I. INTRODUCTION

Walking with a transfemoral prosthesis is a complex task that places higher demands on sensory and cognitive systems [1]. As a result a limited processing capacity is available to perform secondary information-processing tasks [1, 2]. One of the goals of the smart ortho-prosthesis is to detect the user’s level of physical and cognitive effort and, if necessary, adapt the assistance given by the ortho-prosthesis. The goal of this study is to detect which psychophysiological sensors are minimally necessary to recognize the physical and cognitive effort during single and dual walking tasks.

II. MATERIAL & METHODS

Twenty-four healthy male subjects (mean age 24.5 ± 2.9y, height 1.79 ± 0.04m, weight 69.6 ± 7.3kg) participated in this study comprising 6 conditions with increasing task difficulty. The conditions were randomized and consisted out of single tasks such as standing, symmetrical or asymmetrical walking and solving a mental rotation task (MRT) to dual tasks such as (a)symmetrical walking and simultaneously solving the MRT. Nexus-10 was used for monitoring psychophysiological responses of the autonomic nervous system. Subjective workload was assessed by the NASA Task Load Index (NASA-TLX).

For the psychophysiological data only the last 3 minutes of each condition were analyzed to ensure steady-state. The raw subscales and total raw score of the NASA TLX were analyzed. A unitless ordinal sensitivity index (SI) was calculated for all outcome variables, based on the rationale described in Balkin et al. [3], where sensitivity is defined as the ratio of the size of the effect of a variable to its 95% confidence interval. A 2-way repeated measures ANOVA was used to find significant differences in psychophysiological parameters and subjective workload scores. Data are presented as mean with SD. Statistical significance was accepted at p < .05.

III. RESULTS

The highest raw workload score (56.9, SD 12.6) was elicited for the most challenging condition. A 2-way RM ANOVA shows that the raw workload on the NASA-TLX is able to differentiate between the different conditions. The subscales mental demand and frustration were able to differentiate the best between a condition with and without a cognitive task, while the subscale physical demand could clearly make a distinction between physically different tasks. For the psychophysiological measures breathing frequency (BF), heart rate (HR) and skin conductance level (SCL) showed significant differences between almost all conditions. The mean values of these parameters increased significantly with increasing task difficulty and differed between both mentally and physically different tasks. Fig. 1 shows the ranking based on the SIs: BF is the most sensitive outcome variable (SI= 5.52), closely followed by HR (SI= 4.25), mental load (SI= 3.88), total workload (SI= 2.80) and SCL (SI= 2.64).

IV. DISCUSSION & CONCLUSION

Our results suggest that HR, BF and SCL together with subjective measures of workload (fig. 1) are the most sensitive to differentiate between walking conditions involving both physical and cognitive challenges. Yet, Novak et al. [4] suggested to use a combination of BF and ST to differentiate between under- and overchallenging walking tasks while Koenig et al. [5] proposed ST and SCL as main psychophysiological responders. The absence of strenuous physical activity in this study could explain some of the differences. Moreover, from our study it is clear that ST and SC are only stable measures when the environmental temperature is stable which is impossible to achieve in daily life settings. Corresponding to what has been suggested by literature [2, 6], this study confirms that a combination of measures is desirable in biocooperative control systems not only including psychophysiological responses but also biomechanical and subjective parameters.

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REFERENCES

