the user and foods and drinks that the user takes. Therefore, our proposed system lets the user allow enough time for going to a restroom based on the physiological characteristics on average elderly, and recommends their toilet timing while their outing.

III. TOILET TIMING CALCULATION METHOD

A. Estimating the amount of body water

According to previous researches on water balance of human body, we've come up with the simplistic physiological formula for non-invasive estimation of the amount of body water, and based on the estimation, the toilet timing is calculated. According to previous studies, the total amount of voided volume of well-rounded healthy adults in a day is assumed to be about 1500 ml [4][5], and the amount of the urine in the bladder is assumed to be 150 ml when they feel the need of void. Also, based on the Okamoto's study [6], we assume that the total amount of voided volume changes according to the increase of the body weight; it increases or decreases by 1 ml / 1 kg from the average body weight in their study (65.15 kg for male and 53.04 kg for female). Furthermore, we obtain the physiological formula of eq.1 and eq.2 for non-invasive estimation of the amount of body water. The total amount of voided volume is divided by the length of waking hours that is about 17 hours. Then, the toilet timing is calculated by eq.3.

\[ MaleU = 1500 + (W - 65.15) \times 1.0 - (T - 19.4) \times 0.6 \]
\[ FemaleU = 1500 + (W - 53.04) \times 1.0 - (T - 19.4) \times 0.6 \]
\[ Interval = 150 / (U / 17) \]

\( U \) is the total amount of excretion in a day[ml], \( Interval \) is basic interval[hour], \( T \) is outside temperature[degrees celsius], \( W \) is body weight[kg].

B. Rearrangement of the toilet timing

In order to maintain the health, adequate hydration is necessary. For this purpose, the elderly in Japan often carry water flask when their going out. They also have a lunch or a dinner with their friends or family while their outing. Such activities increase the amount of their body water. Excess of water in the body is excreted by the kidney, and is passed into the bladder. We assume the amount of the water intake per a meal as 200 ml, and recalculate the total amount of voided volume at each meal according to eq.4. Then, toilet timing is rearranged by using eq.3. \( U \) means the total amount of voided volume [ml].

\[ DrinkU = U + 200 \] (4)

\( U \) is the total excretion of the day[ml].

IV. SUGGESTION METHOD

We have devised two suggestion methods of the toilet timing to the elderly in order both not to interfere their things to do while their outing and not to be ignored by them.

A. “Considering” with Outing Plans Strategy

The situation where the user can’t go to the restroom often happens in their daily activities. In order to prevent such situation, the system considers user's schedule not to notify the toileting timing in the middle of user’s activities such as shopping, having a lunch or watching a movie while the outing.

Therefore, if the next timing of toileting is expected to be in the middle of user’s activity, the restroom timing is moved to 5 minutes before the start time of this activity, though the system calculates the toileting timing based on eq.1.

B. “Step-by-Step” Suggestion Strategy

Timing to go to the restroom is a sensitive issue in general. If our proposed system unnecessarily recommends going to the restroom repeatedly, the user might feel the system annoying. Also, the suggestion might be ignored when the user is in the middle of their activity. Furthermore, the elderly are likely to have a difficulty of hearing; the verbal toileting suggestion sometimes might be unnoticed. Therefore, we come up with “Step-by-Step” suggestion of the toilet timing. It consists of three types of suggestion depending on the urgency; “Recommend”, “Notify”, and “Alert”. In order to explain the detail of the suggestion algorithm as shown below, we define two types of intervals; current interval \( Ic \) is calculated by using eq.3. And interval for suggestion is \( Im \). Also, \( Ti \) denotes the elapsed time from the last restroom timing.

**Recommend**

When \( Im < Ti < Ic \), because the situation is less urgent, the system only recommend to go to the restroom by both voice and the text message.

**Notify**

When \( Ic = Ti \), because the urgency increases to some
extent, the system notifies once more the user to go to the restroom by both voice and the text message.

Alert

After each suggestion as shown above, the system requires the user the confirmation whether the user actually went to the restroom. If the user ignored the both suggestions, and a certain period of time elapses, the system alerts to go to the restroom repeatedly by both the voice and the vibration because the urgency increases much more.

V. METHOD OF THE EXPERIMENT OF TOILET TIMING CALCULATION

A. Overview of the experimental protocol

The purpose of the experiment was to confirm the validity of the estimation method of the amount of body water. The overview of the experimental protocol is shown in Fig.2. The subjects in experimental group went to the toilet by the suggestion according to the toilet timing that the system calculated. The subjects in control group went to the toilet when they needed. The number of toileting and the amount of the excretion of each toileting were recorded for the analysis. The amount of excretion of the subject was obtained by getting the changes of the body weight before and after toileting. The toilet timing has been rearranged dynamically by using eq.4 every time when the subjects drank water during the experiment. At the end of the experiment, the subjective evaluation was conducted to know the effectiveness and the validity of the toilet timing calculation method.

B. Experimental conditions

The experiments were conducted in the experimental room as shown in Fig.3. The room temperature was kept almost constant using air conditioner during the experiment; the average was 21.4 degree C. The subjects were divided into two groups. One of the groups was experimental group; they were recommended to go to the toilet according to the toilet timing based on our proposed method. Another group was control group; they were instructed to go to a toilet when they need without suggestions from our system. The experimental period was set to be 4 hours (from 2 pm to 6 pm) in order to let the subjects go to a toilet more than twice and avoiding suffer. The subjects watched movies, read books or newspapers and made conversation freely in the room during the experiment.

C. Evaluation items

There are four evaluation items in this experiment. The first of them was to examine the correlation between the body weight and the amount of excretion. The second one was whether the system could suggested the toilet timing sufficient before the subjects needed to urinate. The third one was whether the amount of urine in the bladder was enough accumulated when the system suggested the toilet timing. And the last item was whether the subjects thought the suggestion of the toileting was useful and was not annoying.
D. Subjects

The subjects of this experiment were four male and six female. Their age was from 66 to 70 (the average was 68.6). They were physically unimpaired and didn’t have any urinary disorder. They were divided into two groups (experiment and control). The details of subjects is shown in Tab.1.

VI. EXPERIMENTAL RESULT OF THE TOILET TIMING CALCULATION METHOD

A. The correlation between the body weight and the amount of excretion

The correlation between the body weight and the amount of excretion was significantly correlated with a 5% significance level from the results of this experiment.

B. The number of toileting

Fig.4 shows the average number of toileting under the each experimental conditions. The number of toileting was more in the with-suggestion condition (experimental group) than in the no-suggestion condition (control group). However, the significant difference was not found. The possible reason is the length of experiment time. The number of toileting in the experiment was expected to be about two times or less. Therefore, it might be difficult to obtain the significant difference in this experimental condition. Under the with-suggestion conditions (experiment group), no subject went to a toilet without toileting suggestion.

C. The amount of the excretion per toileting

Fig.5 shows the comparison of the average amount of the excretion per toileting of both groups. The with-suggestion group’s average amount of the excretion was 130 ml. And no-suggestion group’s average amount of the excretion was about 350 ml. No-suggestion group’s result is much greater than the amount of water at which people typically begin to feel the need of urine (150 ml). The reason for this was considered that there are subjects who have priority in conversation and watching movies. Subjects who have this trend answered that there was a scene to put up with toilet, in the questionnaire below.
TABLE I

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Head-count (Male, Female)</th>
<th>Age (average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>experimental</td>
<td>5(2, 3)</td>
<td>64-77(72)</td>
</tr>
<tr>
<td>control</td>
<td>5(2, 3)</td>
<td>60-72(65.20)</td>
</tr>
<tr>
<td>Average</td>
<td>60-77(68.6)</td>
<td></td>
</tr>
</tbody>
</table>

Fig. 5. Experimental result of the amount of excretion

![Experimental result of the amount of excretion](image)

D. Subjective evaluation

At the end of the experiment, we conducted subjective evaluation A of 5 point scale; five means positive and one means negative. The items of subjective evaluation A are shown in Tab.II. The result of subjective evaluation A is shown in Fig.6. In addition, for the with-suggestion group, subjective evaluation B was conducted in a same manner as subjective evaluation A. The items of subjective evaluation B are shown in Tab.III. The result of subjective evaluation B is shown in Fig.7.

TABLE II

| Question items | Q1 You put up with going to toilet during the experiment | Q2 You could not urinate sufficiently due to improper toilet timing |

The Q1 of the subjective evaluation A was the question whether there was the case where the subject put up with toileting for the activities such as the conversation, watching a movie, and reading a book, or waiting suggestions of toileting from the system during the experiment time. Q2 of subjective evaluation A was aimed to know whether there were cases where the subject could not urinate sufficiently when they go to a toilet due to improper toilet timing. According to the results, there were subjects who had answered positive to Q2, although almost all the subject answered negative to both Q1 and Q2.

TABLE III

| Question items | Q1 Toilet timing suggestions from the system were proper for you | Q2 Toilet timing suggestions from the system were annoying for you | Q3 Toilet timing suggestions were helpful for you |

Q1 of the subjective evaluation B was the question whether toilet timing suggestions from the system were proper for the subjects or not. Q2 asked whether toilet timing suggestions from the system were annoying for the subjects because they were doing something like the conversation, watching a movie,
or reading a book. Q3 asked whether toilet timing suggestions from the system were helpful for the subjects.

From the result of subjective evaluation B, majority of the subjects thought that toilet timing suggestions from the system were not annoying and helpful for them, although it suggested toilet timings were not necessarily at the same timings as the subjects needed to urinate.

VII. EXPERIMENTAL METHOD FOR EVALUATING THE SUGGESTION METHOD

In order to evaluate the effectiveness of the suggestion method that we propose, we conducted the experiment. In the experiment, to gauge the level of task achievement and the delay time, the tentative shopping task had been set as shown below. We measured the delay from the suggestion to the action that the subject took, and the achievement of the task. Experiment was conducted for comparing these four conditions as shown in Table V because our proposed suggestion method consists of two strategies: “Considering”, “Step-by-Step”. In this experiment, “Considering” means the suggestion before or after shopping task’s time. And “Step-by-Step” in this experiment was 15 seconds and 10 seconds. The subjects performed trials of all conditions in random order. The subjects answered the questionnaire after each trial in order to investigate the impression of each condition, and also answered the questionnaire at the end of all trials to answer which condition was most preferable for the subject.

<table>
<thead>
<tr>
<th>TABLE IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>EXPERIMENTAL CONDITIONS</td>
</tr>
<tr>
<td>experimental conditions</td>
</tr>
<tr>
<td>Without strategies</td>
</tr>
<tr>
<td>“Consideration” strategy</td>
</tr>
<tr>
<td>“Step-by-step” strategy</td>
</tr>
<tr>
<td>With both strategies</td>
</tr>
</tbody>
</table>

A. Subjects

The target user of our proposed system is elderly people. Therefore, the subjects were recruited from the age group as shown in Table V.

| TABLE V |
| SUBJECTS |
| Group name | number(male,female) | age(ave) |
| subjects | 26(13,13) | 64-75(69.27) |

B. Experimental setup

The experimental setup is shown in Fig.8. This setup simulated toilet timing suggestions during shopping as shown in Fig.9. Pushing the button while the subject sat on the waiting chair indicated that the subject went to restroom. There were three places (A, B, and C) to pick up balls that simulated the displays of the shopping items. There also was the checkout counter in the room. The color cones and plastic tapes were used for indicating the walk path. There are three ball colors of red, yellow and blue as shown in Fig.10. Picking up the balls simulated buying goods. The toilet timing suggestions were notified to the subject by using audio from the portable device.

C. Experimental Scenario

The scenario of experiment was as follow. The subject sat on the waiting-chair, and waited for the direction from the handheld terminal. When the direction was suggested to the subject as shown below, s/he followed the direction.

**Start Shopping Task**

The voice telling for examples, “Start shopping” and “Take a red ball” is announced. The subject takes the basket around the places of supplying ball A, B, C and picks up one color ball that the subject was instructed at each place (A, B, C) for simulating the shopping. Then, the subject takes these three balls to the checkout basket. The subject continues the shopping simulation until “End Shopping Task” is instructed.

**End Shopping Task**

The voice telling “Stop shopping and return to the waiting chair” is announced. Subject returns the shopping basket to the start position and sits down the waiting chair and waits until the next suggestion.

**Suggestion of toileting**

First, the voice message telling “The time to go to a
restroom is coming” is notified. The subject can push the push button at the waiting chair for simulating to go to a restroom after this suggestion. If the subject ignores the first suggestion, “Time to go to a restroom will come very soon” is announced after 5 seconds from the first suggestion. When the subject pushes the button at the waiting chair, the subject cannot bring the shopping basket to the waiting chair in accordance with real shopping situation because shoppers usually prohibited bringing shopping items to a restroom before checkout. Therefore, the subject must return the shopping basket to the start position before returning the waiting chair. After pushing the button, the subject can resume shopping. However, the subject can also ignore the second suggestion.

Alert of toileting
After 10 seconds from the subject ignored the second suggestion, the instruction telling “Go to a restroom now” is announced with the beep sound. Then, the subject must push the button at the waiting chair as soon as the subject can. When the subject pushes the button at the waiting chair, the subject cannot bring the shopping basket to the waiting chair; the shopping basket should return to the start position. After pushing the button, the subject can resume shopping.

VIII. EXPERIMENTAL RESULT OF EVALUATING THE SUGGESTION METHOD

A. The delay from the suggestion to the action
The delay from the suggestion to the action is the time elapsed from the first toileting suggestion to subject’s pushing button. Fig.11 shows the result of elderly subject group’s time average under each condition. We performed two-factor ANOVA with the significant level = 0.05 to analyze each suggestion method’s delay time. The ANOVA indicated two within-subject factors (“Considering” and “Step-by-step”). The ANOVA result is shown in Tab.VI. The result shows that our proposed suggestion method could shorten the time for taking the action of toileting from the suggestion.

Fig. 11. The delay result
### Table VI

**THE DELAY ANOVA RESULT**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Step-by-step</th>
<th>two-factor interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F</strong></td>
<td>975.322</td>
<td>352.371</td>
</tr>
<tr>
<td><strong>significant(5%)</strong></td>
<td>significantly</td>
<td>significantly</td>
</tr>
</tbody>
</table>

### Table VII

**THE TASK ANOVA RESULT**

<table>
<thead>
<tr>
<th>Strategy</th>
<th>Step-by-step</th>
<th>two-factor interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>F</strong></td>
<td>1.177</td>
<td>79.816</td>
</tr>
<tr>
<td><strong>significant(5%)</strong></td>
<td>no</td>
<td>significantly</td>
</tr>
</tbody>
</table>

B. The achievement of the shopping task

Fig.12 is the task achievement result. We performed two-factor ANOVA with the significant level = 0.01 to analyze the each suggestion method’s achievement of shopping task. The ANOVA result are shown in Tab.VII.

The result shows that “Considering” strategy could improve the task performance. On the other hand, “Step-by-Step” strategy had a bad effect for the task performance. However, there were some reasons. One of the reason is the time until the actual suggestion from the forenotice was very short and the early part of the suggestion. Forenotice voice were same, it caused miscommunication and caused bad performance.

**Fig. 12. The task result**

**IX. CONCLUSION**

In this paper, we propose the toilet timing suggestion methods for the elderly in order to support their comfortable outing. For this purpose, we’ve come up with the method for calculating toilet timings based on the estimation of the amount of the body water and the suggestion method of toilet timings that consists of “Considering” and “Step-by-Step” strategies.

From the experimental result on toilet timing calculation, the amount of the excretion per toileting of with-suggestion condition was less than that of in no-suggestion condition and no subject with-suggestion condition put up with going to a toilet. This indicates that the suggestion guides to toilet sufficiently before the subject felt the need to urinate. In addition, almost all subject thought that toilet timing suggestion was useful.

From the experimental result of the suggestion method, the delay time for responding to the suggestion of toileting improved by using our proposed methods. As for the suggestion method, the achievement of the task improved by only “Considering” strategy condition. However, it might have been partly due to improper experimental settings.

We will implement our proposed system in Android mobile device and will conduct the field experiment in the city or shopping center soon.

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