of movement patterns, namely, an approaching movement to take an object, and that of returning to the original point. This dual pattern is repeated eighty times (2).

3.2.1 Signal Acquisition

During the afore-described experiment, multiple sensors were recording different physiological activity from the patient, specifically, the Galvanic Skin Response (GSR), Heart Rate (HR), Heart Rate Variability (HRV), Respiration Rate (RR) and Robot Motion (RM).

Amongst the data gathered during the experiment, we find the Galvanic Skin Response, Heart Rate, Heart Rate Variability, Respiration Rate and Robot Motion. If represented along time, as in Figure 7, we notice some changes at the time that the robot is started (Robot Motion variable goes up to one), marked with horizontal black lines in each graph (2).

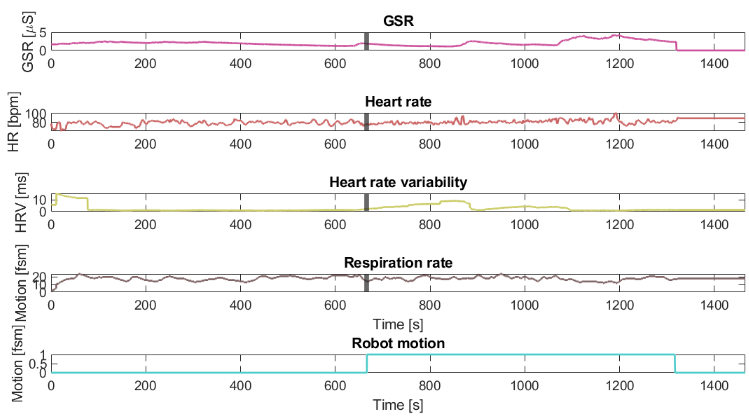

Figure 7: Experimental parameters represented along time.

3.2.2 Signal Processing

As we can see in Figure 7, we have recorded the GSR. The GSR signal was low-pass filtered at 5Hz using a butterworth filter (MatLab in-built function) and filtfilt() MatLab function. This allows us to remove motion artefacts (9).

The resulting filtered signal, however, can give rise, in turn, to two more meaningful variables if properly derived. Applying a Low-Pass Filter with a cutoff frequency of 0.1Hz will yield the low-frequency component of the signal, that is, the Skin Conductance Level (SCL). The SCL represents the baseline or tonic level, given by the hydration or dryness of the skin. In practice, this is done by means of a butterworth filter, which also dephases our signal, but can also be recovered with the MatLab function filtfilt. The result for both the

SCL and SCR is shown in Figure 8. It is noteworthy the fact that the SCR component flagrantly shows a higher-frequency behaviour than that of SCL. Also, there is a correlation between frequency in SCR a and amplitude in SCL, due to the manner in which we derived both components. Therefore, if we were to analyze the baseline of our patient, we ought to focus on the area where the robot was still not active. Note, however, that it does take some time for the SCR signal to arise and make noticeable changes from the moment that the robot was initially activated.

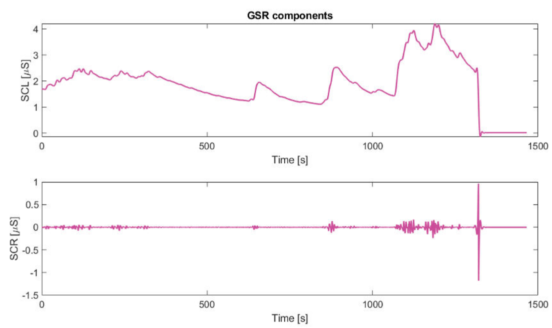

Figure 8: Experimental parameters SCL and SCR (components of GSR), represented along time.

The next step is to compute the physiological response, that is, the response from our body to a given stimuli. For such purpose, we cannot directly analyze the active-robot area but rather compare it with the baseline, that is, study those physiological changes that were recorded in a patient when he perceived certain stimuli, compared with his tonic, resting state. In practice, what we did was splitting our samples from the starting point to the last point before our robot went active (value of 1, in graph). After that, we took the mean of each parameter within the inactive-robot region and computed its baseline by means of Eq. 1, where x_{norm} is the normalized value of each sample in the active-robot region x, with respect the mean or $x_{baseline}$.

$$x_{norm} = \frac{x - x_{baseline}}{x_{baseline}} \tag{1}$$

Then, we divide the time axis for each variable into minutes and take the mean in each one, as shown in Figures 9 and 10.

After which, we can find any significant (10% of the maximal value) variations in our signal means, i.e., we evaluate whether there exists an increase or a decrease in our signal so as to later estimate which physiological indicator is correspondent with such variations. Similarly, we take the peaks in our SCR signal, that is, those values with a minimum distance of 25 samples that are able to reach a threshold of 0.03 μS.

Now that we know how the different variables vary over time (increase or decrease with respect to previous values), we use this as a way of comparison

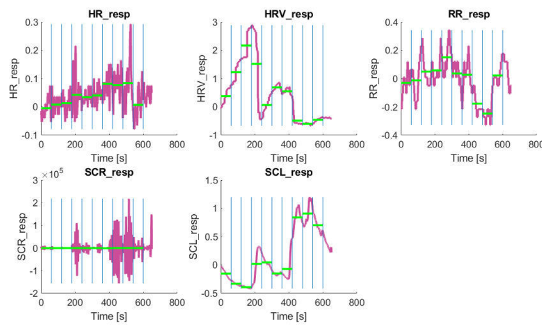

Figure 9: The mean of each parameter per minute of signal acquisition, plotted over the signal.

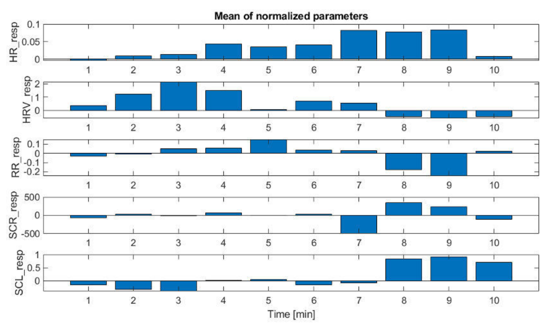

Figure 10: The mean of each parameter per minute of signal acquisition, as bars.

with the expected values of each physiological status that we are studying, i.e., stress, attention and fatigue. In practice we just assign 1 or -1 depending on whether there is an increase or decrease. We store these vectors as columns in a matrix and confront them one by one with our expected values. With the aim of setting a threshold for properly selecting the status, as well as overcoming possible noise or unexpected events that can happen in experimental, real-life situations, we require at least three (out of five) conditions to hold true for a decision to be deemed true. Thus, we can plot the different results and analyze the variation of each state per minute, as shown in Figure 11.

3.2.3 Conclusions

We note in Fig. 11 that the patient seems to have normal or low values in all status, at the beginning of the test. Soon, we can observe an increase in stress, usually followed by an increase in attention, which makes, indeed, much sense, since some stress may help the patient maintain the attention needed to perform the required task. As those variables increase, the physiological

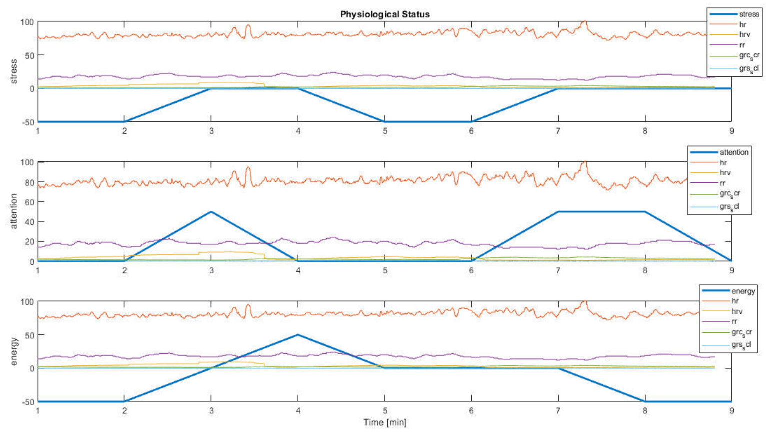

Figure 11: The physiological status of a person per minute; below, the rest of variables.

parameters indicating energy seem to rise at first, maintain a constant, medium level afterwards, and finally start decaying, probably due to the continuous effort that the patient is exerting.

In Fig. 10, we can readily see how the HR is constantly increasing, be it due to stress, attention or both, and reaches maximum values at the last minutes of the test. However, the RR is not always kept at high levels. RR seems to increase at first, which suggests, along with a high HR, that our patient might be stressed but then decreases, while RR simultaneously increases, as well as SCL, which can be a clear sign of attention, since the patient might be focusing harder on the task. Just after that, especially in the last minutes as we approach the end of the test, HR decreases and both components of GSR decrease, as opposed to what would be expected from attention moments. This might be an indication of fatigue, which is also observable in Fig. 11 by a decrease in energy levels.

4 Anthropometry

Anthropometry refers to the measurement of the human individual. In Section 4.1, we present the variables and parameters used. In Section 4.2, we describe the theory from what could be real-life case. We will be studying, within Section 4.3, the mathematical analysis to implement these parameters. In Section 4.4 we study the COM path for different velocities and derive an inference from the different patterns that appear. In Section 4.5, we show the motion of a person -that is simply walking- through the theoretical concepts derived from the aforementioned sections. Furthermore, we will be emulating the body motion in the MATLAB environment.