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Original Article

Supportive Intervention Using a Mobile Phone in Behavior Modification

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The authors previously developed a mobile ecological momentary assessment (EMA) system as a real-time data collection device using a mobile phone. In this study, a real-time advice function and real-time reporting function were added to the previous system as a supportive intervention. The improved system was found to work effectively and was applied to several clinical cases, including patients with depressive disorder, dizziness, smoking habit, and bronchial asthma. The average patient compliance rate was high (89%) without the real-time advice and higher (93%) with the advice. The trends in clinical data for patients using a mobile EMA with/without the new function were analyzed for up to several months. In the case of dizziness, an improving trend in its clinical data was observed after applying the real-time advice, and in the case of depressive disorder, a stabilizing trend was observed. The mobile EMA system with the real-time advice function could be useful as a supportive intervention in behavior modification and for motivating patients in self-management of their disease.

Key words: ecological momentary assessment, intervention, mobile phone, real-time advice

Medical treatments are usually provided by medical doctors to help patients overcome their health problems. Before such treatments are initiated, reliable information about the patient's condition is requested. In the field of behavior modification, information is obtained by interviews and/or diaries. Paper diaries have been used for basic research [1] and have become an important component of clinical assessment for behavior modification [2–4]. The information from paper diaries, however, is usually incomplete and biased.

Recently, ecological momentary assessment (EMA) has been used in scientific and clinical studies to collect patient information during the course of daily life [5, 6]. The EMA represents a method of real-time data collection that avoids the bias associated with retrospective recall [7]. Although clinicians and researchers tried to apply the EMA method to collection of patient information; paper diaries, web diaries (via computer), or electronic diaries (PDA, pocket computer, wrist-watch, *etc.*), often failed to provide complete entries, unbiased clinical data [8], or online data.

We previously developed a real-time data collec-

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tion system based on the EMA method using a mobile phone (the mobile EMA system) [9]. The self-reporting of the mobile EMA system overcame the limitations of paper diaries and other electronic diaries by providing reliable clinical data to the doctor in real-time.

In the field of behavior modification, intervention is usually undertaken to treat a patient's condition by changing his/her feeling and/or behavior. In such interventions, face-to-face treatments are common as they can have a great influence on feeling and behavior modification [10]. However, they often involve a high running cost and a high rate of patient attrition [11], and thus the doctors sometimes lose the opportunity to provide intervention [12].

In this study, we describe our addition of a real-time advice function and a real-time reporting function to the previous mobile EMA system as a supportive intervention in order to eliminate several weaknesses of face-to-face treatments, and we examine the efficacy of the improved system. The real-time advice is given to the patient to provide objective advice at an appropriate time. The real-time reporting is given to the doctor to assist in monitoring of the patient's condition. The support provided to behavior modification by the addition of real-time advice can be expected to improve patients' adherence to treatment, self-management, and health outcomes. The improved system was successfully applied to clinical cases involving mood disorders, behavior disorders, and physical symptoms.

Materials and Methods

The mobile EMA system. In our previous study, the developed mobile EMA system which was used for real-time data collection consisted of a mobile phone as a patient terminal, mobile phone providers as a wireless connection to the Internet, an Internet information service (IIS) as a web server, BASP21 as an e-mail server, and Microsoft Access as a database server (Fig. 1).

The data collection was performed when the patient received an e-mail, clicked the link on the sent e-mail to open the interview page, and answered the question by selecting a number from a combo-box or by typing a number in a text-box using the mobile phone. The selected number was information about his/her condition, for example, the degree of a particular symptom. The collected data was stored on the database server and could be accessed online through a mobile phone or a computer.

Mobile EMA system with real-time advice. A real-time advice function was added to the previous mobile EMA system as a supportive intervention (Fig. 2). Real-time advice consisting of a short message was sent to the patient's mobile phone as an e-mail after his/her EMA data was analyzed. The message took the form of an encouragement or warning, urging the patient to develop better self-management of a disease or to avoid inappropriate behavior.

There were 3 parameters required for the data analysis: 1) the threshold: a value representing the higher/lower limit of a data point; 2) the target data:

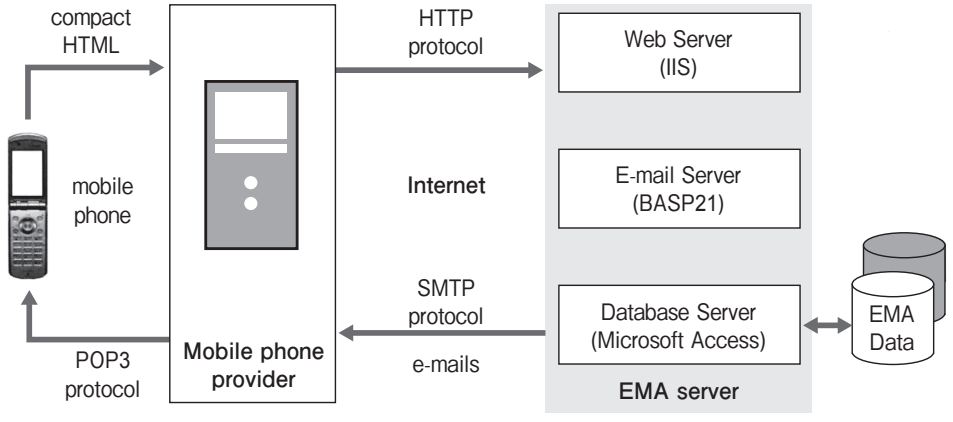


Fig. 1 Mobile EMA system.

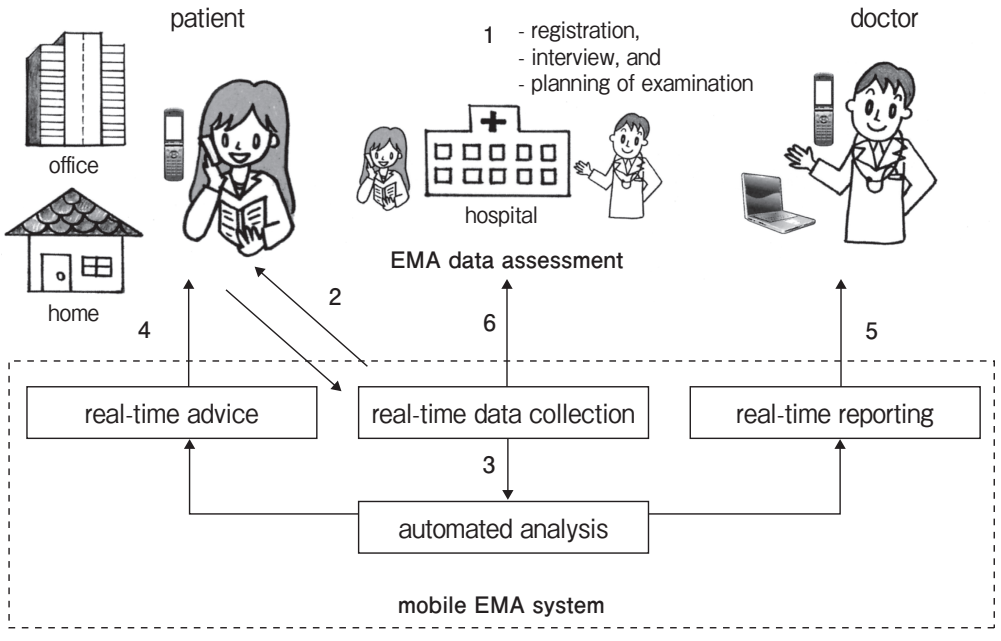


Fig. 2 The procedure for supportive intervention using the mobile EMA system: 1) registration, interviewing, and planning of the examination in a hospital; 2) sending an e-mail to the patient's mobile phone containing a web page link, and collecting data in real-time; 3) analyzing the real-time data automatically; 4) sending an advice e-mail to the patient; 5) displaying the results of automated analysis via a computer and reporting the patient's condition to the mobile phone of the doctor; and 6) analyzing the patient's condition through the EMA data trend.

the number of data points analyzed; and 3) the significant data: the number of values among the target data that were higher/lower than the threshold. The real-time advice was delivered when the number of values among the target data that were higher/lower than the threshold reached the number of significant data points. An example of a real-time advice e-mail is shown in the next section.

Procedure for supportive intervention. The procedure for supportive intervention with the mobile EMA system shown in Fig. 2 was as follows:

1. Registration, interview, and planning of examination: The patient's essential information, such as name, mobile phone e-mail address, age, and sex were registered. As primary treatment, face-to-face interviews were scheduled regularly. The examination period for the data collection with/without real-time advice was determined.

2. Real-time data collection: Real-time data collection was realized by sending the patient an e-mail containing a web page link based on time interval collection time interval, or a particular event [13].

3. Real-time advice: The 3 parameters (threshold, target data, and significant data) for the automated analysis of EMA data were set to determine the advice given to the patient. Fig. 3 shows the process of data analysis to behavior modification in a case of smoking habit. In this case, if the number of significant data points under the threshold is 4 for 7 consecutive data points, then the e-mail advice will be sent.

4. Real-time reporting: The real-time reporting has two uses. One is to display all the results of the automated EMA data analysis on the doctor's computer, and the other is to report the condition of the patient to the doctor's mobile phone via e-mail.

5. EMA data assessment: The progress of a patient's condition was analyzed based on EMA data trends. There were four types of trend, as shown in Fig. 4. An "Improving Trend" was said to be present when the trend improved, a "Stabilizing Trend" occurred when the trend became more stable, a "Consistent Trend" occurred when the trend remained the same, and a "Worsening Trend" occurred when the trend became worse.

Clinical applications. To examine the effectiveness of the system, the mobile EMA with real-time

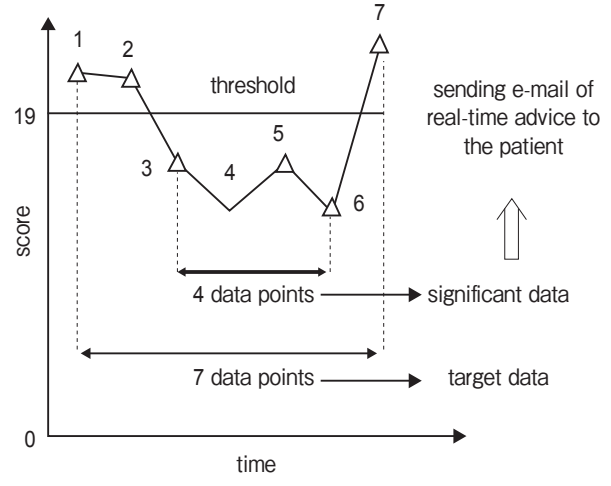


Fig. 3 Example of real-time advice in a case of smoking habit.

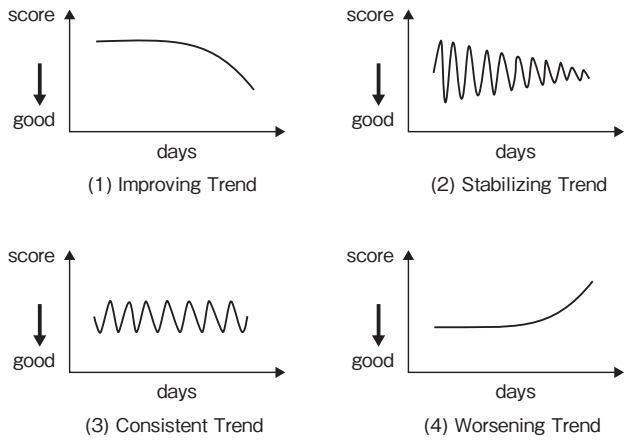


Fig. 4 Long-term trend analysis of EMA data.

advice was used for patients who had health problems associated with mood disorder, behavior disorder, or a physical symptom. There were 5 patients (3 females and 2 males, aged 45–60 years old) with either depressive disorder, dizziness (as appropriate examples of mood disorder), a smoking habit (behavior disorder), or bronchial asthma (physical symptom). They were not compensated for their participation, and paid their own medical fees and the Internet costs of their mobile phones. In the beginning of the examination, the doctor established a good relationship with his/her patients. All patients provided verbal informed consent prior to using the mobile EMA system with the real-time advice.

In this study, the mobile EMA system without real-time advice was given to the patients to collect their clinical data for several weeks or months. The doctor reviewed the data and evaluated whether medical treatment had influenced their conditions. Then, the doctor decided when the real-time advice should be applied and what kind of intervention would be appropriate for each patient according to his/her problem and/or character.

The examination settings for the patients are described in Table 1. The settings for Patient 1 (a 53-year-old male with depressive disorder) were as follows. He recorded his clinical data once a day from April of 2006 to March of 2008. The question for him was "How high is your level of depression?" He was requested to select a value from 0 (good) to 10 (bad) from the combo-box. The real-time advice function was available to him from April of 2007 onwards. The EMA data analysis parameters were set at 5, 4, and 2 for the threshold, target data, and significant data, respectively. When the number of significant data points higher than the threshold was 2 for 4 consecutive data points, an advice e-mail containing the warning "Let's take a rest" was sent to his mobile phone. Examination settings were established for the other patients in a similar manner.

Results

The mobile EMA system with real-time advice. The compliance during the clinical application is shown in Table 2. The numbers of scheduled e-mails, sent e-mails, received data points, and advice e-mails are listed in the upper part of the table. The ratios for system reliability, compliance, and advice rate are listed in the lower part of the table. In this table, the scheduled e-mail was sent once a day in the cases of Patient 1, Patient 3, and Patient 4. In the cases of Patient 2 and Patient 5, the scheduled e-mail was sent twice a day.

The system reliability is represented by the ratio of the number of sent e-mails to that of scheduled e-mails. The total reliability of the mobile EMA system was 99% in the period without advice and 98% with advice.

Patient compliance. The total number of sent

Table 1 Examination settings of the mobile EMA system

Examination type	Patient ID	Age (years)	sex	Period of examination: without real-time advice	Period of examination: with real-time advice	Type of Input box	Value	Question	Analysis of EMA data: threshold[a]	Analysis of EMA data: target[b] data	Analysis of EMA data: significant[c] data	Message type	Message
Depressive disorder	1	53	male	2006/4/4 – 2007/4/7	2007/4/8 – 2008/3/10	combo	0(good) – 10(bad)	How high is your level of depression?	5	4	2	warning	Let's take a rest.
Dizziness	2	58	male	2006/6/21 – 2007/6/15	2007/6/16 – 2008/3/9	combo	0(good) – 10(bad)	How high is your level of dizziness?	0	14	10	encouraging	Your condition is good. Please remain in this state.
Smoking habit	3	56	female	2007/4/26 – 2007/8/29	2007/8/30 – 2008/3/8	text	cigarettes number	How many cigarettes did you smoke?	19	7	4	encouraging	You are succeeding in repressing your desire to smoke. Please remain in this state.
Smoking habit	4	30	female	2006/4/3 – 2007/5/27	2007/5/28 – 2008/3/5	text	cigarettes number	How many cigarettes did you smoke?	19	7	4	encouraging	You are succeeding in repressing your desire to smoke. Please remain in this state.
Bronchial asthma	5	47	female	2006/11/7 – 2007/5/31	2007/6/1 – 2008/3/8	text	PEF value	How high is your value of peak flow rate?	230	4	3	encouraging	Your physical status is good.

[a] a value determining the higher/lower limit of a data point.
[b] the number of data points analyzed.
[c] the number of values among the target data that were higher/lower than the threshold.

e-mails for all patients was 1,980 without advice and 1,822 with advice. The total number of received data points was 1,765 without advice and 1,698 with advice. Therefore, the total compliance of the patients was 89% without advice and 93% with advice, as shown in Table 2.

The effectiveness of EMA data with real-time advice as supportive intervention was examined. The highest increase in compliance was found in the case of Patient 1 (23%). He received 54 advice e-mails (a

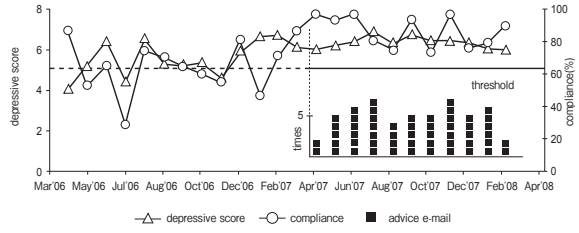
Table 2 Compliance in the clinical application

	Patient 1 (depression)			Patient 2 (dizziness)			Patient 3 (smoking)			Patient 4 (smoking)			Patient 5 (bronchial asthma)			Total		
Numbers	without advice	with advice		without advice	with advice		without advice	with advice		without advice	with advice		without advice	with advice		without advice	with advice	
scheduled e-mail[a]	384	309		717	530		119	187		402	278		381	562		2,003	1,866	
sent e-mail[b]	379	307		708	516		118	180		400	276		375	543		1,980	1,822	
received data[c]	242	268		689	513		111	176		359	222		364	519		1,765	1,698	
within 10 min[d]	82	124		221	177		20	102		65	0		16	8		404	411	
within 10–20 min[d]	13	21		144	58		21	32		11	0		14	14		203	125	
within 20–30 min[d]	5	10		74	50		20	16		14	0		13	10		126	86	
after 30 min[d]	142	113		250	228		50	26		269	222		321	487		1,032	1,076	
advice e-mail[e]		54			33			24			22			28			161	
Ratios	without advice	with advice	change	without advice	with advice	change	without advice	with advice	change	without advice	with advice	change	without advice	with advice	change	without advice	with advice	change
system reliability (%)[f]	99	99	0	99	97	−2	99	96	−3	100	99	−1	98	97	−1	99	98	−1
compliance (%)[g]	64	87	23	97	99	2	94	98	4	90	80	−10	97	96	−1	89	93	4
within 10 min (%)[h]	34	46	12	32	35	3	18	58	40	18	0	−18	4	2	−2	23	24	1
within 10–20 min (%)[h]	5	8	3	21	11	−10	19	18	−1	3	0	−3	4	3	−1	12	7	−5
within 20–30 min (%)[h]	2	4	2	11	10	−1	18	9	−9	4	0	−4	4	2	−2	7	5	−2
after 30 min (%)[h]	59	42	−17	36	44	8	45	15	−30	75	100	25	88	94	6	58	63	5
advice rate (%)[i]		20			6			14			10			5			9	

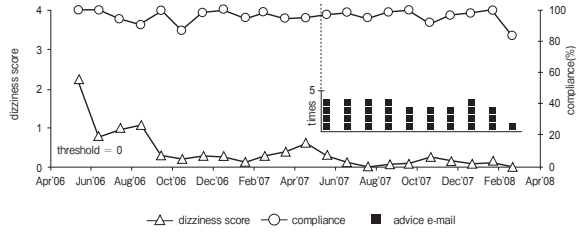
[a] the number of scheduled e-mails containing a web page link.
[b] the number of scheduled e-mail successfully sending.
[c] the number of data point that were recorded by the patient.
[d] the number of data point that were received within 10 min, 10–20 min, 20–30 min, and after 30 min.
[e] the number of advice e-mails that were sent.
[f] the ratio of the number of sent e-mails to that of scheduled e-mails.
[g] the ratio of the number of the received data to that of the sent e-mails.
[h] the compliance within 10 min, 10–20 min, 20–30 min, and after 30 min.
[i] the ratio of the number of advice e-mails to that of received data.

20% advice rate). The highest compliance rates were found in the cases of Patient 2 (99%) and Patient 3 (98%). Their compliance rates increased 2% and 4%, respectively. Patient 2 and Patient 3 received encouraging messages 33 times (6%) and 24 times (14%), respectively. A decrease in compliance was found in the case of Patient 4. Her compliance with advice was 80%, a decrease of 10%. She received 22 advice e-mails (10%) and never came to appointments with the doctor during the two-year examination. Patient 5 maintained a high compliance (96%). She received 28 advice e-mails (5%).

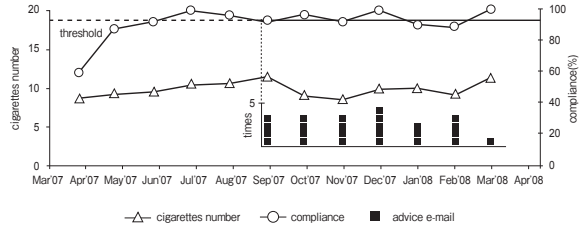
Clinical data with/without the real-time advice. The EMA data with/without the real-time advice are summarized in Fig. 5. These figures consist of monthly averages of EMA data, including those for patient compliance and the number of advice e-mails. In the case of Patient 1 (depressive disorder), his depressive scores fluctuated in the period without the real-time advice, and then became steady with the advice (Fig. 5(A)). In the case of Patient 2 (dizziness), his average dizziness scores decreased but did not reach zero in the first 12 months without real-time advice. The real-time advice function was applied to his case from June 2007 and influenced his dizziness score, which significantly decreased to almost zero (Fig. 5(B)). In the case of Patient 3 (smoking habit), her monthly average number of cigarettes increased gradually until September of 2007 and then decreased during the early period of real-time advice (Fig. 5(C)). In the case of Patient 4 (smoking habit), she received the advice e-mails but her number of cigarettes unfortunately increased (Fig. 5(D)). In the case of Patient 5 (bronchial asthma), the high PEF value designates the good status of her respiration. In the early period of the examination, her peak expiratory flow (PEF) value was high and then gradually decreased, but the daily variance of her PEF values was large. The daily variance of PEF measure the difference between the first PEF value and the second PEF value in a day. In the early period with advice, she achieved higher values of PEF than the threshold and smaller daily variance of PEF. She maintained a higher mean PEF and smaller daily PEF variance until the start of winter in December of 2007 (Fig. 5(E)).



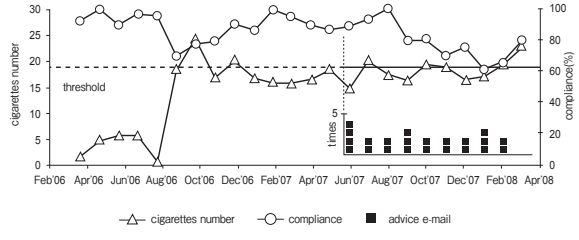
(A) Patient 1 (depressive disorder).



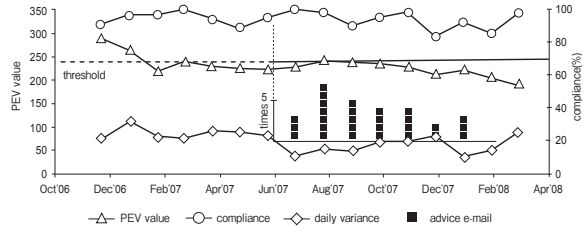
(B) Patient 2 (dizziness).



(C) Patient 3 (smoking habit).



(D) Patient 4 (smoking habit).



(E) Patient 5 (bronchial asthma).

Fig. 5 Monthly average of EMA data with/without real-time advice.

Discussion

The mobile EMA system with real-time advice as a supportive intervention. The mobile EMA system with real-time advice was applied to support face-to-face treatment and eliminate several treatment weaknesses. These included variation in the doctor's attentiveness, missed opportunities to provide intervention [12], and a restriction of time and place. The transmission of repetitive advice may overcome the aforementioned weaknesses, as the advice is given automatically at any time and in any location according to the analysis of a patient's EMA data.

The system appears to have high reliability for real-time data collection; it may thus provide an opportunity to provide reliable data about patients to their doctors. Compared with other diary methods, the mobile phone may become a better tool for collecting the immediate experiences of the patient [14].

Issues related to the security and privacy of health information are still under consideration, because in its present form the system employs an unsecured SMTP/POP3 transfers protocol, public networks and generic mobile phone technology.

Clinical evaluation. Supportive intervention with real-time advice increased patient compliance in the case of Patient 1 (depressive disorder, 23% compliance) and maintained the high compliance rates of Patient 2 (dizziness, 99%), Patient 3 (smoking habit, 98%), and Patient 5 (bronchial asthma, 96%). These patients attended all their face-to-face appointments and had a good relationship with their doctors. In the case of Patient 4 (smoking habit), whose compliance decreased, the decrease appeared to be attributable to a weak relationship with her doctor [15, 16]. The total compliance of the patients increased 4% during the period of real-time advice, although the effectiveness of the real-time advice might be reduced without a good relationship between doctor and patient [17, 18].

The rate of compliance within 10 min of receiving the real-time advice increased for Patient 1, Patient 2, and Patient 3; however, for Patient 4 and Patient 5, compliance decreased. In the cases of Patient 1 and Patient 2, the clinical data was recorded after the e-mail had been sent to their mobile phone. However, in the cases of Patient 3, Patient 4, and Patient 5, the data was recorded after a physical measurement (cigarettes number or PEF value) was performed, which may have affected their compliance within 10 min.

The advice rate represents the percentage of real-time advice that was sent to the patient according to the analysis of EMA data (received data). A high advice rate might indicate a good condition for the patients who received encouraging messages [19] and a bad condition for the patients who received warning messages. The doctor evaluated the advice rate of the patients to assess whether the advice was effective at improving their compliance and condition. In the case of Patient 1, the 20% advice rate obtained with warning messages was effective at improving his compliance. In the case of Patient 2, the 6% advice rate obtained with encouraging messages was effective at improving his compliance and condition.

The progress of the patients' conditions with/without real-time advice summarized in Fig. 5 was analyzed based on the EMA data trends. The EMA data trend of Patient 2 with/without advice approximated an "Improving Trend". In the early examination, his dizziness score was high and then significantly decreased because of medical treatment. After that, he received real-time advice and improved his behavior, with his symptoms gradually decreasing to almost zero. The EMA data trend of Patient 1 with/without advice approximated a "Stabilizing Trend". His depressive score fluctuated without advice and then became steady with advice. It was observed that the real-time advice raised his awareness of his symptoms. The EMA data trends of Patient 3, Patient 4, and Patient 5 with/without advice approximated a "Consistent Trend". This means that the patients maintained good conditions. In the case of Patient 3, she probably maintained a good condition because she was pleased by the real-time advice. In the case of Patient 4, the period when she enrolled in another program was excluded from the evaluation of the EMA data trend. However, during the early period of real-time advice, the advice appeared to help her decrease her smoking behavior.

In the case of Patient 5, she said that the encouraging messages made her happy and motivated her to increase her PEF value. Such a feeling might have stimulated her sympathetic nervous system [20, 21], thereby opening the bronchus, raising her PEF value, and maintaining her good condition.

In summary, a mobile EMA system with the functions of real-time data collection, real-time advice, and real-time reporting was developed and found to work effectively. The system provided reliable data about the patients to their doctors, and real-time advice was successfully sent to the patients based on analysis of the EMA data. The system was shown to help patients in the self-management of their disease, and thus could be useful as a supportive intervention in behavior modification.

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