# Wearable sensors and feedback system to improve breathing technique

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# Overview

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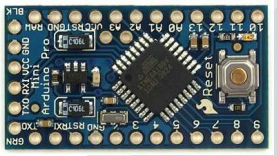
- Introduction

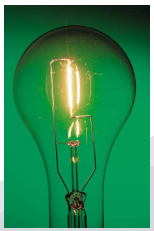
- Sensors

- Data acquisition and processing



- User feedback

- Conclusions



# Importance of Breathing


Breathing – naturally occuring

Unique system– both voluntary and involuntary We can influence the involuntary autonomic nervous system using our voluntary breath

By breathing in a slow, deep and regular manner, the heartbeat become smooth and regular, blood pressure normalizes, stress hormones drop, and muscles relax.

# Importance of breathing technique

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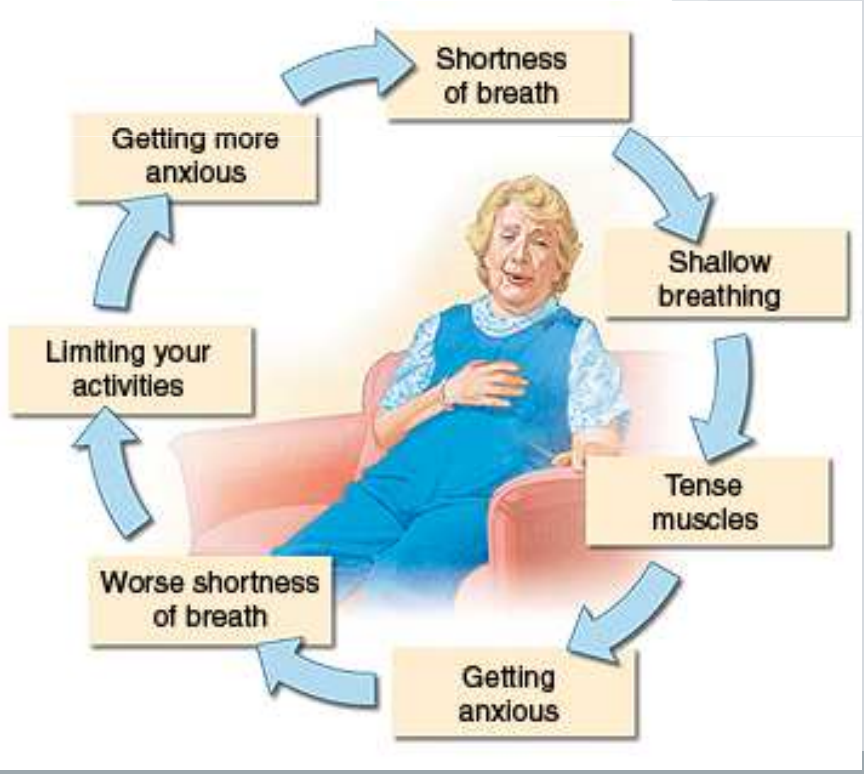
## Sports performance

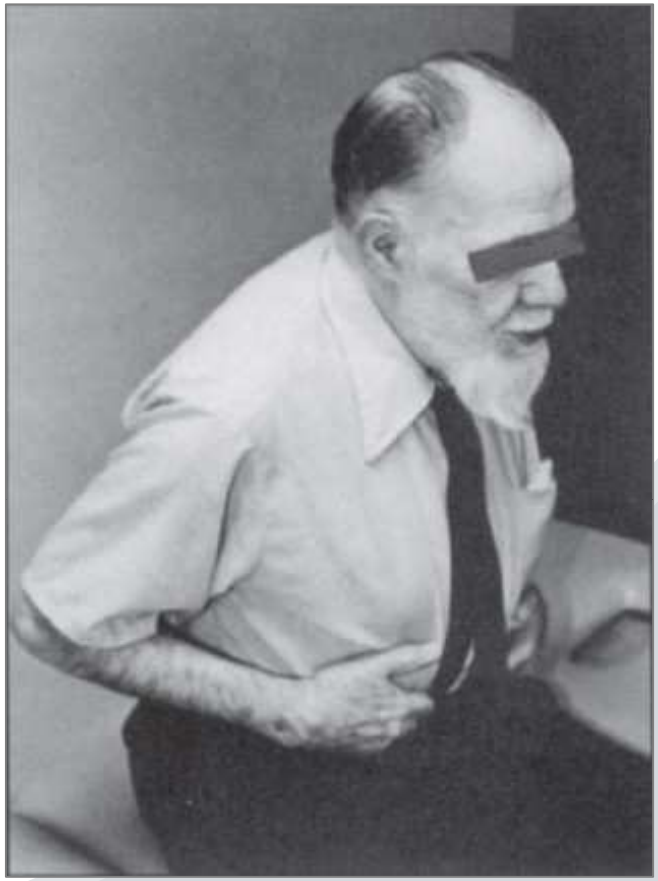
- Use of full lung capacity to maximise oxygen delivery to muscles
- Use of breathing techniques to calm and focus, e.g before kicking a penalty in soccer or a serve in tennis

## Clinical applications

- Chronic Obstructive Pulmonary Disease (COPD)
- Anxiety treatment
- Cystic fibrosis
- Respiratory rehabilitation



# Breathing exercises for patients



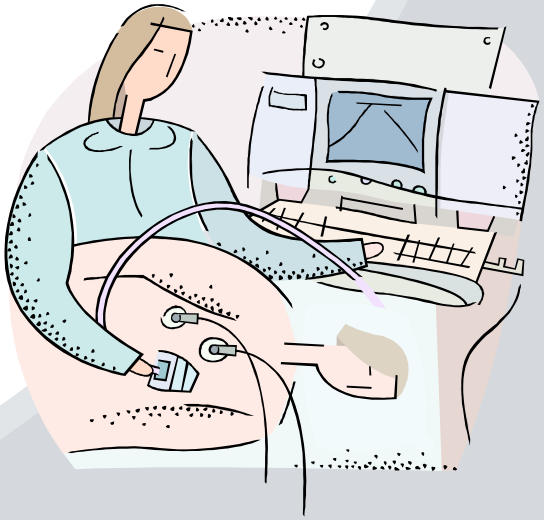
**Kigin C., Breathing Exercises for the Medical Patient: The Art and the Science,** Physical Therapy/Volume 70, Number 11, November 1990

# Breathing monitoring system – system requirements

**Aim – to develop a feedback system for patients to improve their breathing technique, by monitoring thoracic and abdominal movements. Give feedback to the user graphically**

**Sensor must be**
- **Comfortable**
- **Robust**
- **Straightforward to use**

**Wearable sensor/"Smart garment"**



**Feedback/Application must:**
- **Grab users attention**
- **Have a simple interface**
- **Focus user for the full duration of the program**
- **Encourage user to correct their breathing rate**

**and low cost, easy to install on computer systems**

# Breathing monitoring system

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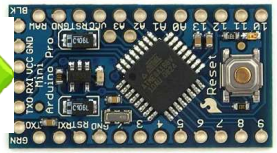
**Wearable Sensor - detect body movement due to breathing**



**Microcontroller and Wireless connection**


**Data processing and User feedback**

# Fabric stretch sensors to measure body movements

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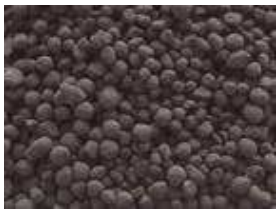
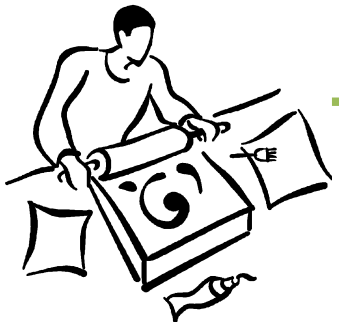


Carbon black

\+

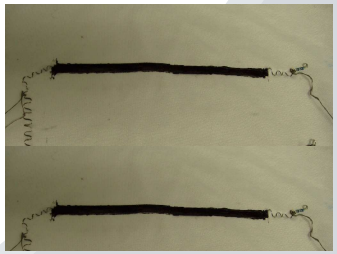
Elastomer



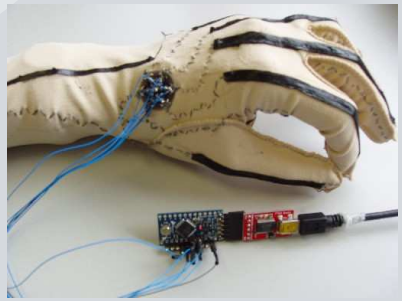
Screen printed onto fabric

Cure

Piezo-resistive sensor



**Wacker ELASTOSIL® LR 3163 A/B Liquid Silicone Rubbers (LSR)**



# Carbon elastomer stretch sensors

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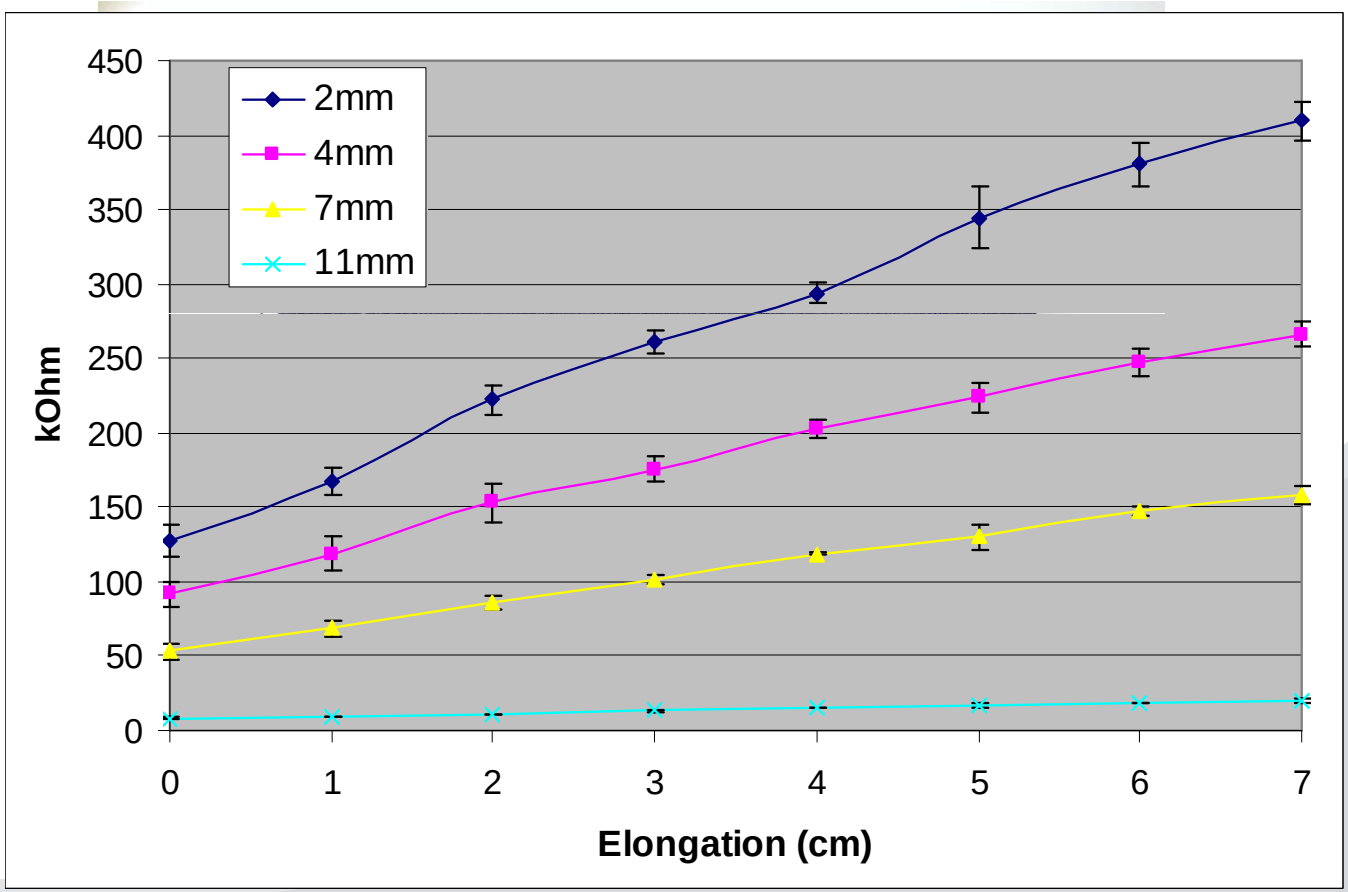
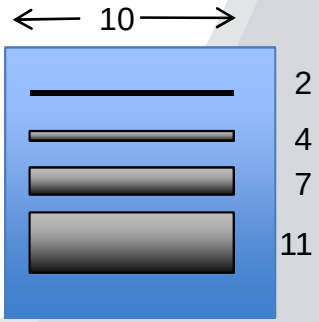
## Stretch sensor - Carbon loaded rubber screen printed onto lycra fabric. Elongation causes increase in resistance

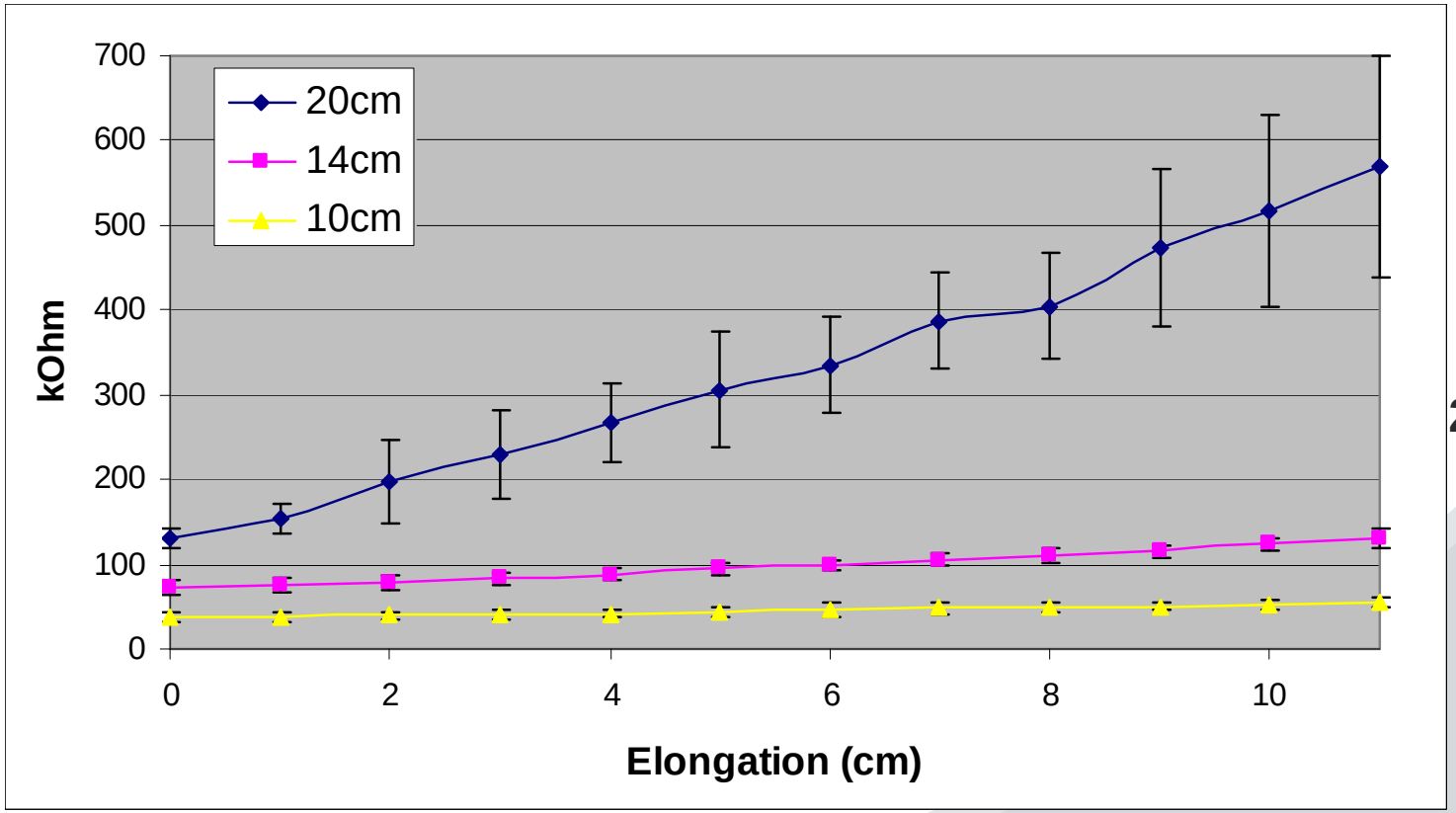


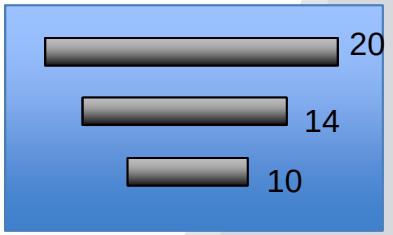




Sensor widths 2mm, 4mm, 7mm, 11mm, (length 10cm)

Average Gauge factor
l(R-Ro)/(R(l-lo)
= 1.6

# Carbon elastomer stretch sensors




**Sensor lengths 20cm, 14cm, 10cm (width 5mm)**

| | GF |
|---|---|
| 20cm | 2.170494 |
| 14cm | 1.006246 |
| 10cm | 0.486631 |

# Sensors – “Smart shirt”

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**Fabric stretch sensors monitor the expansion and contraction of the ribcage and abdomen during breathing.**

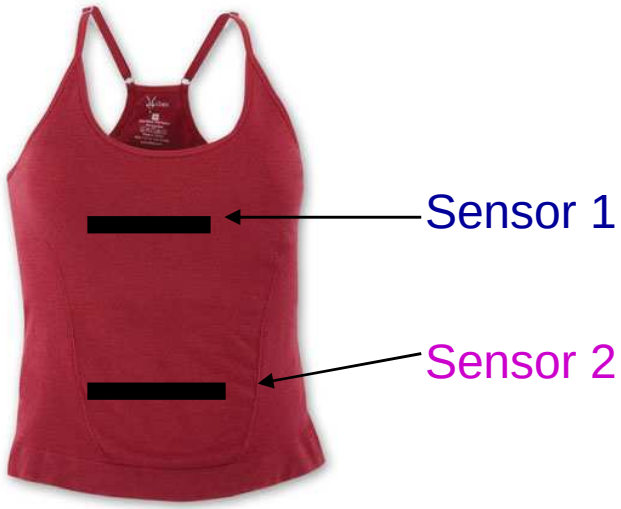
**4 Carbon-Elastomer(CE) sensors (piezo-resistive) are screen-printed onto the front of the t-shirt**

**Sensors connected using conductive stainless steel thread.**

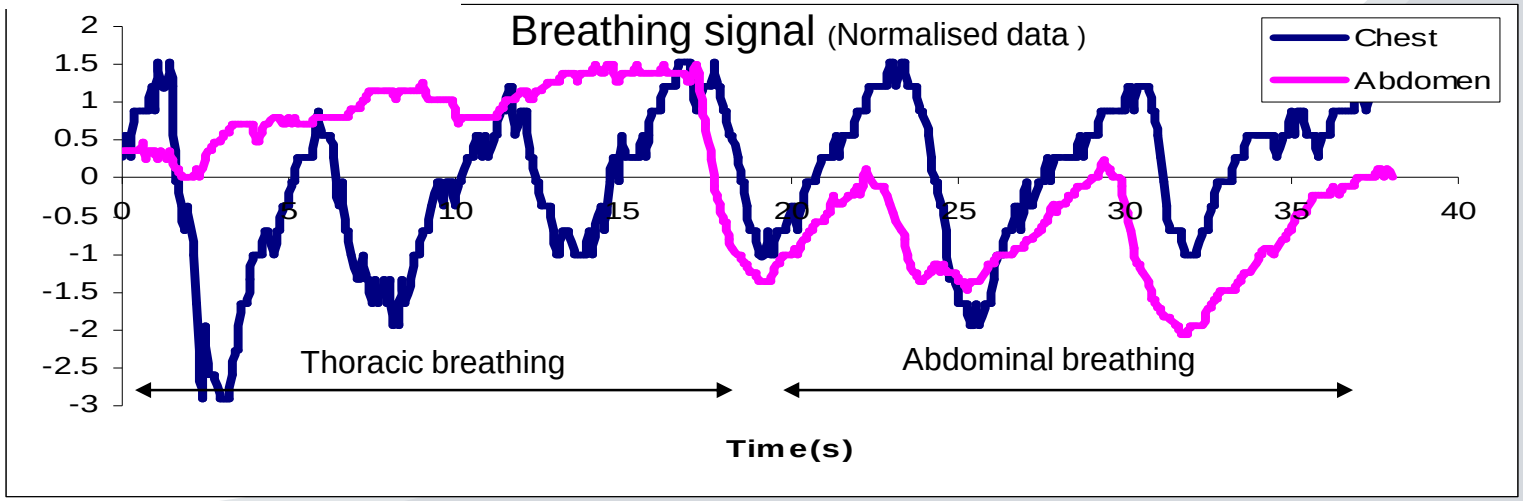
**Resistor leads are embroidered**

**Sew-in micro-controller**


# Breathing monitoring t-shirt

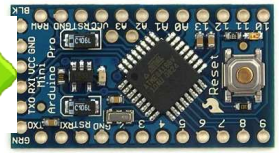



Investigation of thoraco-abdominal movement using CE sensors



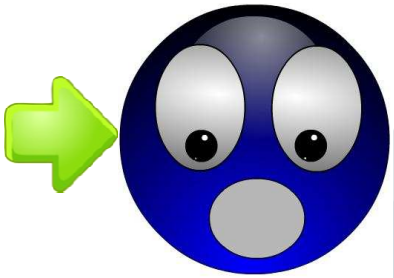
# Breathing monitoring system

Sensor



Arduino microcontroller

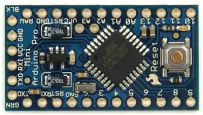
physput



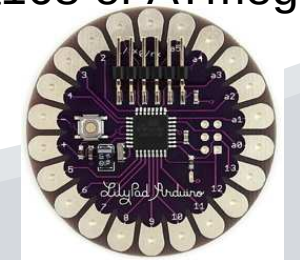
User feedback

**Arduino**
- open-source electronics prototyping platform

**Arduino Pro Mini**
Size: 1.7cm x 3.4cm
Analog Input Pins : 6
Digital I/O Pins :14
Microcontroller: ATmega168 or ATmega328



**Arduino Lilypad**
Sewable microcontroller



**Bluetooth connection**
**BluesmiRF**
Wireless serial cable replacement
Transmits any serial stream from 9600 to 115200bps

# Breathing monitoring system

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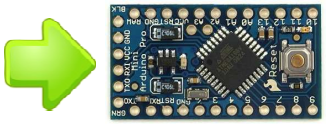
Sensor



Arduino microcontroller

physput

Flash Application

The name Physput is derived from ***Phys***iological in***put***

Allows a user to emulate standard computer input using non-standard input.

Primarily designed to facilitate the design of alternative input devices.

Reads data from the serial port and maps this data to standard input e.g. mouse movements and key presses.


Physput
Written by Edmond Mitchell

# Breathing monitoring system

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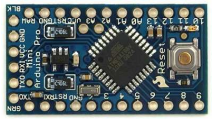
Sensor



Arduino microcontroller

physput

Flash Application

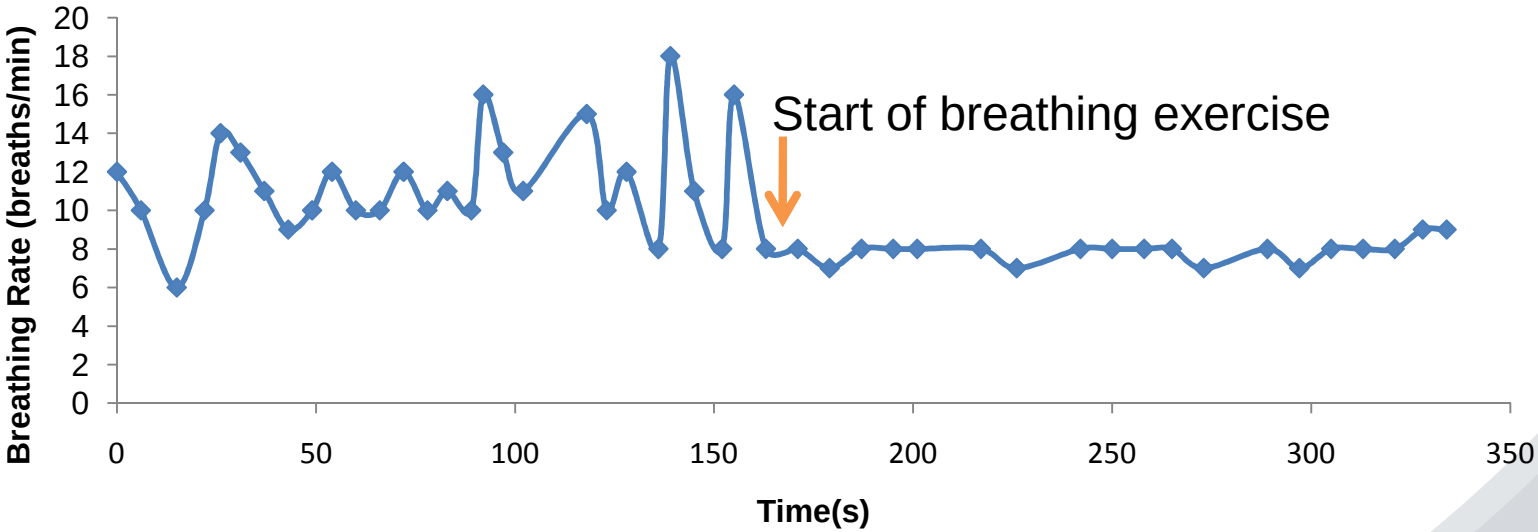
Most popular method for adding animation and interactivity to Web Pages.

Can create rich Internet applications

Available free for web browsers such as a Internet Explorer and Mozilla Firefox

99.3% [1] of all Internet desktop users have the Flash Player installed

# User feedback interface




Breathing patterns measured using the textile sensor and gold standard Sensormedics Vmax

Feedback application encourages constant breathing rate in syncronisation with the avatar

Sensormedics Vmax

# Deep breathing exercise

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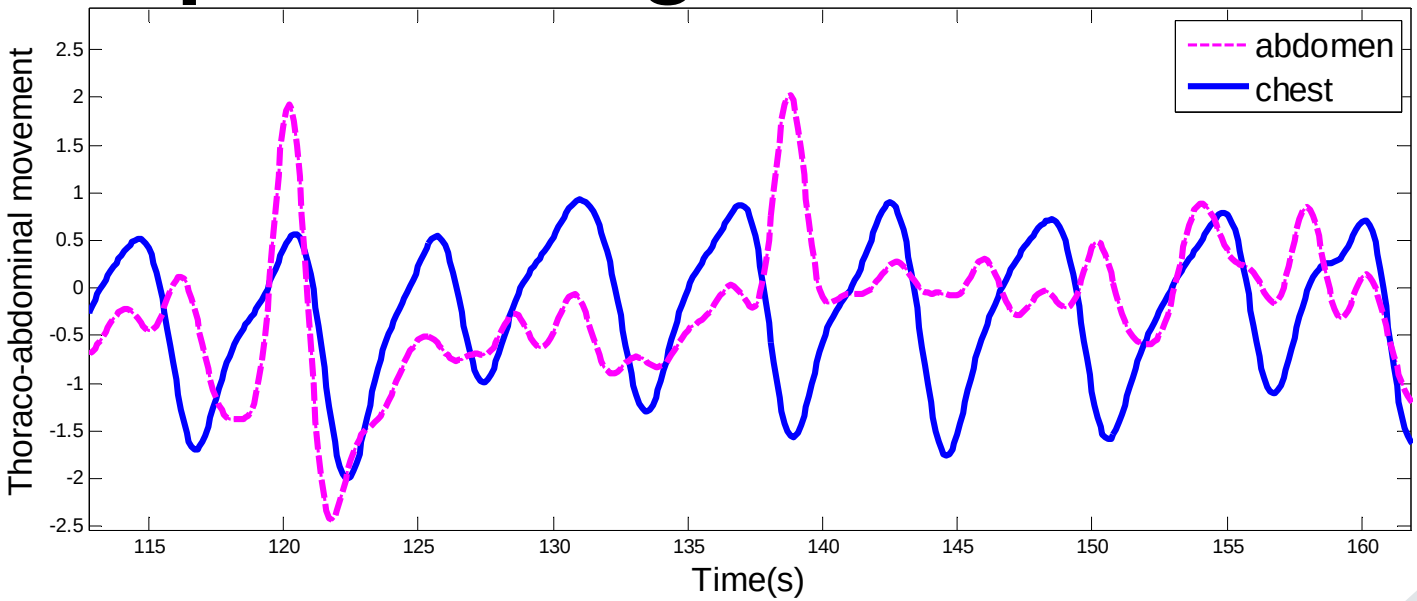
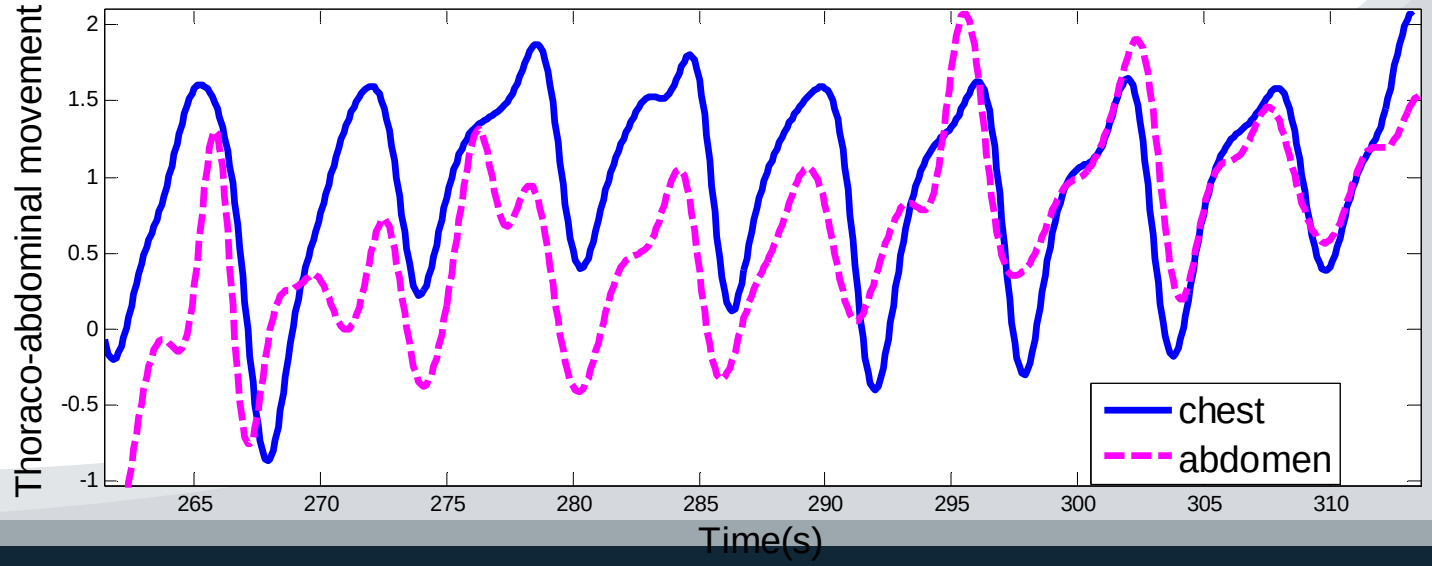
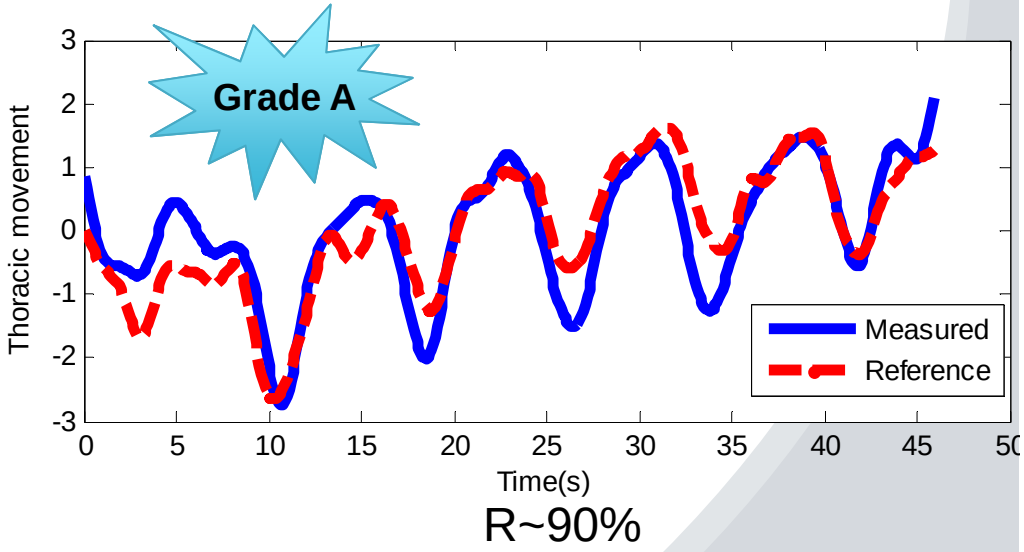



**Before breathing exercise**




**During breathing exercise**

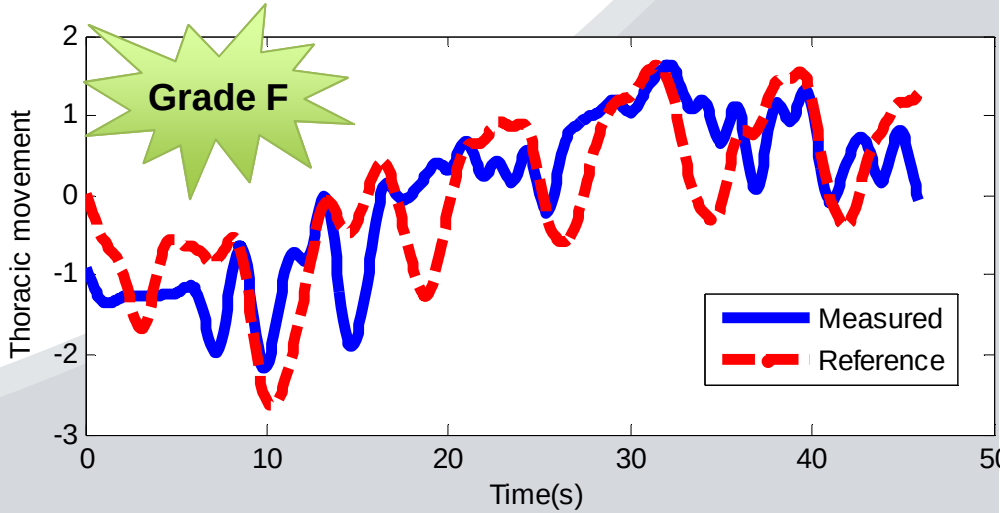
# User feedback


R~90%

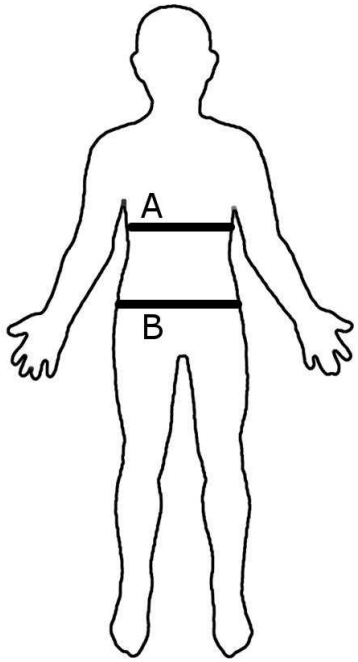
After performing the exercise the user is presented with a breathing efficiency grade.

The grade is calculated by cross correlating the users breathing pattern with a reference breathing pattern embedded in the program

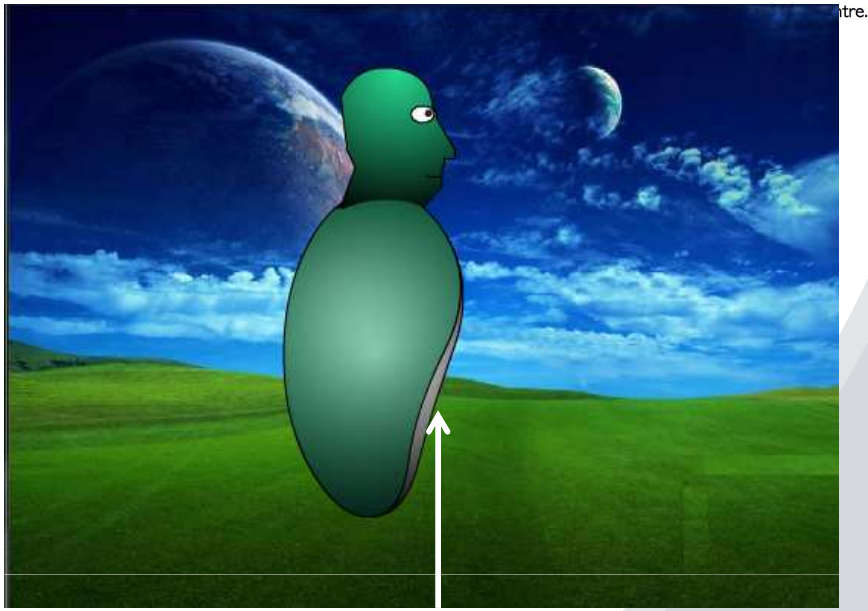



R~40%

# User feedback – multiple sensor input




Two sensors - placed at chest and abdomen



Real-time sensor signal versus computer generated accurate signal

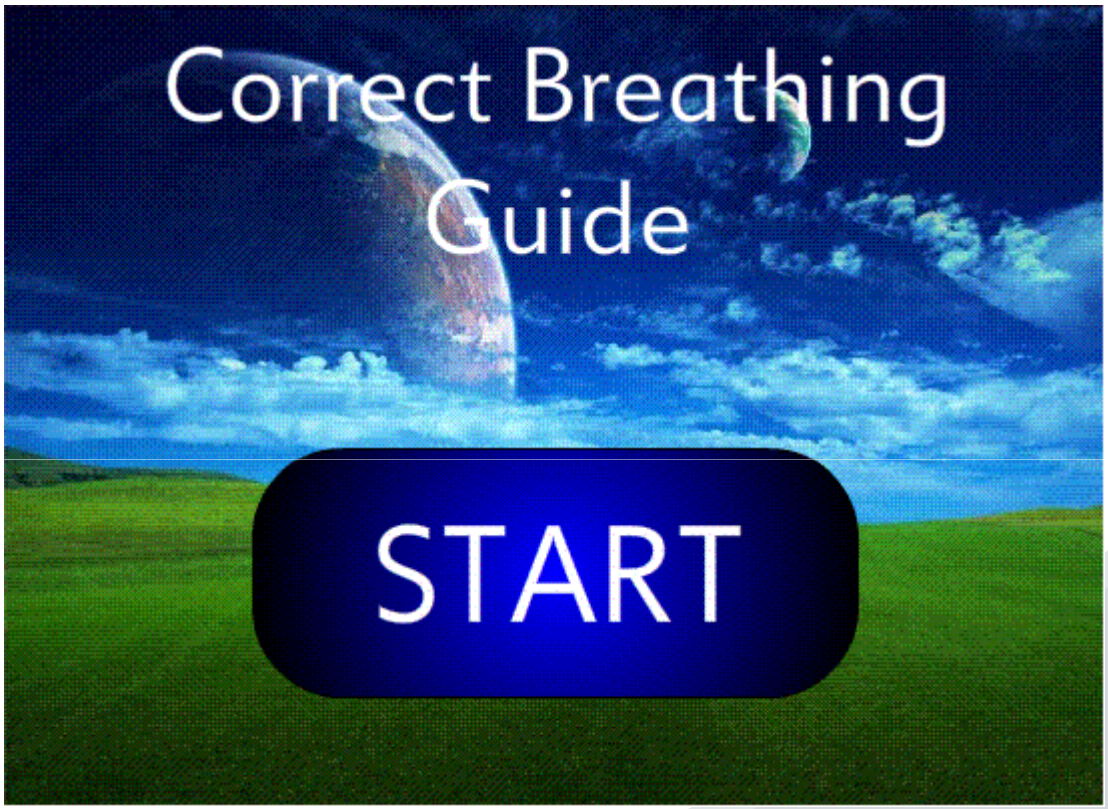
The avatar encourages the user to perform diaphragmatic breathing.

The user aims to synchronise their breathing signal with the avatar

Real time feedback is given

Score given at the end of the exercise

# Breathing trainer



# Conclusions/future directions

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- Developed wearable wireless system to measure breathing patterns, using textile sensors
- Developed user-friendly interface to help users improve their breathing
- Low cost, accessible system
- Next stage to consult the target user groups for feedback – Physiotherapists and Occupational therapists
- Clinical trials

# Thanks to…

- **Edmond Mitchell**, Centre for Digital Video Processing, CLARITY Centre for sensor Web Technologies, DCU

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- **Prof. Noel O'Connor, Prof Niall Moyna, Prof. Dermot Diamond**, CLARITY Centre for sensor Web Technologies, DCU

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