Chapter 8
Ambient Intelligence in the Bedroom

ABSTRACT
Over the past years, ambient intelligence has infiltrated our lives through various home applications, enabled by the decreasing size and cost of computing technology. While in transport or industry, its presence has become second nature; some areas, such as our bedroom, have remained fairly untouched. Since our bedroom hosts the beginning and end of our daily activities, it needs to assist us in the recovery and preparation of daily activities. Therefore, it holds an enormous opportunity for AI applications, which do exactly what is needed: sensibly assist the user, learn his preferences, and react to his/her mood and needs. This chapter outlines the different ways of assisting the user in his/her intelligent bedroom: ways to monitor health, improve both physical and mental recovery during the night by automatically optimising the environment, as well as automate a number of tedious tasks that reoccur at every start and end of the day.

WAYS TO MONITOR HEALTH
Since we spent almost a third of our lives in bed, it presents an enormous opportunity for general health monitoring. During the past decade, numerous methods and techniques have been developed to record vital body parameters such as respiratory and cardiac activity from within or around our bed. Some methods directly measure electrical activity of the heart, while others focus on the mechanical activity of both heart and lungs. The main idea is however to perform all measurements off-body, e.g. without attaching sensors directly to the skin. This will make sure that subjects are not disturbed...
before and during their sleep, both physically and mentally. Physical disturbance can occur due to skin irritation on places where sensors were attached, or the presence of wires connecting the sensors to a registration or transmitting device. Mental disturbance on the other hand can be due to the person being aware that he or she is being measured, or to the nuisance of attaching the sensors before being able to go to sleep.

Once heart and breathing rate are acquired, heart and breathing rate variability analysis (i.e. temporal changes in heart and breathing rate analysed in both time and frequency domain (Cardiology Task Force, 1996)) can lead to information regarding cardiac health, stress and sleep quality. The latter two are based on research that links the variability within heart and breathing rate to the sympathetic and parasympathetic variations within the autonomic nervous system (Somers, Dyken, Mark, & Abboud, 1993). Based on this link, differences in stress level of a person can be perceived (Hall et al., 2004), his/her sleep pattern can be analysed (Willemen et al., 2013) and possible sleep disorders can be detected (Stein & Pu, 2012).

In this subchapter on health monitoring, we will first discuss how respiratory and cardiac activity can be registered off-body from within or around our bed, after which we will go into more detail on the relevant information that can be extracted from these signals and how this information can be used.

**Off-Body Registration of Respiratory and Cardiac Activity**

Mechanical activity of heart and lungs leads to subtle body motions. Respiration causes obvious thorax and abdominal movement, whereas the pulsation of blood with every heart beat gives a small but detectable oscillation of the body due to conservation of momentum,

\[
\vec{p}_{t_1} = \vec{p}_{t_2}
\]

\[
t_1 : \vec{p}_{t_1} = \vec{0}
\]

\[
t_2 : \vec{p}_{t_2} = m_{\text{blood}}\vec{v}_{\text{blood}} + m_{\text{body}}\vec{v}_{\text{body}}
\]

With \(\vec{p}\) the momentum at timestep 1 and 2 (\(t_1\) and \(t_2\)), \(m\) the mass and \(\vec{v}\) the velocity. The registration of the latter is formerly called a ballistocardiogram (BCG) (Braunstein, 1953).

This movement is different from the movement we can feel when placing our hand on our

![Figure 1. Off-body detection of electrical activity from the heart (Peltokangas et al., 2012; Devot et al., 2007).](image-url)