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The Effect of Using Noise Cancellation Earplugs In Open-Plan Offices On The Offices On The Work Well-Being And Work Performance Of Software Professionals

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THE EFFECT OF USING NOISE CANCELLATION EARPLUGS IN OPEN-PLAN OFFICES ON THE WORK WELL-BEING AND WORK PERFORMANCE OF SOFTWARE PROFESSIONALS

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Abstract

The popularity of open-plan offices has been on the rise recently and expanded to all sectors of working life. While moving to open-plan offices brings savings to companies, open-plan offices have been connected with various different negative consequences, such as noise. Noise has been found to be a central cause of dissatisfaction towards working in an open-plan office and lead to subsequent negative outcomes, such as decreased self-perceived health and weakened cognitive performance. Therefore, it is important to study the ways and technologies that could possibly mitigate the negative effects of noise on work well-being and work performance. This explorative study investigates both the objectively measured and subjectively perceived effects of adopting noise cancellation earplugs by open-plan office workers in a software company. In physiological measurements, the usage of noise cancellation earplugs was not found to affect work stress or work strain nor affect the stress-recovery balance. In psychological measurements, the perceived effects of using the earplugs on work well-being and work performance were small but rather negative than positive. This could be due to negative perceived comfort and usage experiences with the earplugs. Besides open-plan offices, the findings are mostly generalizable to other office settings as well.

Keywords: Noise cancellation earplugs, Open-plan office, Work well-being, Work performance.

1 Introduction

The popularity of open-plan offices has been on the rise recently and expanded to all sectors of working life. In this, the software industry and other industries employing information technology (IT) and information systems (IS) professionals are no exception. The reasons behind this popularity stem from space-efficiency, which provides savings regarding properties and energy consumption (Haapakangas, 2017). While moving to open-plan offices brings savings to companies, open-plan offices have been connected with various different negative consequences, for example, noise (Nemecek and Grandjean, 1973; Pejtersen, Allermann, Kristensen and Poulsen, 2006). Noise refers to sound that is perceived unpleasant. It can be disturbing and hamper important tasks at hand (Cohen & Weinstein, 1981). Despite the fact that objectively measured noise levels in open-plan offices are not typically exceptionally high (Haapakangas, 2017), noise has been found to be a central cause of dissatisfaction towards working in an open-plan office (e.g., Danielsson and Bodin, 2009; De Croon, Sluiter, Kuijer and Frings-Dresen, 2005; Haapakangas, Helenius, Keskinen and Hongisto 2008; Pejtersen et al., 2006). Cohen and Weinstein (1981) point out that the loudness of the sound does not necessarily make it a noise. For example, depending on the occasion, loud music can be perceived as desirable sound, while soft whisper can be undesirable noise. Thus, the unwanted noise in open-plan offices is not necessarily loud but disturbing in other ways.

Noise can have further subsequent negative consequences in open-plan office setting. For example, decreased job satisfaction (Sundstrom, Town, Rice, Osborn and Brill, 1994), decreased self-perceived health (Lee, Lee, Jeon, Zhang, and Kang, 2016), weakened cognitive performance, and worsened subjective perceptions of the acoustic environment (Haka, Haapakangas, Keränen, Hakala, Keskinen and Hongisto, 2009). In the study by Jahncke, Hygge, Halin, Green and Dimberg (2011), participants rated themselves as more tired, remembered less words, and had lower work motivation in noise compared to low noise. These issues are closely connected to the work efficiency and health of the employees, which of course are highly important matters for any company, and can also have subsequent economical consequences for companies.

Therefore, there is a need and it is important to study the ways and technologies that could possibly mitigate the negative outcomes of noise on work well-being and work performance. One example of such technologies are noise cancellation earplugs, on which previous research is still very limited. To address this gap in existing literature, this study examines both the objectively measured and subjectively perceived effects of adopting noise cancellation earplugs by open-plan office workers in a software company. More precisely, we conduct an intervention study containing both an intervention group and a control group and employing both physiological and psychological measurement instruments in order to examine the potential changes in the work well-being and work performance of the participants. Because of the lack of prior research on the subject, the study is explorative in nature, meaning that it mainly aims at providing preliminary insights on the topic, which are intended to act as a starting point for more profound examinations. Therefore, the results are examined without utilizing any prior theoretical frameworks, and we do not propose any *a priori* hypotheses or claims.

2 Study Setting

2.1 Open-plan office in this study

The definition of open-plan office is not unambiguous. They may vary in multiple elements, such as size, architecture, functional features, workstation density, and use (Haapakangas, 2017). In the case of this study, the open-plan office workers were software professionals who had assigned workstations. The whole office space was not symmetrical but included different shaped corners and areas, some of which were divided by walls. The number of workers in different sections of the office varied between 15 and 30. However, the measured background noise level was almost equivalent throughout the whole office.

2.2 Noise cancellation earplugs

Noise cancellation earplugs, also known as noise-cancelling earplugs, are in-ear passive earplugs with active noise cancelling features. They can be categorised as a type of smart earbuds, also called hearables (Dysart, 2017), a term first introduced by Nick Hunn (2014). Hearables can be defined as electronic and wireless in-ear computational earpieces and cover a multitude of devices for varying purposes. The market for hearables is rising and the overall market revenue is expected to exceed $40 billion in 2020 (Hunn, 2016).

Active noise cancellation “involves the electro-acoustic generation (usually with loudspeakers) of a sound field to cancel an unwanted existing sound field” (Hansen, 2001, p. 1). In other words, it uses a microphone to sample the sound and a speaker to create a phase-shifted sound that cancels the original sound. The earplugs selected for this study are, according to the manufacturer, designed to provide noise reduction across the whole audible spectrum but to be especially effective at low frequencies, which is typical for these kind of devices (Elliot, 2007). Typical sources of low frequency sounds include traffic and engine noise, airplane noise, music coming through a wall, and environmental noise from industrial sites. The earplugs used in this study consists of a microphone, speaker, electronics, battery, cover, and changeable silicone tips.

Previous research using noise cancellation earplugs is very limited. Most prior research on the subject has used noise cancellation headphones that are placed over the ears, instead of in-ear earplugs. Also, studies conducted in real (non-simulated) office setting are few. Jahncke, Björkeholm, Marsh, Odelius and Sörqvist (2016) found that (in office setting) background speech can impair performance, but the effect can be mitigated by using headphones with (nature) sound masking. However, they also reported that headphones without sound masking do not have this effect. Focusing on aviation context, Molesworth, Burgess, Gunnell and Duong (2014) found that using active noise cancellation headphones is effective in improving the signal to noise ratio of oral information and can thus protect against detrimental effects of noise. Another study found that improved signal to noise ratio by noise cancellation headphones can also improve recall performance (Molesworth, Burgess, Gunnell, Löffler and Venjakob, 2014). Further, Molesworth, Burgess and Kwon (2013) found that task performance was significantly better when using noise cancellation headphones compared to not using ones, and thus noise cancellation headphones can have beneficial effects in task situations.

3 Methodology

The study was conducted as an intervention study containing both an intervention group and a control group. As participants for the study, we were able to recruit 28 software professionals from the local site of a large Finnish software company. The participation was entirely voluntary, meaning that the employees could freely choose whether or not to take part in the study. After the recruitment, the 28 participants were randomly allocated to an intervention group of 14 people and a control group of 14 people. For both the groups, two measurements lasting approximately for three full days were conducted during weeks 13 and 15 of 2017. These are from here on referred to as measurements A and B. Measurement A was the baseline measurement, during which none of the participants used the noise cancellation earplugs. After the measurement, the earplugs were distributed to the participants in the intervention group, who were asked to use them as much as possible while at work both during the week between the measurements and during measurement B. For the participants in the control group, no earplugs were distributed, so their measurements were used only for control purposes.

In the measurements, we employed both physiological and psychological measurement instruments to examine the potential changes in the objectively measured and subjectively perceived work well-being and work performance of the participants. As the physiological measurement instrument, we used the Firstbeat Lifestyle Assessment service in which the participants were asked to wear a Firstbeat Bodyguard 2 heart rate monitor continuously for approximately three days (both day and night except for situations of extreme humidity, such as shower and sauna) and additionally to report their daily activities as well as their potential usage of medication and alcohol to an online diary by using a computer or a mobile phone. This collected data was then analysed by using the Firstbeat Analysis Server to produce reports on their work well-being. Although the collected data covered also non-work time, only the work time data based on the work hours self-reported by the participants to the online diary was used in the analysis. The variables in the Firstbeat Lifestyle Assessment reports included the basic heart rate (HR) of the assessed individuals as well as various other physiological variables estimated from their heart rate variability (HRV), such as their respiration rate (RR), oxygen consumption (VO_2), and energy expenditure (EE). The exact estimation methods are described in more detail in the white papers published by Firstbeat (2012a, 2012c). All the four aforementioned variables (HR, RR, VO_2, and EE) were utilised in this study as indirect indicators of the work strain and work stress of the participants.

In addition, HRV and its associations with the sympathetic and parasympathetic divisions of the autonomic nervous system (ANS) can be used to make more direct estimations on the physiological states of the assessed individuals, particularly the balance between their stress and recovery. The exact estimation method is described in more detail in another white paper published by Firstbeat (2012b). In the Firstbeat Lifestyle Assessment reports, the estimations are presented as profiles exemplified in Appendix 1, in which the red bars indicate a stress state and the green bars indicate a recovery state. In addition, the profiles contain light and dark blue bars, which indicate the states of more intensive physical activity (e.g., physical exercise) in which one's VO_2 rises to 20–30 % (light blue) or to over 30 % (dark blue) of one's maximum VO_2. However, these states were not of interest in this study. The height of the bars represents the intensity of the respective physiological state, but on a subjective scale relative to one's maximum and minimum intensity that does not enable comparisons between the assessed individuals. Therefore, from the reported profiles, we only utilised the ratio between stress and recovery time, which is from here on referred to as stress–recovery balance (SRB). We scale this variable to vary from -1 to 1, in which -1 indicates time spent only in stress state and not at all in recovery state, 0 indicates an equal amount of time spent in both stress and recovery states, and 1 indicates time spent only in recovery state and not at all in stress state.

As the psychological measurement instrument, we used two online surveys conducted at the end of measurements A and B, which contained items concerning the perceived work well-being and work performance of the participants, the perceived effects of using the earplugs on the work well-being and work performance of the participants, as well as the usage and use experiences of the earplugs. The perceived work well-being was measured by using two dimensions (work strain and work stress), whereas the perceived work performance was measured by using three dimensions (work concentration, work efficiency, and work productivity). In addition, the two online surveys also contained control items concerning the workstation noise and the work practices of the participants. Responding to all the items was voluntary, so the participants could also skip individual items, which resulted in a missing value.

The collected quantitative data was analysed with the SPSS Statistics version 24 software by using the Student's t-tests to examine the statistical significance of the measurement results as well as the potential differences and changes in them between the intervention and control groups as well as between measurements A and B. Because of the explorative nature of our study, the probability level of $p < 0.1$ was used as the threshold of statistical significance. In analysing the collected qualitative data, guidelines for thematic analysis by Braun and Clarke (2006) were followed, but as they suggest, the guidelines were applied flexibly to fit the research aim and data. The analysis began by getting familiar with the data (reading all the responses) and marking all the interesting features in the responses. The analysis continued by searching recurring themes and recursively reviewing them in relation to the data.

4 Results

As mentioned above, we were able to recruit 28 participants for the study, who were allocated to equally sized intervention and control groups. However, between the measurements, there was one dropout in the control group, which resulted in a final sample size of 27 participants (14 in the intervention group and 13 in the control group). The descriptive statistics of this sample in terms of gender and age are reported in Table 1.

	All participants (N = 27)		**Intervention group (N = 14)**		**Control group (N = 13)**	
	N	**%**	**N**	**%**	**N**	**%**
Gender						
Male	19	70.4	9	64.3	10	76.9
Female	8	29.6	5	35.7	3	23.1
Age						

–29 years	5	18.5	2	14.3	3	23.1
30–39 years	7	25.9	4	28.6	3	23.1
40–49 years	11	40.7	7	50.0	4	30.8
50– years	4	14.8	1	7.1	3	23.1

Table 1. Descriptive statistics of the sample

4.1 Control variables

In terms of control variables, the participants were inquired at the end of measurement A about their perceived workstation noise and the perceived effects of the noise on their work strain, work stress, work concentration, work efficiency, and work productivity. Table 2 reports the responses of both the intervention group (N = 14) and the control group (N = 13) as well as the results of the t-tests that were used to examine the statistical significance of the potential differences between the groups. For the perceived workstation noise and the effects of noise on work stress, we used the standard Student's t-test, whereas for the remaining effects of noise, we used the Welch's t-test due to the unequality of variances between the intervention and control groups suggested by the Levene's tests. The measurement scale ranged from 1 (not noisy) to 5 (extremely noisy) for perceived workstation noise and from -5 (decreases strongly) to 5 (increases strongly) for the perceived effects of the noise. As can be seen, the participants in both the groups perceived their workstations as moderately noisy, but did not perceive this noise having a strong effect on their work well-being or work performance. All the differences between the groups were statistically not significant.

	Intervention group			Control group			Difference between the groups		
	N	Mean	SD	N	Mean	SD	t	df	p
Workstation noise	14	2.6	0.9	13	3.1	1.0	1.330	25	0.196
Effect of noise on work strain	13	1.0	1.0	12	2.0	2.0	1.591	16.1	0.131
Effect of noise on work stress	13	1.3	1.3	12	2.0	2.0	1.047	23	0.306
Effect of noise on work concentration	14	1.4	2.1	13	-0.2	3.5	-1.412	19.3	0.174
Effect of noise on work efficiency	13	1.2	1.7	13	0.1	3.4	-1.012	17.7	0.325
Effect of noise on work productivity	12	1.2	1.9	13	0.1	3.3	-1.028	19.1	0.317

Table 2. Perceived workstation noise and the perceived effects of the noise

In addition, the participants were inquired at the end of both the measurements about the percentage of their total work time spent at their workstation during measurements A and B. For the intervention group, the reported percentage was 83.8 % during measurement A and 78.8 % during measurement B. For the control group, the reported percentage were 76.2 % during measurement A and 60.9 % during measurement B. When using the Student's t-test, the difference between the groups concerning measurement A was found as statistically not significant (t(25) = 1.095, p = 0.284), whereas the difference between the groups concerning measurement B was found as statistically significant (t(25) = 2.314, p

= 0.029), meaning that the participants in the control group spent slightly less time at their workstation during measurement B in comparison to the participants in the intervention group.

4.2 Effects of using the earplugs (physiological measurements)

The amount of valid data collected with the Firstbeat Bodyguard 2 heart rate monitors and analysed by using the Firstbeat Analysis Server was about 492.6 hours for measurement A and about 505.3 hours for measurement B, which averages to about 18.2 hours per participant for measurement A and about 18.7 hours per participant for measurement B. Table 3 reports the measurement results for the intervention group (N = 14) and the control group (N = 13) during measurements A and B as well as the results of the Student's t-tests that were used to examine the statistical significance of the potential changes in the results between the measurements. As can be seen, statistically significant changes were found only in the HR, VO_2, and EE of the control group, which all had increased slightly between the measurements.

	N	A		B		Difference between A and B				
		Mean	SD	Mean	SD	Δ	SD	t	df	p
HR (beats / min)	14	73.1	10.3	72.8	9.9	-0.3	3.9	-0.277	13	0.786
	13	69.4	10.1	71.5	10.8	2.1	3.2	2.414	12	**0.033**
RR (breaths / min)	14	13.5	1.8	13.6	2.0	0.1	0.6	0.756	13	0.463
	13	14.3	2.1	14.2	1.9	-0.1	0.6	-0.554	12	0.590
VO_2 (ml / kg / min)	14	4.3	0.9	4.4	1.0	0.1	0.3	0.891	13	0.389
	13	4.2	0.7	4.3	0.9	0.2	0.3	2.027	12	**0.065**
EE (kcal / min)	14	94.6	37.0	97.1	41.3	2.5	6.9	1.361	13	0.197
	13	96.4	23.4	99.9	26.6	3.5	6.9	1.832	12	**0.092**
SRB (from -1 to 1)	14	0.68	0.39	0.68	0.49	0.01	0.39	0.052	13	0.960
	13	0.69	0.40	0.86	0.12	0.17	0.39	1.592	12	0.137

Table 3. Changes in physiological variables

4.3 Effects of using the earplugs (psychological measurements)

Table 4 reports the ratings given by the participants in the intervention group (N = 14) and in the control group (N = 13) about their perceived work strain, work stress, work concentration, work efficiency, and work productivity during measurements A and B as well as the results of the Student's t-tests that were used to examine the statistical significance of the potential changes in the ratings between the measurements. The five-step rating scale ranged from 1 (low) to 5 (high). As can be seen, all the changes were found as statistically not significant, except for work efficiency in the control group, which had increased between the measurements.

	N	A		B		Difference between A and B				
		Mean	SD	Mean	SD	Δ	SD	t	df	p
Work strain	14	2.9	0.8	2.9	0.9	0.0	0.9	0.000	13	1.000
	13	2.5	1.1	2.6	1.0	0.2	0.7	0.805	12	0.436

Work stress	14	2.4	1.0	2.9	1.1	0.4	1.0	1.578	13	0.139
	13	2.2	1.1	2.5	1.0	0.3	0.9	1.171	12	0.264
Work concentration	14	3.4	0.8	3.4	1.0	-0.1	1.0	-0.268	13	0.793
	13	3.0	0.6	3.3	0.6	0.3	0.8	1.477	12	0.165
Work efficiency	13	3.5	0.9	3.5	0.9	0.0	1.0	0.000	12	1.000
	13	2.9	0.5	3.6	0.8	0.7	0.6	3.959	12	**0.002**
Work productivity	14	3.2	0.9	3.6	0.8	0.4	1.0	1.325	13	0.208
	12	3.0	0.6	3.4	1.0	0.4	1.0	1.449	11	0.175

Table 4. Changes in perceived work well-being and performance

Table 5 reports the ratings given by the participants in the intervention group about the perceived effects of using the earplugs during measurement B on work strain, work stress, work concentration, work efficiency, and work productivity as well as the results of the Student's t-tests that were used to examine their statistical significance. The 11-step rating scale ranged from -5 (decreased strongly) to 5 (increased strongly). All in all, the effects of using the earplugs were perceived as quite negative, as there was an increase in both work strain and work stress as well as a decrease in work efficiency and work productivity. In contrast, work concentration seemed to have increased slightly, which can be considered as a positive effect. However, of these effects, only the effect on work strain was found as statistically significant.

	N	**Mean**	**SD**	**t**	**df**	**p**
Work strain	14	0.5	1.0	1.836	13	**0.089**
Work stress	14	1.0	2.3	1.636	13	0.126
Work concentration	14	0.7	2.6	1.046	13	0.315
Work efficiency	14	-0.1	2.1	-0.126	13	0.902
Work productivity	14	-0.3	2.1	-0.502	13	0.624

Table 5. Perceived effects on work well-being and performance

4.4 Usage and usage experiences of the earplugs

In terms of the usage of the earplugs, the participants in the intervention group were inquired about the percentage of their total work time that they used the earplugs during the week between measurements A and B as well as during measurement B. These percentages were 49.3 % for the week between measurements A and B and 56.0 % for measurement B, meaning that the earplugs were used quite actively when considering that there are many work situations in which the usage is not either possible or preferable (e.g., meetings). None of the participants reported having used the earplugs outside the work time.

In terms of the usage experiences on the earplugs, the participants in the intervention group were inquired about the perceived comfort of using the earplugs and their willingness to use the earplugs in the future if provided ones for free by the employer. The 11-step measurement scale for the perceived comfort ranged from -5 (extremely uncomfortable) to 5 (extremely comfortable), whereas the five-step measurement scale for the willingness to use (or the likelihood of future usage) ranged from 1 (very unlikely) to 5 (very likely). The mean rating given by the participants in terms of perceived comfort was -2.1 (SD = 2.8), which was statistically significant when examined with the Student's t-test ($t(13) = -2.810$, $p = 0.015$). The mean rating given by the participants in terms of willingness to use was 2.3

(SD = 1.3). In other words, the usage of the earplugs was perceived as quite uncomfortable by the participants and there was low willingness to use them in the future.

In addition, the participants in the intervention group were also asked two open-ended questions about the positive and negative aspects of using the earplugs. The responses to these questions revealed that, for most of the participants (9 / 14), the usage caused pain, irritation, or feeling of pressure in the ears. Half of the participants (7 / 14) also reported that the earplugs did not fit well into one's ear or did not stay in the ears very well – there was a need to adjust the position of the earplugs from time to time. Other negative aspects concerned interaction, as many of the participants (8 / 14) reported that the earplugs made it more difficult to communicate with others and were cumbersome to use, as one had to remove and re-insert them, for example, when discussing with a colleague. A few participants (3 / 14) also mentioned that using the earplugs caused a negative feeling of being "isolated", as one was not able to properly hear what was happening around. The main positive aspect was the ability of the earplugs to attenuate background noise, especially coming from further distance, as reported by most of the participants (10 / 14). In that regard, the earplugs used in this study can be considered effective in what they were designed for – noise cancellation.

5 Discussion and Conclusions

This study examined the objectively measured and subjectively perceived effects of adopting noise cancellation earplugs by software professionals working in an open-plan office of a software company. The examination was exploratory in nature. The study was conducted as an intervention study containing both an intervention group and a control group and employed both physiological and psychological measurement instruments in order to examine the potential changes in the work well-being and work performance of the participants.

In terms of physiological measures, the usage of noise cancellation earplugs was not found to affect work stress or work strain nor affect the stress-recovery balance. In terms of psychological measures, the perceived effects of using the earplugs on work well-being and work performance were small but rather negative than positive. This suggests that in-ear noise cancellation earplugs cannot be suggested as an efficient solution for promoting the work well-being and work performance of software professionals in an open-plan office.

The earplugs used in this study were perceived effective in attenuating noise. However, the earplugs were also perceived as uncomfortable to use, cumbersome in practice, and not well fitted to be used in an open-plan office if one needs to discuss with others. Thus, not surprisingly, it seemed unlikely that people would be willing to use the earplugs in the future even if they would be provided ones for free by the employer.

As a theoretical contribution, this study extends previous research on noise cancellation in open-plan office setting and is, to our knowledge, the first study to measure the effects of adopting in-ear noise cancellation earplugs by open-plan office workers. Thus, it provides important insights in to this previously little researched topic and acts as groundwork for future IS research. The study also contributes to the research on occupational stress and work well-being – not just from the point of IT and IS professionals but knowledge workers in general (including IS researchers). From a practical point of view, the findings offer insights to the managers of software companies and others using open-plan offices regarding the potential new ways and technologies to mitigate the negative outcomes of noise on work well-being and work performance. These insights can be used to evaluate whether or not to invest in such solutions in the future. More specifically, we suggest that the managers would discuss with the employees about the possible different solutions before acquiring and deploying ones. Even better would be if the employees would be able to test different devices before making the decision to implement one, as some might find in-ear devices and others might find over-the-ear devices more suitable for their personal needs. Besides open-plan offices, the findings are for the most parts generalizable to other office settings as well.

The findings also suggest that it might be difficult to design sound cancellation earplugs (or devices per se) that are perceived both effective and satisfactory to use in an open-plan office. Yet, for the post-adoption continued use of these devices, they would need to be perceived as effective in terms of attenuating unwanted noise and satisfactory in terms of comfort and practicality. As an example, one obvious advantage of earplugs over headphones is their smaller size, which makes them much lighter and easier to carry along. On the other hand, over-the-ear headphones do not cause irritation or pain inside the ear. Thus, finding an equilibrium between the effectiveness and use comfort and satisfaction seems to be the main challenge facing the developers of wearable noise cancellation devices.

6 Limitations and Future Research

This study has three notable limitations. First, the data was collected only from 27 software professionals working in one open-plan office of one software company, which limits the generalizability of the findings. Future studies should conduct similar examinations in open-plan offices of other companies as well, and with larger samples. Also, considering the reports that the earplugs were cumbersome to use as one had to remove and re-insert them when communicating with others, it could be beneficial to concentrate on employees who mostly work by themselves without the need to verbally communicate with others. It would also be interesting to replicate this study with over-the ear noise cancellation headphones and compare the findings with those of this study.

Second, due to the selected physiological measurement instrument (the Firstbeat Lifestyle Assessment service), the duration of this study was relatively short, as the two conducted measurements were scheduled approximately one week apart and each lasted approximately only for three days. This limits the findings to only the short-term effects of using noise cancellation earplugs instead of the longer-term effects. Thus, future studies would benefit from more longitudinal study settings. Regarding the psychological measurements, those could be conducted also during the measurements, as we only conducted them at the end of measurements A and B.

Third, regarding the background noise level in the open-plan office, we measured the noise levels at different parts of the office during measurement A by using a decibel meter and also inquired the participants about their perceptions on the typical workstation noise levels by using an online survey. However, it was not possible to measure the actual noise levels at the office constantly during both the measurements. Although unlikely, it is possible that there might have been different levels of background noise during the measurements A and B.

Additionally, it should be noted that the Firstbeat Lifestyle Assessment service does not have a medical classification. However, its estimates on energy expenditure and oxygen consumption have been found as sufficiently accurate for field studies (e.g., Montgomery et al., 2009; Smolander, Ajoviita, Juuti, Nummela and Rusko, 2008; Smolander et al., 2011), and several previous studies have successfully used it as a measurement instrument of these variables (e.g., Finni, Haakana, Pesola and Pullinen, 2014; Mutikainen, Helander, Pietilä, Korhonen and Kujala, 2014) as well as stress (e.g., Salonen, Kokko, Tyyskä, Koivu and Kyröläinen, 2013; Föhr et al., 2015; Makkonen, Silvennoinen, Nousiainen and Vesisenaho, 2016).

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Appendix 1 Firstbeat Lifestyle Assessment Report (Firstbeat, 2017)