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# Psychophysiological body activation characteristics in daily routines

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## Abstract

*We present a novel approach to analyse and model psychophysiological body activation patterns that emerge from physical and mental activity during daily routines. We analyse our approach on a 62h dataset of daily routine recordings using acceleration and heart rate sensors. We present a descriptive analysis of psychophysiological activations during the routines using a novel visualisation technique. Our results show that daily routines exhibit different psychophysiological body activation characteristics. While physically-related routines are correlated with heart activity, mentally-related routines show activation patterns without physical activity.*

## 1. Introduction

Daily routines involve different contexts that are reflected in psychophysiological body activations emerging from physical and non-physical activity. Physical activations typically correspond to body movements, such as walking between office rooms. In contrast, non-physical activations can indicate situations that are not related to physical activities, but can be attributed to mental activity [1].

In this paper we aim at a combined analysis to attribute psychophysiological body activations to their respective physical and non-physical origins. This relation has not been sufficiently studied to characterise mental activity in daily routines.

The particular challenges for our combined monitoring approach are twofold: Firstly, an adequate monitoring system is required that can unobtrusively track physical and psychological activation throughout a day. Secondly, a simultaneous analysis of both activation types must be performed to assess such activation characteristics in daily routines. This paper addresses the analysis by introducing a methodology to visualise and quantify psychophysiological activation patterns in annotated daily routines. We evaluate our approach on a dataset of 62 h recorded from two subjects over seven days using a body-worn sensor system [2].

In contrast to classical laboratory-based psychophysiological activation assessments that may use heart activity, respiration, and electrodermal skin response concurrently, such as

in [3], we reside on heart activity as activation measure. We deployed the heart activity monitoring to minimise inference with the routines. Moreover, heart activity has been identified as an essential indicator of mental activity [4]. Although, recently researchers have started to analyse specific motion patterns as elements of daily routines over multiple days, such as in [5], interpretation of physiologic body activation patterns during routines has not been sufficiently studied [1].

## 2. Daily routine analysis

**Analysis procedure.** To obtain a characteristic description of the routine-specific body activations, we analysed the relationship between body movement and heart activity. As there is no established concept for combined analysis of physical and non-physical body activations in daily routines, we selected and analysed a set of typical routines that usually cover 15 min or longer durations during a day, to capture physiological adaptations.

We used an existing study dataset and annotations from [2]. The body-worn recording system consisted of a heart rate monitor chest-belt, measuring the time between adjacent heartbeats (RR interval), and three 3-axes wireless acceleration sensors, called BodyANT. The BodyANTs were attached to wrist, chest, and leg thigh to measure physical activity.

Averages of the acceleration readings from all BodyANT nodes and the RR interval signal were computed in sliding windows of 12 s, with a step size of 6 s. An activity representation for each BodyANT node was obtained by computing the  $L^2$ -norm from all three acceleration axes. Subsequently, both the acceleration features and the RR interval features were individually standardised, by deducting the feature mean and normalising by the standard deviation, allowing to combine the recordings of individual users in the analysis. In total our featureset included 18619 observations (62 h) of daily routines from the entire set.

The activation characteristics were analysed in two steps: Firstly, we evaluated the correlation between the acceleration features for each BodyANT position with the RR interval features, using the Pearson linear correlation coefficient. Secondly, we derived a geometric body activation model using the Principle Component Analysis (PCA) to provide

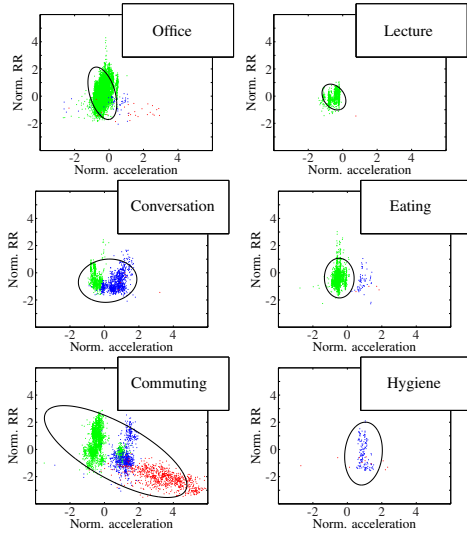


Figure 1. Scatter cloud and ellipse model of body activation characteristics for individual daily routines w.r.t activity sit (green), stand (blue), and walk (red).

both a graphical representation and a quantitative estimate of the predominant activation origin (physical or non-physical). We used the principle components to model an ellipse in the feature space. The ellipse’s semiaxes length and centroid were computed from the standard deviation and mean, respectively, of the feature projection onto the principle components. Additionally, we computed the angle  $\alpha$  between the semi-major axis and the acceleration feature axis, discretised to  $\alpha \in \{-45^\circ, 0^\circ, 45^\circ, 90^\circ\}$ . We attribute  $\alpha \in \{-45^\circ, 45^\circ\}$  to indicate effects of physical activity on the body activation, while these effects are neglectable for  $\alpha \in \{0^\circ, 90^\circ\}$ . The PCA was performed for individual routines using the same acceleration and RR interval features as used for the correlation analysis.

**Experimental results.** The correlation analysis was performed for all three BodyANT positions. For both users the highest negative correlations,  $-0.75$  and  $-0.73$ , were achieved in the commuting routine and the leg thigh BodyANT position. This result corresponds to the physical activation pattern, which results in larger accelerations at higher heart rates (hence shorter RR intervals). In comparison to the other daily routines, the commuting routine included episodes of sitting, standing, and walking at different intensities. All other routines as well as the chest and wrist positions showed no clear correlations.

Figure 1 shows the body activation characteristics of each daily routine. The scatter clouds represent the observation instances, the ellipses the model representation, derived as described in Section 2 above. All routines exhibited ellipsoidal-shaped clusters. The visual separable clusters in commuting and conversation routines could be attributed to

Table 1. Ellipse model parameters for daily routines.

Routine	Semiaxis length		Angle $\alpha$ [ $^\circ$ ]
	<i>Major</i>	<i>Minor</i>	
Office	1.57	0.60	90
Commuting	3.98	1.54	$-45$
Eating	1.17	0.69	90
Conversation	1.38	1.25	0
Lecture	0.79	0.51	90
Hygiene	1.85	0.87	90

the physical activities sit, stand, and walk. Typically, sit had the lowest physical activity level, compared to stand and walk. Sit and stand show a vertical alignment (large RR interval variation with small acceleration changes), while, by contrast, walking shows a slope. This can be attributed to the correlation between physical activity and physiological activation for walking.

Table 1 summarises the ellipse model parameters for all daily routines. Especially commuting exhibited a notable body activation by physical activity, indicated by  $\alpha = -45^\circ$ . According to our modelling assumption, this result was expected as this routine involved the most physical activity. Remarkably, routines having  $\alpha = 90^\circ$  with predominant sitting activity differ in shape, indicated by the semiaxis length. We attribute these differences in body activations to routine-related characteristics in non-physical activity, in particular mental activity.

### 3. Conclusion and future work

This paper presented a novel approach to model both physical and non-physical body activations in daily routines. We derived a geometric model to quantify and visualise these activations. While our analysis showed that both types of activations can co-occur (correlations of up to 0.7), particular daily routines were dominated either by physical or non-physical (mental) contributions. We plan to further investigate non-physical and mental activations to describe them in daily routines.

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