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General recommendations for development of new sensors

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List of abbreviations

BAN	Body area network
CO ₂	Carbon dioxide
ECG	Electrocardiogram
EEG	Electroencephalogram
EOG	Electrooculogram
EMG	Electromyogram
LAN	Local area network
PTT	Pulse transit time
SaO ₂	Blood oxygen saturation
URAS	Ultra red absorption spectroscopy

Table of contents

List of abbreviations	2
Table of contents.....	3
List of Tables.....	4
Executive summary.....	5
Introduction.....	6
1. General recommendations.....	6
1.1. Sensors.....	6
1.1.1. Sensor quality.....	7
1.1.2. Sensor attachment.....	7
1.2. Data recording.....	7
1.2.1. Usability and safety.....	7
1.2.2. Recording quality.....	8
1.2.3. Optimisation of data recording.....	8
1.2.4. Transmission of data.....	9
1.3. Data.....	9
1.3.1. Access to data.....	9
1.3.2. Data recording format and data exchange.....	9
1.3.3. Data storage.....	9
1.4. Data analysis.....	9
1.4.1. Autonomous diagnosis system.....	9
1.4.2. Tuning the prediction algorithms.....	10
2. Specific recommendations for the improvement of existing recording techniques.....	10
3. Classification of the sensor and technical improvements to be done.....	16
Conclusions.....	19
References.....	19

List of Tables

Table 1: *Main pitfalls of the existing recording techniques and recommendations for improving them.....10*

Table 2: *Suggestions about a priority order of the technical improvements to be done.....17*

EXECUTIVE SUMMARY

Recording physiological states and their transitions is possible through the use of sensors and techniques which are reliable and accurate. However, these elements should be clearly improved in order to make possible recordings in the work or the home places, thus giving access to monitoring difficult and dangerous worker's tasks as well as monitoring patients in their usual environment.

The purpose of this deliverable is to list the main recommendations which can be made at the different levels of the recording process, such as the required sensor characteristics, and the way data are recorded, stored and analysed. Some specific recommendations are also suggested in order to improve the recording techniques. These suggestions are mainly based on existing sensors but it is also stressed the necessity to develop new types of sensors, which should better satisfy the general recommendations.

Then a priority order is proposed for the development of innovative improvements of the sensors and recording techniques. This classification has been done according to the priorities made from a user's point of view. It is obvious that some improvements would be more costly than others, although a significant amelioration in one technique can originate unexpected promising developments.

Introduction

Up to now, recording physiological states and their transitions in humans has been possible through sensors and techniques which have been conceived and developed mainly for the laboratory or the clinical settings. In most cases, these elements are reliable and accurate, but they lack other qualities, such as low size and weight, low cost, user friendliness and high storage capacity. These characteristics and others would make possible more frequent recordings in the work or the home places in order to improve monitoring difficult and dangerous tasks as well as monitoring patients in their usual and private environment.

The existing sensors suffer from several constraints, pitfalls and technical limitations. In order to be used more widely, they need to be improved. The purpose of this deliverable is therefore, to stress the main questions which were identified when using these sensors and techniques and to propose some solutions to the most frequent problems. It is also obvious that some of the expected improvements will come with the development of new sensors which will satisfy some of the criteria established by the users. In this case, it is expected that a new generation of biological sensors will make possible recordings in some of the everyday situations where immediate safety is a major goal.

The present document is mainly based on the results presented in other SENSATION deliverables (Del.1.2.1 and Del.1.2.2). It will first summarize the general recommendations about the improved or ideal new sensors and recording techniques and then present the detailed suggestions to improve the existing sensors and recording techniques.

1. General recommendations

1.1. Sensors

It is obvious that one of the major recommendations is that a minimal number of sensors should be attached to the subject. In order to have a minimal disturbance to the subject or the patient, sensors should be as small as possible. They should also have high sensitivity, good reliability and stability in different ambient conditions.

From the beginning, it is important to focus on the adequacy of sensors to the actual need of experimenters, clinicians and company doctors, as very innovative sensors may be of no use if not wanted by these specialists.

On the same line, sensors and the recording devices have to be well accepted by the recorded persons. Weight, visibility, additional constraints in the course of usual activities can be limiting factors as far as acceptance of the subject or the patient is concerned. It is obvious that this acceptance is better when the purpose and advantages of these new sensors and techniques are carefully explained.

1.1.1. Sensor quality

- The quality of the sensor or electrode must be high. Absence of corrosion in extreme environmental conditions and resistance to diverse manipulations is a necessity. Absence of irritation and allergic reactions is also necessary. Among the

manipulations, sterilization is often a requirement, primarily in the medical applications.

1.1.2. Sensor attachment

- Obviously, non intrusive recording methods (no contact, no gel interface,...) should be preferred and developed on priority.
- In some specific cases, sensors could be fixed to the subject's clothes, to a cap or a hat (active subject) or to the sheets (sleeping subject) and not directly to the skin.
- When sensor attachment is necessary, low electrode impedance and secure attachment must be achieved and maintained throughout the duration of the recording, which may last for several hours.
- When it is necessary to fix the sensors on the body surface, preparation of the skin should avoid irritant or corrosive detergents.

Specific cases

- In most cases, there is a need for a multiplicity of combined measures, such as: EEG, EOG, eye/eye-lid movements (2).
- For the EEG measurements, there is a need for several channels, including at least one occipital and one central derivation. For topographic and specifically for tomographic analysis (LORETA) (5, 6), multi-channel EEG recordings are necessary (minimally 19 channels according to the international 10/20 system, optimally 48 or more).
- For the EOG measurements, there is a need for both horizontal and vertical axes, especially when recording subjects in a waking state.
- For eye/eye-lid movement measures, there is a need for piezoelectric transducers or other transducers that can measure small eye movements, with no clear EOG signature, or eye-lid motion unrelated to eyeball motion.
- In the medical environment, the sensor attachment is usually done by trained technicians. This is true for hospital based recordings as well as for home based recordings. However, it is preferable that systems are developed where sensors can be self-attached by the patient. This requires easy attachment with minimum training and a very easy control of correct placement, in front of a mirror, for example. This could also be an important issue in the work place.

1.2. Data recording

1.2.1. Usability and safety

- Recording data should be accessible to any experimenter or clinician without referring to complex procedures. A “on/off” system or a time-triggered “on” and “off” could be a way of simplifying the procedure. Recording should also be easily accessible on line in order to check the quality of recorded data. At least, a warning signal of no or bad data acquisition should be given when recording.
- The recording procedure must also be safe (against electric shock, biocompatibility, magnetic interference....) for both the recorded persons or the recording people.

1.2.2. Recording quality

- Appropriate signal processing should be employed, utilizing high quality amplifiers with judicious and conservative use of filters and/or any other processing options, including all forms of digital signal manipulation.
- Common time or possible universal time-code signal (such as the radio signal from the Frankfurt atomic clock or GPS-based time) should be recorded in order to facilitate time-comparison of data.
- Power consumption should be kept as low as possible and new smaller energy sources should be made available.
- Recording system should be able to operate in extreme environments, in terms of ambient temperature, humidity, ambient pressure and vibrations. Quite often, people forget to put off a recorder when taking a shower.
- Recognition of artefacts should be employed, with appropriate corrections made as necessary, maintaining optimal signal integrity in all channels.

1.2.3. Optimisation of data recording

- Possible integration of a set of sensors into one single system and easy integration of additional sensors should be investigated.
- A common interface system should be developed for various sensors.
- Systems combining different sensors recording under different modes (electrophysiology, motor behaviour, autonomic functions,...) simultaneously, should be prioritized.
- New sensors under development should integrate from the beginning embedded connectivity to BAN and LAN.
- Systems combining different physiological data, simultaneously with data of environmental parameters (light, noise, ambient temperature,.....), should be investigated.

- Specific workplaces, where subject's monitoring is highly recommended, or specific home environments (i.e. of senior citizens or some patients) could be equipped with integrated transmission techniques and should be developed whenever possible.
- A dedicated network joining all elements in a manner suitable to the specific application scenario should be developed.

1.2.4. Transmission of data

- When possible, radio wave transmission of data should be preferred. In this case, the sensors should transmit the signals to a remote recording box and the remote recording box would transmit the signals to a telemedicine service provider.
- Recording and transmission of data should follow specific coding procedures, in order to guaranty anonymity and only authorized access to them. In this aspect, transmission by wires is always safer against misuse, because wireless transmission is in principle broadcasting the data. So, the issue is to find good compromises between patient security and less wires. We have to be aware that in some countries, wireless transmission of medical data is not allowed in most hospitals.

1.3. Data

1.3.1. Access to data

- The access to data should be reserved to authorized persons (those in charge of analyzing them or of making a diagnosis in case of patient recordings). Data should be prevented to be disseminated to non authorized users. In order to do that, specific codes should be made while recording (see above).

1.3.2. Data recording format and data exchange

- The uniqueness of data recording format should be considered as of high priority.
- The adoption and recording of a common time-code in every recording should be considered (see above).
- SENSATION WP5.9 (leader: Medcare), is concerned with international standardization of systems, protocols and formats.

1.3.3. Data storage

- In order to reduce data storage, instead of a fixed sampling frequency for every channel, a channel to channel adjustable sampling frequency or a pre detection, which allows to keep rare events time only, should be used (e.g. EDF or EDF+) (3, 4).

1.4. Data analysis

1.4.1. Autonomous diagnosis system

- When possible, the autonomous system should be able to provide a diagnosis about what is measured: a change in the physiological state, for example. This assumes a non-supervised decision (no expert intervention in real time), based on pre-established rules and an autonomous decision making process.

1.4.2. Tuning the prediction algorithms

- One of the most innovative aspects of SENSATION should be to upgrade or to modify the prediction algorithms by using the developed models (sleep and stress models, for instance). Thus, in order to identify most accurately a specific physiological state or transition or the occurrence of a pathological event, it should be important to take into account the individual characteristics (such as age, sleep pressure, fatigue, stress....), the ambient characteristics (temperature, noise....) and the situational aspects (type of task, time of day.....) and tune the algorithms accordingly.

2. Specific recommendations for the improvement of existing recording techniques

The existing recording techniques have been and are used successfully in specific situations and places for the benefit of patients and of a few workers. Most of these techniques should profit of technical improvements and some of them will make possible to extend the use of these techniques outside their usual environment. However, we have to keep in mind that some recordings can hardly be simplified or reduced in number. Thus, it is often necessary to record simultaneously several EEG sites, as significant differences in brain activity might be visible depending on the cortical areas considered (7, 8). In some other cases, it could be recommended to record the same indicator by different or complementary techniques (1, 7). Some of the proposed solutions are indicated in the following table in order to reach these goals. However, arising technical findings which are not described here might accelerate the expected improvement of the sensors and recording techniques.

Table 1: *Main pitfalls of the existing recording techniques and recommendations for improving them.*

Measurement technique	Pitfalls	Possible solutions
EEG	EEG is highly vulnerable to technical and biological artifacts from extra-cerebral sources. Artifacts can mimic almost any kind of EEG pattern and artifacts included in automatic analysis can seriously affect the results. Artifacts can originate from different levels: - surface contact (electrode material,	The best way of dealing with the problem of artifacts is to avoid their occurrence when recording the EEG. This goal can partially be achieved by using high-quality EEG recording techniques. The use of dry electrodes might reduce the surface contact problems. Development of new wires could be profitable too.

	<p>paste, fixation method) - type of wire - amplification technique - noise</p> <p>Beside technical and movement artifacts, biological signals from eyes, muscles, skin, cardiovascular and respiration electrical activities can interfere with the EEG and produce artifacts.</p> <p>Electrode leads (cables) constrain the patient's freedom to move and thus, may disturb sleep.</p> <p>Current electrodes above hairline are harder to prepare compared to periorbital electrodes.</p> <p>Conducting gel dries in a few hours. Compared with other recording procedures, skull skin preparation and electrode application is time consuming. Loose electrical contact. Furthermore, it may lead to skin irritation.</p> <p>In ambulatory recording systems, the high battery power consumption is still a limitation for sampling rate, number of channels and recording time.</p>	<p>Electrode placements and recording techniques avoiding or reducing these interferences. Development of online/off line artifact detection, analysis and rejection.</p> <p>Recording without wires or reducing the length of them by a system attached to the subject's body with high storage capacity or telemetric transmission.</p> <p>Dry electrodes. Pre wired recording systems with permanent good electrical contact. Preparation should avoid irritants chemicals.</p> <p>Develop higher battery capacity or lower consumption of the system. Make discontinuous recording when possible.</p>
<p>EOG</p>	<p>Similar to the EEG recording, the EOG leads can be contaminated by various artifacts of biological and technical origins.</p> <p>Furthermore, electrode cables and large electrodes are disturbing for the patient and thus, may exert a negative influence on his sleep.</p> <p>The procedure of skin preparation and electrode application may lead to skin irritation.</p> <p>Electrode positions can vary more compared to EEG.</p>	<p>Same remarks as for EEGs.</p> <p>-id-</p> <p>-id-</p> <p>New standards for electrode locations.</p>
<p>Gaze direction</p>	<p>Constraint related to a moving subject.</p>	<p>System with multiple cameras.</p>
<p>Eyelid sensor</p>	<p>Results obtained are different depending on conditions of the recording. Globally, the main reasons for low detection rate are bright incident illumination by daytime driving (e.g. sundown), glasses, fast head movement, driver specific behavior (hand on face, inclination of the head).</p>	<p>Better cameras with larger dynamics. Develop new algorithms for face and eyes recognition, taking into account changes in ambient lighting.</p>

Pupillometry	<p>If the recording conditions are not controlled the signal reflects more sympathetic influences than sleepiness.</p> <p>Eye blinks and eye closure disturb or make recording impossible.</p>	Controlled recording conditions: Video camera, head fixation, totally dark room with 20 minutes controlled recording conditions.
EMG	<p>Similar to the EEG recording, the EMG leads can be contaminated by various artifacts of biological and technical origins.</p> <p>Furthermore, electrode cables and large electrodes are disturbing for the patient or the subject and thus, may exert a negative influence on their sleep.</p> <p>The procedure of skin preparation and electrode application may lead to skin irritation.</p>	<p>Same remarks as for EEGs.</p> <p>-id-</p> <p>Avoid irritant products for skin preparation. When necessary, fresh shaving of subject helps to get a better signal.</p>
Sensitive mattress (Body posture)	The amplitude of the signal varies with body posture.	Use of a capacitive foil which is large enough to be placed under a mattress and which is sensitive enough to record signals through a mattress. An analogue (or digital) filter for the three components of the SCSB signal.
actimetry	Displacement and thereby change in sensitivity to specific movements e.g. leg movements.	Use of standards for actimeter placements; modify sensitivity depending on the limb measured.
ECG	<p>Artifacts such as main interference, changes in impedance, sweat or movement artifacts can spoil the ECG measurement.</p> <p>During sleep, electrodes and wiring can limit the freedom to move or to lay on the stomach.</p> <p>Electrode gel may dry out and decrease impedance values.</p>	<p>Better fixation of the electrodes.</p> <p>Telemetry equipment for wireless signal transmission.</p> <p>Dry electrodes with low impedance e.g. fractal surface.</p>
Pulse transit time	<p>This measure is highly sensitive to the movements of the segment where peripheral detectors are placed.</p> <p>Captors have to be placed very precisely on the artery.</p> <p>There is no PTT signal in case of arrhythmias.</p>	<p>No additional sensors but high sampling rate and good signal quality. Good algorithms for ECG R-wave detection and pulse wave detection.</p> <p>Automatic assistance when placing the captor.</p>

Arterial tonometry	<p>In case of arrhythmias no signal is recorded.</p> <p>There is some sensitivity to large movements of the arm or the body. There is a risk that patients may loose the sensor.</p> <p>Patients with low diastolic blood pressure values during the night might experience some discomfort.</p>	<p>A robust rigid finger sensor for different finger sizes which could produce a sub diastolic pressure when applied. The sensor can be similar to the pulse oximetry sensor but must be stiff and must apply a defined low constant pressure.</p>
Pulse wave amplitude	Motion artifacts.	Use of system which provides variable gain and detection of output saturation.
Blood pressure	<p>The method most commonly used are blood pressure readings using periodic arm cuff inflations and these inflations disturb sleep quite often. As a consequence these blood pressure readings do present more often readings for nocturnal awakenings than for sleep.</p> <p>The size of the inflator pump also constitutes a limitation for ambulatory recording.</p> <p>Also the arm cuff cannot keep track of such rapid blood pressure changes as they are observed in sleep apnoea and during arousals.</p> <p>With the finger plethysmography method, the finger cuffs create some discomfort because the venous return of blood flow is reduced and this may disturb sleep as well.</p>	<p>More sophisticated and validated models for continuous non-invasive measurement are necessary.</p> <p>New generation of pumps including reduction of size.</p> <p>Non invasive beat by beat recording systems.</p> <p>No suggestion.</p>
strain gauge measurement	<p>The optimal working range of a strain gauge sensor is very narrow: under stretching or overstretching will not produce reliable signals.</p> <p>The elastic tube is rather fragile and may break in case of violent stretching from the subject.</p> <p>Signal quality from strain gauges is affected by sleep position, movements during sleep, and displacement of the strain gauges during the monitoring period.</p>	<p>Modify the working range with an automatic correction system.</p> <p>New material.</p> <p>Detection of sudden blockage of the strain gauge.</p>
Inductance plethysmography	Changes in body position may cause artifacts.	<p>A frequency to voltage converter for the induced current.</p> <p>To avoid slippage during overnight monitoring, the bands should be tapped firmly to the skin.</p>

Pneumography	During apnoeas, the negative intra thoracic pressure pools blood into the pulmonary circulation. Both air volume related and fluid related changes are measured. Therefore, a precise measurement of respiratory patterns may not be possible	No suggestion.
Esophageal pressure	Some baseline adjustments must be made during the recording due to changes in position of the sensor. Swallowing and coughs produce artifacts. A somewhat invasive technique which is not accepted by every patient. Some discomfort may be reported.	Automatic correction system. Detection of these events to eliminate artifacted periods. Reduce the size of the sensor. Micro pressure transducer with high signal stability and small very flexible leads The lead coating must be acid resistant and must be resistant to fluid sterilisation.
Pneumotachography	Although this is the most accurate means of assessing the volume of airflow, it is a large and relatively uncomfortable device due to resistor size (this can be avoided).	Light weighted flow resistors with either linear pressure flow characteristics or another known characteristic which can be used in flow calculations. A accurate calibration is needed.
Thermistor	Temperature changes of respiratory air often bear little correlation to airflow. Thermistors cannot reliably differentiate between a prolonged inspiration and cessation of breathing. Even minor displacements of the thermal sensors or alternations in the proportion of nasal and oral breathing relative to the sensor position can lead to large changes in signal amplitude. A thermocouple and a thermistor cost only a few cents. High costs are currently made by sleep equipment distributors. In any case the thermistor signal is dependent on the temperature in the room. Therefore this method is no longer recommended for airflow.	They have to be combined with a device measuring sensitivity to respiratory effort. Precise standards for placements and attachment. Maintain room temperature stable as much as possible and calibrate the thermistor according to the ambient temperature
Nasal airway pressure	Some patients may not breathe via the nose. The nasal pressure has a quadratic relationship to actual flow.	Correction of pressure by using the non-linear relationship in order to obtain a flow signal.

<p>Tracheal sound recording</p>	<p>The obvious limitation of this method is the interference by environmental noise.</p> <p>Piezoelectric microphones usually are too sensitive to movements and close down for considerable time after skin rubbing.</p> <p>A better analysis of tracheal sounds would evaluate the proportion of low frequencies (below 800Hz) on total signal power with the use of a hardware filter to discriminate snoring from general breathing noise.</p>	<p>A good air-coupled microphone. Active noise cancellation.</p> <p>Avoid this type of microphone when possible.</p> <p>To preserve the full frequency content of snoring noise a sampling rate of 5000 Hz would be needed. Develop hardware for noise discrimination.</p>
<p>Measurement of expired CO₂</p>	<p>Like thermistors, these sensors cannot reliably differentiate between a prolonged inspiration and cessation of breathing.</p> <p>The disadvantage of the method using the ventilated air is impairment of patient sleep comfort due to the need for a mask or a small tube inserted in the exhaled air.</p> <p>Another disadvantage is that CO₂ cannot be analysed during the course of an apnoea because there is no airflow.</p>	<p>A calibration in terms of CO₂ is needed. A mask at the patient is needed in order to get a continuous flow of air near the nose.</p> <p>Combine CO₂ measurement within pressure transducer.</p>
<p>Pulse Oximetry</p>	<p>If the sensor is placed on a digit, bending might restrict its ability to detect pulse, and therefore spoil the measurement. Therefore, it is sometimes recommended to immobilize the digit.</p> <p>Unfortunately in a considerable number of patients the interpretation of oxygen saturation is limited. Due to the oxygen binding curve oxygen saturation may not show clear drops with apnoea or hypopnea events if the patient has a healthy lung and a very high blood gas baseline.</p> <p>In patients with additional lung diseases (e.g. chronic obstructive pulmonary disease) the baseline oxygen saturation may be low even when awake. In these patients it is hard to detect apnoea related events based on the analysis of oxygen desaturations.</p> <p>Most oximeters low-pass filter the SaO₂ signal. The greater the filtering, the less likely brief, mild hypoxemic episodes are detected.</p> <p>In heavy smokers, SaO₂ will be overestimated, due to the presence of carboxyhaemoglobin.</p>	<p>Resolution above 1 % of current systems.</p> <p>No suggestion</p> <p>Identify this particular case and adapt the measure.</p> <p>A variable setting for the averaging is needed with settings between 1 and 12 pulses.</p>

Capnography or transcutaneous measurement	In neonates and small children, since the electrodes are heated their position needs to be changed every 90 minutes or two electrodes are applied and the heating is switched between the two. Due to these limitations this technique is rarely used in adults. This applies to the Severinghouse electrode.	
Core body temperature	<p>Recording of body temperature requires standardized settings (such as control of the thermal environment) which are not always available in a sleep laboratory with settings for clinical routine.</p> <p>Rectal probe is not always well accepted and it can limit the freedom of the active subject.</p> <p>Ear probe has to be mould precisely to the ear pavilion and the sensor should not hurt the tympanic membrane.</p> <p>Oesophageal probe gives high quality recording when adequately placed and it can be maintained for a few days. However, it is not well accepted by the patient.</p>	<p>Combine physiological data acquisition with recording of environmental variables.</p> <p>Smaller probe and stable fixation. Wireless solution.</p> <p>Very supple sensor maintained in contact with the tympanic membrane.</p> <p>Thin oesophageal probe to be inserted through the nose with wireless transmission of data.</p>
Skin temperature	The large size of the sensors and the presence of wires limit the use of such recording.	More wireless solutions.
Sweat production	The size of the capsule and the tubes attached to it, limit the movements and even the postural changes of the subject. The measure can only be applied to sleeping subject lying on the same position.	Develop new sensors (foils sensitive to water loss).
Skin resistance, skin potential,	The size of electrodes and their placement on fingers, wrist and hand palm, together with wires limit their use.	Smaller electrodes with wireless transmission.
Videometry	Video recording needs a certain level of ambient light or use of infrared cameras.	<p>High sensitivity camera.</p> <p>Studying possibilities of thermal imaging.</p>

3. Classification of the sensor and technical improvements to be done

The effort to achieve improvements in sensor and recording techniques should be organized, according to the priorities which can be made by the users. It is obvious however, that some of the improvements will be much more costly than others, although a significant amelioration in one technique can originate various unexpected developments.

In the present document, it is neither our purpose to evaluate the cost of each suggested changes or improvement nor to give a picture of the possible applications of those ameliorated

sensors or techniques. Our priority ranking rather reflects what is expected by the users of these devices in term of better and extended use of data acquisition, in areas where these recordings have been out of reach until now.

The following prioritization has been made through discussions with experts and recommended choices have been obtained from several groups. Therefore, the following recommendations and suggestions should be considered as the result of a consensus between experts in the field.

Table 2: *Suggestions about a priority order of the technical improvements to be done.*

COMMON RECOMMENDATIONS		
<ul style="list-style-type: none"> • Sensor and recording techniques should be safe to the users and the subject-patient. • Recording and transmission of data should follow specific coding procedures to guaranty anonymity and authorized access only. 		
SENSOR improvements		
High priority	Average priority	Low priority
<ul style="list-style-type: none"> • High sensitivity, reliability and stability under various conditions. • Adequacy to the needs of the users. • Non intrusive methods. 	<ul style="list-style-type: none"> • Minimal number of small size. • Well accepted by the subject-patient. • Incorporation in clothes or immediate surroundings of the subject-patient and not directly attached to the skin. • Better skin preparation. • Self-attachment sensors 	<ul style="list-style-type: none"> • Corrosion. • Resistance to manipulations. • No gel.
RECORDING TECHNIQUE improvements		
High priority	Average priority	Low priority
<ul style="list-style-type: none"> • Integration of a set of sensors in one single system. • Easy integration of additional sensors. • New sensors under developement should integrate embedded connectivity to BAN and LAN. • Wireless transmission of data. 	<ul style="list-style-type: none"> • Recording accessible to any experimenter or clinician. • On-line control of recording quality and normality. • Appropriate signal processing. • Low power consumption. • Able to operate in extreme environments. • Combination of different recording modes into the same 	<ul style="list-style-type: none"> • Signal of poor or bad data acquisition. • Recognition of artifacts with appropriate corrections.

	<p>system.</p> <ul style="list-style-type: none"> • Equipment of specific work or home places with integrated transmission systems. 	
DATA ACQUISITION AND ANALYSIS improvements		
High priority	Average priority	Low priority
<ul style="list-style-type: none"> • Prevent access to non authorized persons (see general recommendations). • Uniqueness of data recording. • Common time-code during recording. • Development of autonomous diagnosis system. 	<ul style="list-style-type: none"> • Channel to channel adjustable sampling frequency. • Rare event recording. • Tuning of the prediction algorithms. • Standard data formats 	

Conclusions

Recording physiological states and their transitions has, for a long time, been possible only in the laboratory or the clinical environment and limited, for practical reasons, to very specific research or medical purposes. Of course, the different techniques used for those recordings have been regularly improved, but with the same main objectives. They have scarcely been used in other places like the workplace or the home environment due to several constraints in terms of size, weight, cost or operational difficulty.

The main objective of the SENSATION project is to make possible such work or home recording in order, for example, to monitor workers engaged in difficult or dangerous tasks or to monitor patients in their usual home environment. In order to reach this goal, this document has presented some generic as well as specific recommendations which can be made at the different levels of the recording process. These suggestions concern mainly the existing sensors and techniques, as it is believed that significant improvements can still be made in these areas. They also stress the necessity to develop new types of sensors, which should ideally satisfy the wishes of the users.

The priority order, which has been proposed for the development of new improvements, mainly satisfies the user's point of view. We understand, however, that some suggested improvements could be more costly than others, although we may not exclude that a significant amelioration of one single technical aspect can originate unexpected and promising developments. Any of these developments will contribute to the achievement of the main goal of the SENSATION project, bringing a new era in the understanding of human physiological and psychological states, in order to improve safety and health.

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