IS-ACTIVE

Inertial Sensing System for Advanced Chronic Condition Monitoring and Risk Prevention

D5.1 – User interaction and feedback

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Abbreviations

Below is a list of abbreviations used in this document.

ADL	Activities of Daily Living
COPD	Chronic Obstructive Pulmonary Disease
CHF	Chronic Hearth Failure
D	Deliverable
ELS	Elias University Hospital
GOLD	Global initiative for chronic Obstructive Lung Disease
ICT	Information and Communication Technology
INE	Inertia Technology
LHL	Norwegian Heart and Lung Patient Organisation
NOR	NORUT Northern Research Institute
NST	Norwegian Centre for Telemedicine / University Hospital of North Norway
PDA	Personal Digital Assistant
PRS	PROSYS
RRD	Roessingh Research and Development
SUS	System Usability Scale
UTAUT	Unified Theory of Acceptance and Use of Technology
WP	Work Package

1 Introduction

The objective of IS-ACTIVE is to devise a person-centric healthcare solution for elderly with chronic conditions – especially people with COPD – based on the recent advances in wireless inertial sensing systems. The project emphasizes the role of the home as care environment, by providing real-time support to patients in order to monitor, self-manage and improve their physical condition according to their specific situation.

IS-ACTIVE focuses on simple and ubiquitous feedback interfaces, such as PDA, Tablet, TV and the inertial sensors themselves. In the initial experiments, prototype versions of the PDA and the Tablet feedback devices and the sensor have been tested with users.

This document describes the three prototype interaction and feedback mechanisms that have been developed in the IS-ACTIVE project:

1. A Smartphone application has been developed that patients can carry with them, in order to receive real-time feedback on activity behaviour while on the move.
2. For providing feedback in the home environment, a Tablet PC was developed, focussing on activity feedback as well as guided exercises.
3. An interactive game has been developed for in-home exercise coacing.

In this document, we firstly describe in Chapter 2 the sensor node casing design for wearablity, which will be used by the Smartphone and Tablet PC feedback devices. Next, in Chapter 3 we present the Smartphone feedback device, while Chapter 4 describes the Tablet PC feedback device. In Chapter 5 we present the *Orange Submarine* interactive game. Chapter 6 concludes this document.

2 Sensor node casing design

The input for all three feedback devices comes from the ProMove inertial sensor node developed in the IS-ACTIVE project. Figure 2 shows a rendering of the latest ProMove prototype, called **ProMove 3D**, which the patient has to wear on his/her hip. A dedicated casing has been designed and developed for wearability (see Figure 2), taking into account several factors:

- We designed a total fool-proof system, through a special clip that automatically switches on the node; on the inside of the clip there is a notch to operate the switch when the housing is placed in the clip with the top cover facing outward.
- We included a belt mounting clip for ease of use and wearability
- We prevent moisture and dust to enter the housing through a seal (O-ring)
- Slim design, user-friendly look-and-feel

Figure 1: The ProMove 3D wireless inertial sensor, pictured here as a 3D render with an attached belt clip for mounting on the patient's hip.

3 The Smartphone feedback device

The goal of the Smartphone feedback device is twofold: a) to give COPD patients insight into their daily levels of physical activity, and b) to motivate patients to increase their physical activity. In short, the smartphone application aims to achieve these goals by providing constant visual feedback on the patient's current activity level by displaying a real-time graph of activity, and to provide feedback messages to the patient if they deviate too much from a predetermined reference activity pattern.

This chapter describes the various functionalities of the Smartphone application that are used in the IS-ACTIVE project.

Figure 1 shows the Smartphone used in the IS-ACTIVE project, an HTC Desire running Android version 2.2. The figure shows the home screen of the application: a graph, displaying the patient's current activity pattern (in blue) and the predefined target (or reference line) in green. The green 'Status' box is a feature that shows the deviation of the patient from the reference line in the last 5 minutes.

Figure 2: The Smartphone (HTC Desire) showing the graph screen, with reference line (green) and current activity (blue). The status icon shows the activity trend from the past 5 minutes.

3.1 Sensor node integration

The ProMove sensor node measures the movement on all three axes by sampling an internal 3D-accelerometer. The samples are summed up over the three axes for 10-second intervals and stored as *activity counts*. Each minute 6 of these 10-second activity count values are sent over Bluetooth to the Smartphone.

Each Smartphone is linked to one ProMove sensor node through a wireless connection that is handled automatically. When the patient switches on his Smartphone, the Activity Monitor application automatically launches, and the patient only has to press the 'Start' button to get going (Figure 3). If the sensor node is within range and lays in its clip-holder (e.g. switched on), a wireless connection will automatically be established, and the sensor node will start sending activity count values every minute.

Figure 3: The start screen of the Smartphone application. After switching on the phone, the only thing left to do is to press 'Start' once.

3.2 Activity graphs & home screen

As soon as the sensor connection is established, the patient will see the home screen of the Activity Monitor application. The home screen (already depicted in Figure 1) shows a graph of the patient's current activity plotted over a reference (or target) activity line. The reference line can be set individually for each patient and serves as a goal for the patient to reach. For patients with less severe COPD and an already more active lifestyle the reference line can be set higher than for patients in the later stages of the disease. The graph runs from 8:00 AM in the morning till 10:00 PM in the evening, which is the period in which the patient is supposed to use the system.

The home screen shows an information bar at the top of the screen, where the patient can see status information on the device:

- The current time.
- Sound enabled, on/off (a button).
- An icon indicating connection status between Smartphone and sensor.
- An icon indicating the battery status of the Smartphone.

The blue 'Advice' button at the bottom of the screen can be pressed to request the last feedback message from the system (described in 2.3).

3.3 Feedback messages

The Activity Monitor sends feedback messages to the patient in order to remind him/her of their current activity status. If the patient is too inactive, he can receive an *encouraging* message, e.g.

"*Take a nice walk!*"

Figure 4: The Smartphone application showing an encouraging feedback message: "Take a nice walk!".

The goal of the IS-ACTIVE project is to encourage a more active lifestyle for COPD patients, therefore patients are regularly reminded to become more active if their current activity levels are below the reference standard.

If the patient is over-performing, or is being too active, the system can send a *discouraging* message: a message to discourage activity, e.g.:

"*Pick up a fun magazine.*"

Figure 5: The Smartphone application showing a discouraging feedback message: "Pick up a fun magazine".

The discouraging messages are given to COPD patients in order to balance their activity levels. Research has shown that patients often are very active in the mornings, but suffer from a steep decline in activity throughout the early afternoon. In order to become more active overall, the goal is to spread out activities over the day. Therefore, sometimes patients should be reminded not to become too active in order to save energy for the remainder of the day

Similarly, if the patient is performing according to the predefined reference line, the system can compliment him on his performance with a *neutral* message: a message indicating that all is well, e.g.

"*Keep it up!*"

Figure 6: The Smartphone application showing a neutral feedback message: "Keep it up!".

As counterpart to the encouraging and discouraging messages, neutral messages are send to the patient in order to offer a reward for 'good' behaviour, i.e. not being too active or too inactive.

3.3.1 Message timing

The IS-ACTIVE application supports two ways of defining the timing for the feedback messages. First, it can operate in a 'simple' mode where the timing of the feedback is fixed in a configuration setting. For example, the application can be set to give feedback every X minutes (e.g. every hour, or half hour, etc...).

The more advanced mode of feedback timing is to let the device decide when to give feedback based on context and learned patient behavior. In this mode, a self-learning, context-aware feedback module is polled every minute to indicate whether or not this is a good time for providing feedback. This module then looks at the context of the patient (location, weather, time of day, time of week, etc...) and the patient's previous interactions with the system (how often did the patient receive feedback already, to which messages did the patient respond, etc...). The module then predicts whether or not the patient is likely to respond to a feedback message at this point in time; and based on that decision feedback is given or not. The details of the algorithms behind the predictive feedback module can be found in [Akker et al., 2010] and [Akker et al., 2011].

3.3.2 Message content

As for the feedback message timing, the system also supports two different modes for determining the content of the feedback messages. In the simple mode, if the system needs to present the user with an encouraging feedback message, it simply selects randomly from a predefined list of feedback messages. Table 1 lists the possible feedback messages for the IS-ACTIVE application. Encouraging- and discouraging messages are categorized as either 'minor' or 'major', indicating the 'severity' of the deviation from the reference line, and the advice that should be given. If, e.g., the patient's current activity level is between 10-19% below the reference line, a minor encouraging message is given to indicate that he has to perform a minor activity in order to get back to the reference; if the patient is more than 20% below the reference line, a major encouraging messages is chosen.

Neutral Messages		**ID**
It's going well!		1
Well done.		2
Keep it up!		3
Allright.		4
Encouraging Messages		**ID**
(*minor*)	Have you got any dishes to do?	5
(*minor*)	Take a nice walk!	6
(*minor*)	Go get a breath of fresh air.	7
(*minor*)	Have you been outside yet, today?	8
(*minor*)	Take a walk around the block	9
(*minor*)	Try to walk around for a bit.	10
(*major*)	Go for a nice and long walk.	11
(*major*)	Go for a good bit of cycling!	12
(*major*)	Do you need anything from town?	13
(*major*)	Is there anything to clean around the house?	14
(*major*)	Time to go shopping.	15
Discouraging Messages		**ID**
(*minor*)	Sit down for 10 minutes.	16
(*minor*)	Make a nice cup of coffee or tea.	17
(*minor*)	Have you read the newspaper yet?	18
(*minor*)	Pick up a fun magazine.	19
(*minor*)	Perhaps you could sit down for a while.	20
(*major*)	Try to relax for a bit.	21
(*major*)	Sit down for a while.	22
(*major*)	Take some time for yourself.	23
(*major*)	Stop what you are doing for a while.	24

Table 1: List of neutral, encouraging and discouraging feedback messages for the simple feedback content mode of operation (English).

See Appendix A, B and C, for the feedback message content in Dutch, Norwegian and Romanian which are used in the IS-ACTIVE trials.

The second mode of operation with regard to the feedback message content is based again on a self-learning and context aware algorithm. It uses an ontology (a structured tree) of possible feedback messages for its selection. When a message has to be send to the patient, the tree is traversed, pruning along the way all branches of the tree that contain messages that are not suitable for the patient's current context. For example, if the weather at the current time is bad (e.g. cold and raining), all messages that tell the patient to go outside are not considered, and are pruned from the tree. From the messages that *are* relevant to the current context, a choice is made based on the patient's reaction to those messages. Whenever a patient responds well to a given feedback message (e.g. the patient is told to 'go for a walk', and after the message he has become more active), that information is stored alongside that given feedback message in a database. This information is then used in the selection of feedback messages, so that message types that the individual patient responds well to are selected more often. For details of the algorithm of the ontology-based feedback message content generation see [Wieringa et al., 2011].

3.4 Questionnaires

The smartphone application can query the patient to answer small questionnaires at regular intervals. Figure 7 shows the screen where the patient is asked a question about his shortness of breath: "Have you been short of breath?". The patient can tap one of the possible answers: "Normal", "A bit more than normal", or "Clearly more than normal", which have been colour coded in levels of severity from green to yellow to red respectively.

Figure 7: The Smartphone application displaying a question to the patient: "Have you been short of breath?", which the patient can answer.

4 The Tablet feedback device

The aim of the Tablet feedback device is to motivate and support people with COPD in taking part in physical activity and exercising in their daily life. The participants will follow a home-based program for a specific amount of weeks, where they will be divided in groups and take part in scheduled and un-scheduled outdoor walking, and do exercising at home using a follow-along video. The tablet feedback device provides functionality that support people with COPD in following this concept.

The prototype is running on a tablet computer that is tailored for the needed IS-ACTIVE functionality, and other standard functionality is disabled or removed. The tablet used in the prototype is a 7” Samsung Galaxy Tab P9000 running Android 2.1. The prototype also interacts with the ProMove 3D inertial sensor (see Chapter 2) in order to get the users activity data.

The Tablet is easy movable and can be mounted on the wall or placed on a table in the living room, the kitchen, the hallway, or any place where it is easily visible. Using a docking station the tablet can easily be attached to a TV via HDMI and show exercise videos in full screen on the TV.

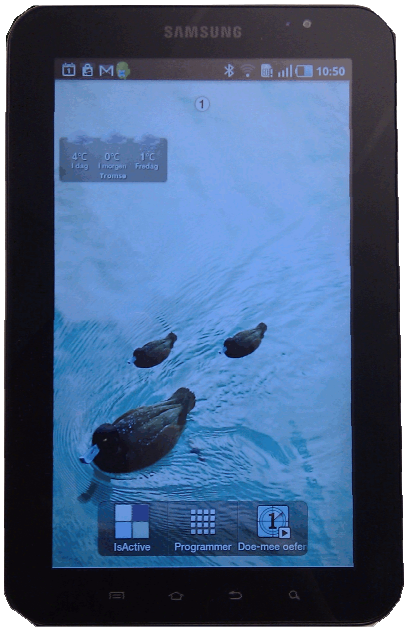

Figure 8: The Tablet feedback device home screen

4.1 Functionality

The Tablet feedback device prototype has the following functionality:

- A home screen with a wallpaper image that increases in enrichment based on the user achieving personally defined weekly activity goals.
- A week-plan with an overview of activities:
  - Pre-scheduled virtual group-walks
  - Individual activities (walks, exercise sessions), which may or may not be pre-scheduled.
- A follow-along exercise videos with a physiotherapist
- Other relevant information, e.g. weather information

4.2 Visual feedback

The Tablet feedback device exploits image enrichment in order to provide positive feedback when the user achieves personal activity goals. This approach is inspired by the work on Ubifit Garden at the U. Washington [Consolvo et al., 2008]. The intention is to have a pleasant home screen wallpaper image, which is enriched with objects based on user activities and exercises. The idea is to have an initial nice picture on the Tablet, even if you are unable to perform physical activity a particular week, or less than your weekly goal.

The wallpaper image can be country or culture specific or tailored to each user. Currently the Tablet prototype uses a single duck in water as initial image, and for each walk or other physical activity a new duckling is added to the image (see Figure 8). The wallpaper image will be reset at the start of each week.

4.3 Activity week-plan and virtual walk

The activity week-plan gives an overview of a user's physical activities during a week. It contains entries for pre-scheduled virtual group-walks, where one can confirm or decline participation and see the intentions of others participants. It also has entries for individual physical activities such as walks, biking and exercises.

The intention of the virtual group-walk is to exploit the social influence of peers as a motivating factor for doing exercising and physical activity. The concept of a virtual-group walk is that participants are not walking physically together in "space", just simultaneously in "time". We aim at forming a community feeling by introducing the concept of a virtual group-walk. Social pressure can sometimes be encouraging while other times discouraging, so we

want to concentrate on the aspects of being virtually together and doing a healthy walk. We try to prevent users “dropping out” due to lack of performance.

Figure 9: The Week plan, virtual walk overview, and registration of new individual activities.

Users are initially scheduled for their virtual group-walks, and all group members see the status of the others. Users are initially registered as “not decided yet”, and they have to manually change their status to “intend to participate”, “participating”, and “done”.

The users can also register individual physical activities during the week, such as walks, biking and exercises. These are not shares with the other participants in the virtual group.

For each virtual walk and other individual activities, the user gets a new duckling on the Tablet home screen.

The Tablet feedback device is also interfaced wireless with the ProMove 3D inertial sensor. A user who wears their sensor node during a virtual walk or during individual activities and exercises will have their activity data loaded into the Tablet feedback device. Later they are able to view their activity data, the history, and progress.

See Figure 9 for the week plan, the virtual walk overview, and the registration of new individual activities.

4.4 Follow-along exercise videos

Figure 10: The follow-along exercise video

The exercise videos are intended for doing follow-along exercising at home (see Figure 10). They are by a pulmonary physiotherapist doing specially selected exercises suitable for users with COPD. These can be viewed in both portrait and landscape mode, and played back on a TV using a docking station. By touching the screen the user toggle pause and play.

For each exercise session the user get a new duckling on the home screen of the Tablet.

4.5 Additional relevant information

The Tablet can also contain other freely available programs that may be useful for the target user group.

Figure 11: The home screen weather widget

Since weather information is of importance for users with COPD a home screen widget that shows updated weather forecast for the area in question has been included. The weather information could be used both for planning of a walk (e.g. is it going to rain in the morning and the evening), but also for in general for keeping the “awareness” of the picture frame (see Figure 11).

5 The Orange Submarine game

The *Orange Submarine* game is part of the exercise coaching program of IS-ACTIVE, where patients are encouraged to do more physical activity through an interactive exercise. The development includes the design of a sensorized dumbbell and the design of the game.

5.1 The sensorized dumbbell

A sensorized dumbbell is used to create a sensor-enhanced exercising experience to the user. The dumbbell contains a ProMove sensor node that detects the direction of the vertical motion and a Nonin pulse oximeter that reads the oxygen saturation and heart rate levels. The motion data and the oxygen saturation and heart rate values are sent wirelessly by the ProMove2 sensor node embedded in the dumbbell to a computer that runs the game. This data has is used as input for the game.

The design of the dumbbell is shown in Figure 12 below. The following key design points have been considered:

- Incorporation of ProMove, oxygen saturation and heart rate sensors
- Selectable amount of weight
- Prevent stigmatizing the COPD patient through a pleasant look-and-feel

Figure 12 – Design of the sensorized dumbbell

5.2 The design of the game and graphical interface

The game consists of a submarine, which moves to the right at a constant speed (see Figure 13). The player controls the vertical position of the submarine by moving the dumbbell up and down. A sine wave of bubbles is displayed on the bottom of the sea. The user has to catch bubbles by moving the dumbbell up and down, which translates on the screen by the movement of the submarine. The score shown in the top right corner is based on the amount of bubbles which are caught by the submarine. The heart rate en oxygen saturation levels are shown in real-time during game play, in the upper right corner of the screen. The game stops when the oxygen saturation or heart rate exceeds the patient's threshold and shows a pop-up warning message instructing the patient to rest.

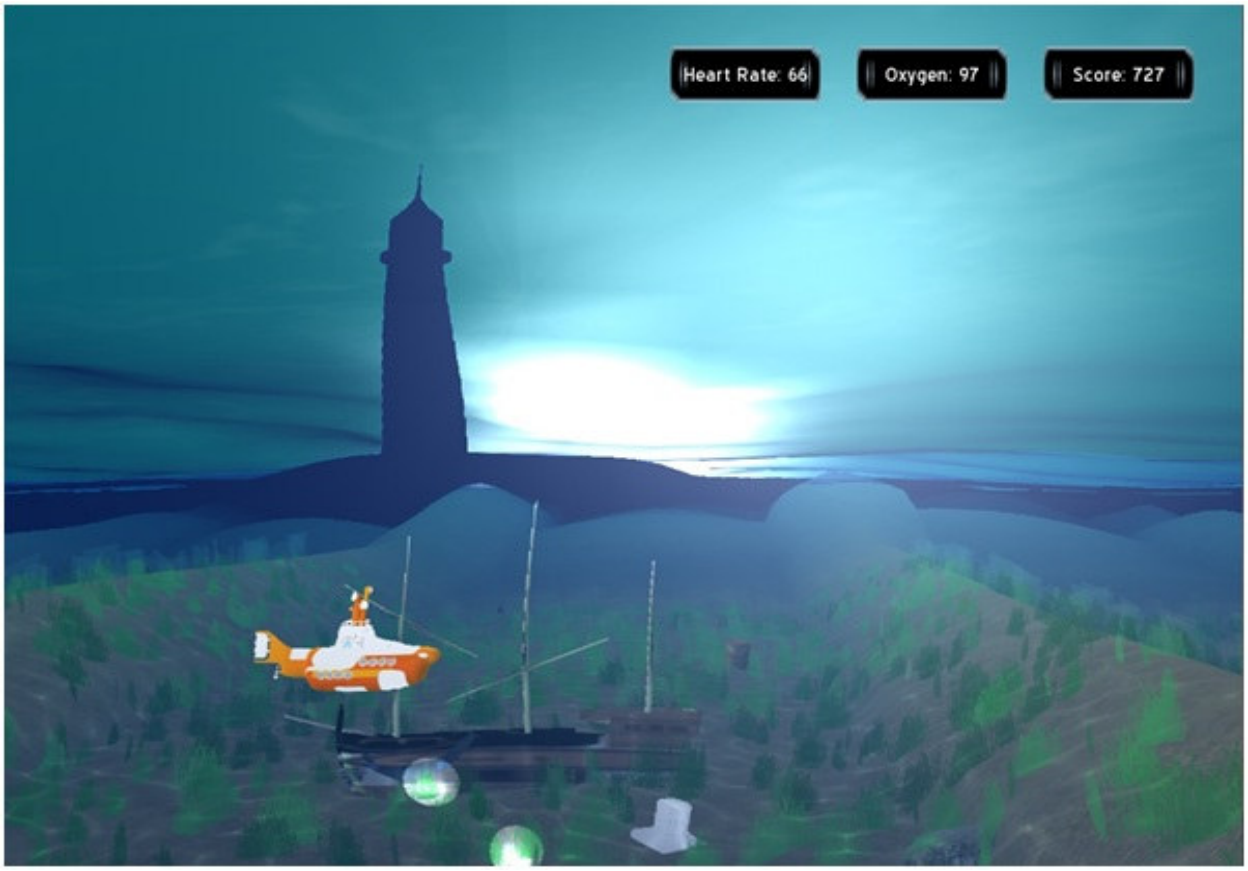

Figure 13 - Screenshot of the Orange Submarine game

Figure 14 shows a user playing the game with the prototype dumbbell.

Figure 14 – Orange Submarine game: dumbbell and graphical interface

6 Summary and conclusions

We have presented three IS-ACTIVE prototype feedback devices that all guide and support users in being physical active and in doing exercising. The feedback devices are all exploiting the ProMove wireless inertial sensor in order to detect the detailed activity and movement of the users.

All prototypes have both been tested by users and evaluated in initial lab trials. The results from the trials were very positive and the prototypes are being modified based on the feedback and lessons learned in the trials. For more detailed information on the initial lab trials see:

IS_ACTIVE D6.2 - Results and analysis of initial experiments

The IS-ACTIVE prototype feedback devices will be thoroughly evaluated with users in the final field trials to come.

7 References

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Appendix A: Feedback messages (Dutch)

Neutral Messages		**ID**
Het gaat goed!		1
Goedzo.		2
Blijf zo doorgaan!		3
Prima.		4
Encouraging Messages		**ID**
(*minor*)	Heeft u nog een afwas staan?	5
(*minor*)	Maak een lekkere wandeling!	6
(*minor*)	Ga even een frisse neus halen.	7
(*minor*)	Bent u vandaag al buiten geweest?	8
(*minor*)	Ga even een blokje om.	9
(*minor*)	Probeer even een beetje rond te lopen.	10
(*major*)	Maak een lekkere lange wandeling.	11
(*major*)	Gaat u even een lekker stuk fietsen!	12
(*major*)	Heeft u nog iets uit de stad nodig?	13
(*major*)	Is er nog iets in huis om schoon te maken?	14
(*major*)	Tijd om boodschappen te doen.	15
Discouraging Messages		**ID**
(*minor*)	Gaat u even 10 minuten zitten.	16
(*minor*)	Zet een lekker kopje koffie of thee.	17
(*minor*)	Heeft u de krant al gelezen?	18
(*minor*)	Pak even een leuk tijdschrift.	19
(*minor*)	Misschien dat u even kunt gaan zitten.	20
(*major*)	Probeer wat te ontspannen.	21
(*major*)	Gaat u even zitten.	22
(*major*)	Neem even de tijd voor uzelf.	23
(*major*)	Stop even met wat u aan het doen bent.	24

Table 2: List of neutral, encouraging and discouraging feedback messages for the simple feedback content mode of operation (Dutch).

Appendix B: Feedback messages (Norwegian)

Neutral Messages		**ID**
Dette går bra!		1
Bra gjort.		2
Fortsett sånn!		3
Flott.		4
Encouraging Messages		**ID**
(*minor*)	Har du oppvask stående?	5
(*minor*)	Ta en fin tur!	6
(*minor*)	Få deg litt frisk luft.	7
(*minor*)	Har du allerede vært ute i dag?	8
(*minor*)	Ta en liten luftetur i nabolaget.	9
(*minor*)	Prøv å gå litt.	10
(*major*)	Ta deg en lang fin spasertur.	11
(*major*)	Ta deg en sykkeltur!	12
(*major*)	Trenger du noe på butikken?	13
(*major*)	Trengs det rengjøring i huset?	14
(*major*)	Tid for å gå og handle.	15
Discouraging Messages		**ID**
(*minor*)	Sett deg ned i 10 minutter.	16
(*minor*)	Lag deg en god kopp kaffe eller te.	17
(*minor*)	Har du fått lest avisen?	18
(*minor*)	Kos deg med et ukeblad.	19
(*minor*)	Kanskje du kan sette deg ned litt.	20
(*major*)	Prøv å slappe litt av.	21
(*major*)	Sett deg ned ei stund.	22
(*major*)	Bruk litt tid for deg selv.	23
(*major*)	Stopp ei stund med det du holder på med.	24

Table 3: List of neutral, encouraging and discouraging feedback messages for the simple feedback content mode of operation (Norwegian).

Appendix C: Feedback messages (Romanian)

Neutral Messages		**ID**
Merge bine!		1
Foarte bine.		2
Continua tot asa!		3
OK.		4
Encouraging Messages		**ID**
(*minor*)	Ai vase de spalat?	5
(*minor*)	Ai nevoie de o plimbare!	6
(*minor*)	Ai nevoie de aer curat.	7
(*minor*)	Ai fost pe-afara astazi?	8
(*minor*)	Ar fi bine sa faci o scurta plimbare pe-afara.	9
(*minor*)	Incearca sa mergi un pic.	10
(*major*)	Ar fi bine sa faci o plimbare mai lunga pe-afara.	11
(*major*)	Ai nevoie sa exersezi un pic cu bicicleta.	12
(*major*)	Nu vrei sa mergi la cumparaturi?	13
(*major*)	Nu vrei sa faci curatenie in casa?	14
(*major*)	E timpul sa faci cumparaturi.	15
Discouraging Messages		**ID**
(*minor*)	Relaxeaza-te 10 minute.	16
(*minor*)	Nu vrei sa iti faci o cafea sau un ceai?	17
(*minor*)	Ai citit ziarele de azi?	18
(*minor*)	Citeste o revista amuzanta.	19
(*minor*)	Ai putea sa te relaxezi un pic.	20
(*major*)	Incearca sa te relaxezi un pic.	21
(*major*)	Incearca sa iei o scurta pauza.	22
(*major*)	Acorda-ti un scurt ragaz.	23
(*major*)	Opreste-te din activitate pentru un timp.	24

Table 4: List of neutral, encouraging and discouraging feedback messages for the simple feedback content mode of operation (Romanian).