Monitoring the skin temperature at acupoints

Methods and equipment used

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In the experiments, the skin temperature was monitored using sensors that consisted of a thermistor (a resistor whose value varies according to temperature). A constant current was passed through the thermistor and the voltage across it monitored.

The sensors need to be custom made (full instructions are provided below). These were then wired to a box containing simple electronics that produces a constant 4volt current, and utilizes a voltage divider circuit to monitor the voltage across each sensor. The box's design is shown in the accompanying circuit diagram, temperature3.pdf.

The box requires a +/- 12 volt supply. The supply used in the experiments is shown in the accompanying circuit diagram, power.pdf.

This signal was then output to a data logger. A PicoLog1216 was used. An Access database and macro was used to control the data logger and record the samples. This made it straightforward to control more than one data logger simultaneously, so that samples of temperature and impedance could be taken at the same time.

Note that the "PicoSDK" must be installed for this macro to work. This can be downloaded from: www.picotech.com/downloads.

The samples were converted to Celsius values by the Access macro, using the following formula.

> T=(1 / ((1 / 298) + (1 / 3435 * Log((47000 * V / (4 - V)) / 10000)))) – 273.15
>
> where "V" is the voltage across the sensor and a 47kOhm resistor is used in the voltage divider circuit, as shown in the circuit temperature3.pdf.

As shown in the circuit diagram, a voltage of 4V was placed across the simple voltage divider, and a value of 47 kΩ used for the known resistor. This produced a current of around 70 µA through the thermistor. This value does not produce the widest possible range of voltage samples (2.5V is the maximum value that the PicoLog1216 can read). However a known resistor of 10 kΩ was first used, which produced a wider range of voltage samples, but a current of around 200 µA through the thermistors; and it was found that this level of current tended to warm the thermistors, which produced a false, gradually rising trend in the results. The lower current of around 70 µA seems to avoid this problem.

The Access Macro can be used to calibrate the sensors. In a subroutine called Calibrate, a value can be set to be added to every reading from each sensor. When all the sensors are monitoring the same temperature, from the output plots it can be determined how much adjustment should be added to each sensor so that they all read near to the same value.

The samples were then exported to an Excel sheet (version 2007 or later needs to be used to cater for rows in excess of 65,000), and then imported into Matlab, where a lowpass filter was used to filter out all frequencies above about 1Hz, and the results plotted. The Matlab scripts used are included in the dataset to each experiment; see www.curiouspages.com/research.

For those working to a tight budget, free software is available that is largely compatible with Matlab. See www.gnu.org/software/octave, though this experiment's accompanying Matlab scripts have not been tested on GNU Octave.

As can be seen from the following figures, the thermistors are delicate. The body of the thermistors can also be easily bent. It was found that it was best to bend the thermistors before placing them on the skin, so that they have a small amount of spring in them, which then holds the sensing head in contact with the skin throughout the experiment.

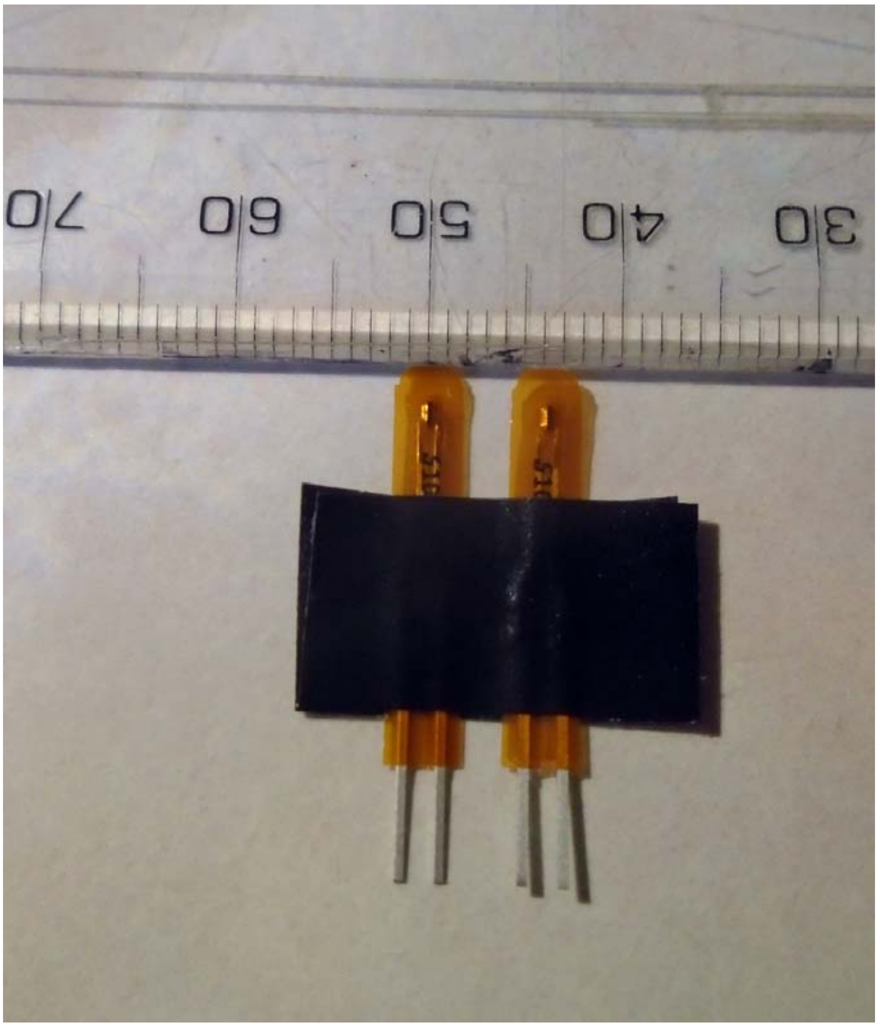
The sensor assemblies were then held in place on the subject with a 20 mm wide elasticated band, which was wrapped around the limb or the torso, depending on the acupoint location. The tension on the band needs to be adjusted so as to keep the sensors in constant contact with the skin, but while not applying too much pressure, so that the sensors become uncomfortable after a few minutes. It was found that it was best to place the band so that it covered the thermistor heads. This prevented false features appearing in the results due to the effect on the thermistors of drafts in the air.

Manufacturing the sensors

The thermistors used were: ATC Semitec 103JT-025.

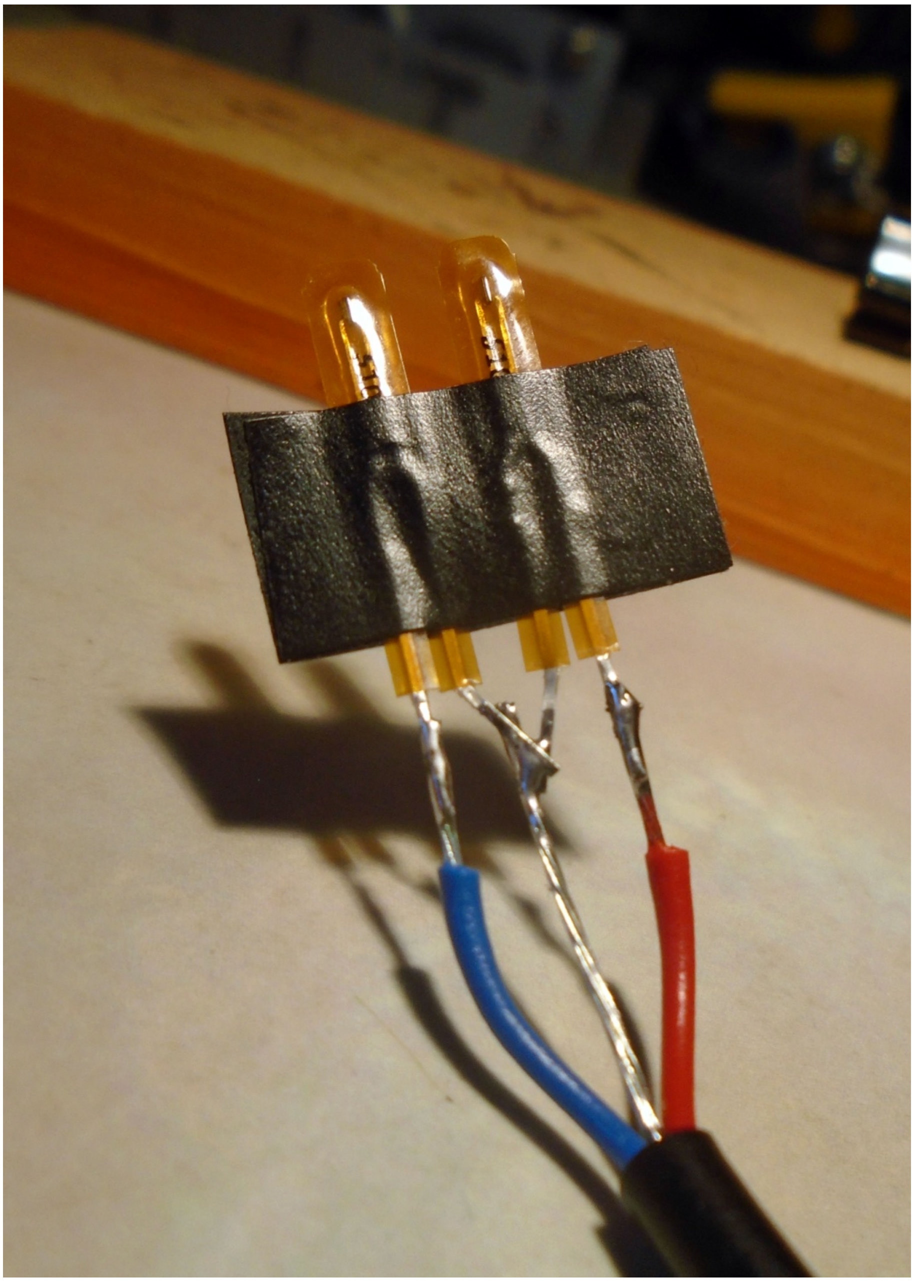
These were connected in pairs to make one sensor pair, which was able to simultaneously monitor the skin temperature at two locations, 6mm apart.

Figure 1. Two thermistors taped together



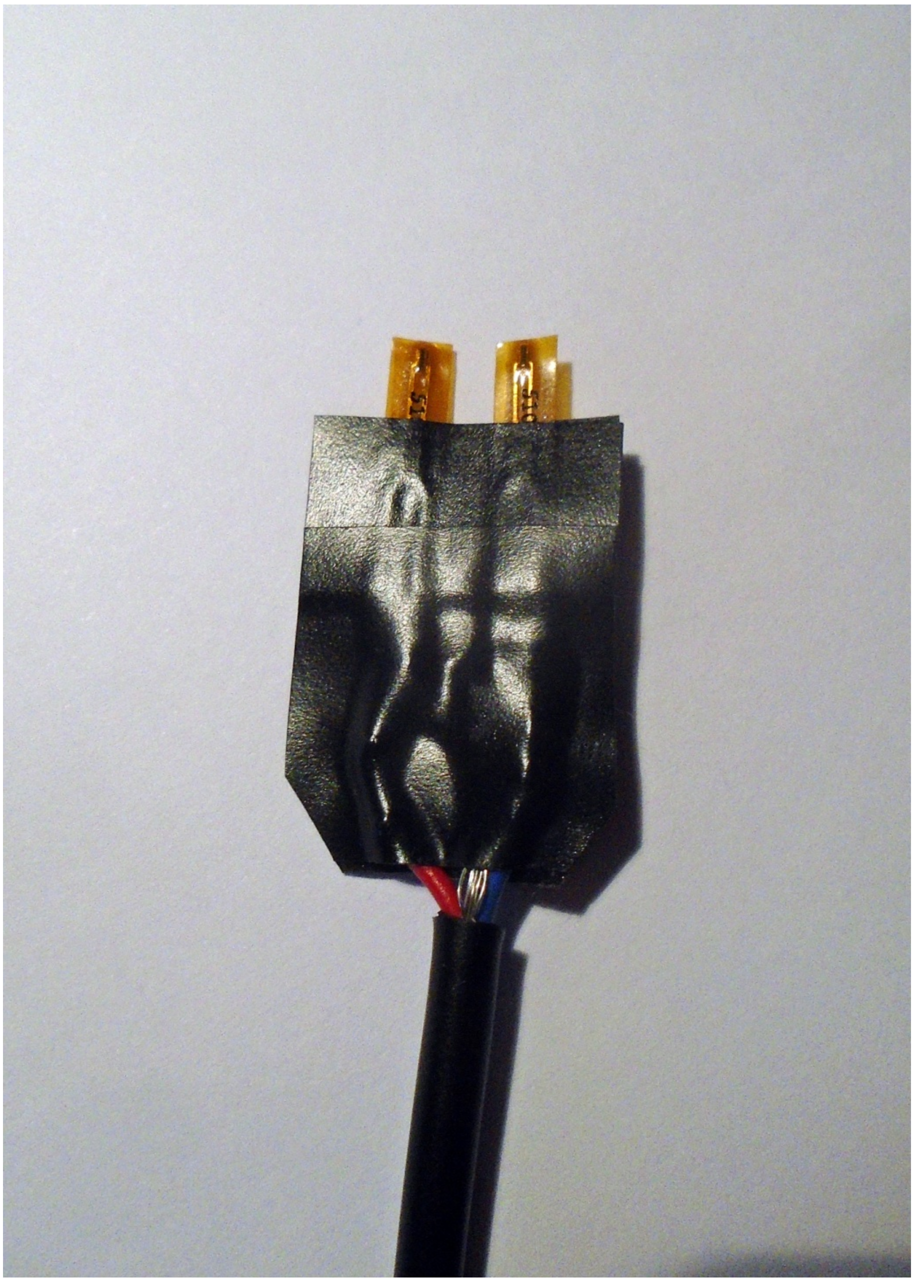
First place two thermistors side by side, with the thermistors 6mm apart, and use electrical insulation tape to fix them in place, as shown in Figure 1 above.

Figure 2. Attach the two sensor wires



Solder the sensor wires in place, as shown in Figure 2 above. The central earth wire should be incorporated into the cable's shielding. In the experiments, "Evolution XPC 301-031 Professional Analogue Audio Cable" cable was used.

Figure 3. Cover the wires with tape



Use the same insulation tape to cover the exposed wires, as shown in Figure 3 above. Any suitable plugs could be used to attach each senor pair to the above box. In the experiments, “banana” plugs and sockets were used.

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