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The effect of open-plan office designs on employees: A study on hair cortisol, functional comfort and job complexity

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Master Thesis, Organisational psychology

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Abstract

Due to the changing nature of work, organisations are increasingly investing in office redesign from traditional to open-plan. However, studies have shown that employees in open-plan offices experience more self-reported strain than employees in traditional offices. A possible biological indicator of strain in individuals is the hormone cortisol. Therefore, the current study investigated, among 131 employees from multiple companies, the relationship between office design and cortisol concentrations in hair. Possible moderating effects of functional comfort and job complexity on the relationship between office design and cortisol were investigated. The results showed no evidence for a relationship between office design and cortisol concentrations in hair, nor did it show moderating effects of functional comfort or job complexity on this relationship. However, these results are preliminary and the possibility of a relationship between office design and cortisol concentrations in employees cannot be completely refuted. Further research is needed on the association between work-related stressors and cortisol concentrations in the hair of employees, the individual differences in the appreciation of the open-plan office design and the specific conditions under which the open-plan office design might elicit changes in cortisol levels.

Key words: Office design, Open-plan office, Strain, Cortisol, Hair, Functional comfort, Ergonomics, Job complexity

The effect of open-plan office designs on employees: A study on hair cortisol, functional comfort and job complexity

Office design is currently transitioning from the traditional office to the open-plan office (Gillen, 2006). Due to the changing nature of work, organisations are increasingly investing in office redesign to facilitate more flexible working styles (Gillen, 2006). Within the organisational literature, a distinction is usually made between traditional offices, enclosed or cellular, and open-plan offices. Whereas traditional offices often house a maximum of three individuals and the required facilities in an enclosed, private room (Danielsson, & Bodin, 2008), open-plan offices are characterized by large office spaces with few to no interior walls, a greater number of workers and groupings of individual workstations within the open office (Brennan, Chugh, & Kline, 2002).

Depicting the open-plan office; incitement of implementation and consequences

In an ever changing and innovating economy, the work environment and office design need to be able to accommodate and reflect the nature of the work and the business needs (Gillen, 2006). The design of the office environment is always driven by several, often competing, concerns (Allen, & Henn, 2007; Laing, 2006). Primarily because of economic reasons the open-plan office has become the dominant choice over traditional office plans (Duffy, 2000; Laing). Open-plan offices allow a higher density of employees by having office configurations with fewer interior walls and fewer enclosed offices (Charles, & Veitch, 2002; Vischer, & Fischer, 2005). These higher offices densities have become a method for organisations to reduce overheads, building costs and maintenance and service costs (Duffy; Vischer, & Fischer). By increasing the flexibility of the office layout, cost savings can also be realized for future reorganisations (Vischer, 2007). Besides financial benefits, it has been suggested that an open-plan office design aids and increases inter- and intra-team communication and generates greater group sociability (Sundstrom & Sundstrom, 1986). In line with this, a more recent post-intervention study showed that employees in refurbished open-plan offices reported greater co-worker

satisfaction, greater collaboration and a more positive view of the organisational culture than employees in non-refurbished, traditional offices (McElroy, & Morrow, 2010).

However, studies have also found important negative outcomes of the implementation of the open-plan office design. A literature review showed that open-plan offices led to less productivity, creativity and satisfaction and led to lower concentration and motivation among employees compared to traditional offices (Davis, Leach, & Clegg). This review showed that people in open-plan offices experienced more social interactions by others, which could not (easily) be avoided, and there was more reported strain than in traditional offices (i.e. overstimulation and cognitive overload) (Davis, Leach, & Clegg). Other studies have also shown that employees working in an open-plan office have reduced levels of environmental satisfaction and psychological comfort and have an increased risk for sickness, when compared to employees working in traditional offices (McElroy, & Morrow, 2010; May, Oldham, & Rathert, 2005; Fried, Slowik, Ben-David, & Tiegs, 2001; Danielsson, Chungkham, Wulff & Westerlund, 2014). In line with these findings, a study has shown that after relocating from a traditional office to an open-plan office, employees can become more dissatisfied with the physical office environment, their co-worker relations and their productivity levels (Brennan, Chugh, & Kline, 2002). This decreased satisfaction did not abate after an adjustment period, which suggests that the diminishment in satisfaction was unlikely to be due to the relocation itself (Brennan, Chugh, & Kline). Furthermore, other research has shown that employees in traditional offices reported lower levels of cognitive strain (i.e. psychosocial workload and strain) when compared to employees in open-plan office types (Seddigha, Berntsonb, Danielsona, & Westerlund, 2014).

Cortisol concentrations as a measure of systemic, physical levels of strain

Most research into the effects of the open-plan office design has mainly focused on self-report measures. This overreliance may lead to disadvantages because of limitations of self-report, such as measurement biases (e.g. anchoring effects, time pressure, motivation), accuracy and credibility issues (e.g. consistency seeking, self-enhancement, self-presentation, self-deception) and issues with memory (e.g. recall problems) (Robins, Fraley, & Krueger, 2007;

Patterson et al., 1993). Assessing biological markers as an indication of the experience of strain does not have these disadvantages. A possible biological indicator of strain in individuals is the hormone cortisol (Babisch, 2003). Cortisol can be measured non-intrusively in plasma, urine, saliva and hair (Babisch; Sharpley, McFarlane, & Slominski, 2012).

It is suggested that cortisol can be used to study physiological responses to environmental stressors (Vaernes, Ursin, Darragh, & Lambe, 1982). For example, a study showed that government employees who worked in old workspaces had larger rises in morning cortisol than employees who work in workspaces with improved views and lighting (Thayerd et al., 2010). Another study showed that for healthy industrial workers, urinary levels of cortisol excretion were higher under conditions of chronic noise exposure than under conditions were noise was attenuated with earmuffs (Melamed, & Shelly, 1996). However, it should be noted that there is some inconsistency in the literature regarding the association between cortisol and environmental stressors. A review of 28 studies on cortisol in blood or urine did not find consistent results on the association between psychosocial working environment and cortisol; it reported 11 studies that showed no association, nine that showed a positive association and three that showed a negative association (Hansen, Larsen, Rugulies, Garde, & Knudsen, 2009).

The inconsistencies in the literature on the relationship between environmental stressors and cortisol levels may be explained by individual differences in the appreciation of these stressors. The Social Self-Preservation Theory suggests that not all stressors elicit changes in cortisol activity, but only under specific conditions cortisol levels are influenced (Dickerson, & Kemeny, 2004). The theory proposes that environmental stressors can elicit increases in cortisol activity when there is a threat to the social self-esteem or status of an individual. Social-evaluative threat is most likely to occur when failure or poor performance could lead to negative judgement by others of an important aspect of the self-identity (Dickerson, & Kemeny, 2004). Furthermore, the theory proposes that cortisol activity increases particularly when the stressors are perceived by the participants as uncontrollable (Dickerson, & Kemeny, 2004). Possibly, employees in open-plan offices experience more social-evaluative threat (e.g. due to

performance in the presence of others) and have less control over their work environment (e.g. lack of control over noise, lighting, temperature) than employees in traditional offices. According to the Social Self-Preservation Theory, the employees who appreciate the open-plan office design as a threat to the social self and as uncontrollable would have higher cortisol concentrations than employees who do not appreciate their office design as a threat to the social self and as uncontrollable.

Two non-statistical meta-analytic reviews have shown that assessing hair cortisol is a valid method to determine systemic, physical levels of strain in individuals over a predetermined period (Russell, Koren, Rieder, & Van Uum, 2012; Sharpley et al., 2012). This method has the advantage that, unlike assessing hormonal concentrations in saliva, urine and blood, hormonal levels in hair are not influenced by the circadian and weekly rhythms of hormone excretion (Baum & Grunberg, 1995). However, the measurement of cumulative cortisol concentrations in hair may be limited to sampling over the last six months prior to sample collection, due to a wash-out effect (Sharpley et al., 2012).

There is ample evidence of the association between cortisol concentrations in hair and the experience of strain in individuals. The first experimental animal study that investigated cortisol in hair showed that, after relocation to a new environment, rhesus macaques showed both increased cortisol concentrations and behavioural characteristics of strain (Davenport et al., 2006). In healthy pregnant women, it has been shown that cortisol levels in hair were positively correlated with strain, as measured with the Perceived Stress Scale (Kalra et al., 2007). Similarly, it was shown that hair cortisol concentrations were higher for middle-aged women who reported higher levels of perceived stress (Faresjö, Jullander, Götmalm, & Theodorsson, 2014). For young adults it was shown that individuals who had experienced serious life events, had increased hair cortisol concentrations compared to individuals who did not report experiencing serious life events (Karlén et al., 2011). With regard to work-related strain, a study showed that individuals who had been unemployed for at least one year had both higher levels of hair cortisol concentrations and higher levels of perceived strain than

individuals who were employed (Dettenborn, Tietze, Bruckner, & Kirschbaum, 2010). These studies suggest that hair cortisol concentrations may be a possible indicator of strain in individuals.

Aiding effective office design by improving office ergonomics and functional comfort of employees

To evaluate the effects of the open-plan office design on employees, organisations increasingly take into consideration the interaction between employees and their physical office environment (i.e. office ergonomics) (Duffy, 2000). Several studies show associations between employees' health and aspects of the physical work environment (Milton, Glencross, & Walters, 2000; Veitch & Newsham, 2000). The ergonomic approach to work stress investigates the effects of office ergonomics on employees' 'functional comfort'. Functional comfort is ensured by employees having appropriate office ergonomics, like good lighting, ventilation and spatial layout, ergonomic furniture, visual privacy, thermal comfort and little noise distractions (Vischer, 2007). It is suggested that functionally uncomfortable workplaces fail to support employees in their tasks and activities and cause stress (Vischer, 2007). In line with this, studies have shown that employees tend to judge noise as one of the biggest sources of discomfort in the open-plan office (Rashid & Zimring, 2008; Smith-Jackson & Klein, 2009). Furthermore, cross-sectional studies have shown that occupational noise increases cortisol levels (Sudo et al., 1996; Ising & Braun, 2000; Rai, Singh, Upadhyay, Patil, & Nayar, 1981).

Although studies have shown that there are negative outcomes related to implementing an open-plan office design (Davis et al., 2011; McElroy, & Morrow, 2010; May, Oldham, & Rathert, 2005; Fried et al. 2001; Danielsson et al., 2014), these negative outcomes can potentially be minimized by improving office ergonomics and thus increasing functional comfort of the employees. For instance, a study showed that participants were more fatigued, less motivated, and performed worse on memory tasks in a condition with loud noise as compared to a condition with low noise (Jahnckea, Hyggea, Halina, Greena, & Dimberg, 2011). A similarly designed study showed that participants were more fatigued, less environmentally satisfied, and performed worse on memory tasks in a condition with high intelligible speech, high room

temperature and bad ventilation as compared to a neutral condition (Varjoa et al., 2015). Furthermore, a study that compared two open-plan offices within the same building showed that employee satisfaction increased for employees who had work stations with more privacy, less distractions and proximity to a window (Yildirima, Akalin-Baskayab, & Celebi, 2007). This study also showed that the increase in employee satisfaction compensated for the diminished satisfaction of employees in an open-plan office (Yildirima, Akalin-Baskayab, & Celebi). It was shown that refurbishing an open-plan office design to achieve better thermal conditions, visual and acoustic privacy, furniture ergonomics, interior design, and lower spatial density led to increased environmental satisfaction and job satisfaction (Hongistoa, Haapakangasa, Varjoa, Heleniusb, & Koskelaa, 2016). In conclusion, the studies mentioned in this paragraph show the necessity of appropriate office ergonomics to minimize the potential negative effects of the implementation of the open-plan office design.

Differentiating in employees' job complexity to aid effective office design

It has been suggested that employees are affected differently by the office environment and this may largely depend on the complexity of their job (Vischer, 2005; Charles & Veitch, 2002). It has also been suggested that offices should offer different types of workspaces depending on the complexity of the employees' jobs (Duffy, 2000). This seems to be supported by literature, showing that employees performed better on complex tasks in enclosed offices, while simple tasks were performed better with others present (Block & Stokes, 1989). Likewise, managers were more satisfied in enclosed offices, while clerical colleagues preferred open-plan offices (Carlopio & Gardner, 1992). It was also found that employees reported the least amount of distractions and cognitive stress (psychosocial workload and strain) in cell offices as compared to all other office types (Seddigha et al., 2014). This seems to be in line with a later study that showed that employees in open-plan offices reported more problems with employee health and performance as the need for concentration increased. Contrarily, employees in cell offices reported a steady level of employee health and performance despite increased need for concentration (Seddigh, 2015).

Current study; aims and hypotheses

To my knowledge, research thus far has not yet examined cortisol concentrations in hair as a possible indicator of strain in employees working in an open-plan versus traditional office. The current study investigated the effect of office design on cortisol concentrations in 131 employees. Hair strands were cut to assess cortisol concentrations and functional comfort and job complexity were assessed with questionnaires. Firstly, I hypothesized that cortisol concentrations were higher in employees who work in open-plan offices than in employees who work in traditional offices. Secondly, I hypothesized that the relationship between office design and cortisol concentrations was moderated by functional comfort. I expected that for low levels of functional comfort, cortisol concentrations were higher in employees who work in open-plan offices than in employees who work in traditional offices. However, I expected that for high levels of functional comfort, cortisol concentrations were not different between employees in open-plan and traditional offices. Lastly, I hypothesized that the relationship between office design and cortisol concentrations was moderated by job complexity. I expected that for high levels of job complexity, cortisol concentrations were higher for employees who work in open-plan offices than for employees who work in traditional offices. For low levels of job complexity, I expected that cortisol concentrations were lower for employees who work in open-plan offices than for employees who work in traditional offices.

Method

Participants

The current study included 131 employees from multiple companies with office designs that either met the requirements of the open-plan office condition or traditional office condition. In the current study seven office types, as defined by Danielsson and Bodin (2008), were used to categorise the office environments of the participants as either open-plan *(n* = 64) or traditional (*n* = 67). Participants were included when, at the time of the appointment, they were actively employed in a white-collar, desk-job, function, were between 18 and 65 years of age and were Dutch speaking. Included participants were however excluded when they had been employed for a period shorter

than three months (*n* = 3), worked less than 20 hours per week at the office (excluding hours worked from home, *n* = 25), had been on vacation- (*n* = 1) or sick- (*n* = 3) leave for more than three weeks, had hair shorter than three centimetres, had a depression- or anxiety disorder, used prescribed anxiety- or depression (*n* = 4) medication, were pregnant (*n* = 1), consumed an average of more than two glasses of alcohol a day (*n* = 4) and consumed drugs daily. The final dataset (*n* = 131) existed of 31 men and 100 women with an average age of 37.4 (*SD* = 11.8, Min = 18.0, Max = 64.0). The men had an average age of 36.7 (*SD* = 11.6) and the women of 37.6 (*SD* = 11.9). The open-plan office condition consisted of 18 men and 64 women and the traditional office condition consisted of 13 men and 54 women.

Procedure

The recruitment of the participants was done in the period March until June 2015, by identifying companies that fit the criteria for this study and approaching them via email, telephone or a visit. To this end a leaflet was made, informing the companies of the study. With permission from the companies, employees were approached for voluntary, uncompensated, participation via email. When permission was granted appointments were made at the companies or at the participants' homes. During the appointments the participants were verbally informed by one of the researchers about the study and the procedures. They were asked to sign a written informed consent and were appointed a participant code. Hereafter hair samples were taken and labelled with the participant code. After the hair sampling, participants were asked to fill out a form about hair products or hair dye they might have used. Lastly, participants were asked to fill out an online survey within two weeks of the appointment. Participants were sent a link to the survey via email, within a day of the appointment. A reminder was given via email two weeks after the appointment when participants had not filled out the online survey. The survey asked participants to state their assigned participant code at the start of the survey and to choose the office type most closely resembling their own. Two kinds of traditional offices were given, namely employees having an individual space or a shared space with one or two others. The open-plan offices were described as either a small, medium, large, flex or combi office type (see Appendix 1). The survey then asked participants respectively about

their demographics, functional comfort and job complexity. Lastly, participants were asked whether they wanted a debriefing about their personal hair cortisol concentration.

Cortisol concentrations in hair

Cortisol concentrations were determined from hair segments 3 cm closest to the scalp, which represents hair grown over the last 3 months prior to sampling, when assuming an average hair growth of 1 cm per month (Wennig, 2000). Hair sampling was done according to the instructions of the biological psychology at the Technical University of Dresden (Kirschbaum, 2015). Three hair strands were cut with scissors as close as possible from the scalp from a posterior vertex position and tied with a thread. Hair strands were placed in aluminium foils that were put in envelopes. The envelopes were placed in a specially prepared box and sent to the laboratory of biological psychology at the Technical University of Dresden (Germany) for analyses. Cumulative cortisol concentrations were determined from the hair samples with a liquid chromatography tandem mass spectrometry method (LC-MS/MS) (Gao et al., 2013). Intra- and inter-assay coefficients of variation are between 3.7 and 9.1%. The limits of quantification (LOQ) are below (or equal to) 0.1 pg/mg. After a check for normality and outliers, it was shown that 3 participants had cortisol concentrations that could be considered outliers (z-score > 3) and these participants were removed from the dataset. It was shown that the variable for cortisol concentrations (M = 6.3, SD = 6.6, Min = .4, Max = 45.9) was not normally distributed (see Table A1). After logarithmic transformation de variable appeared normally distributed and therefore the transformed variable was used during analyses (see Table A1).

Self-report measures

Functional comfort of employees was measured with the Building-In-Use (BIU) Assessment, which aims to access office ergonomics by measuring the functional comfort of building occupants. The BIU is a short questionnaire composed of 30 items about office ergonomics on which participants rate, on a five-point scale, how comfortable they are, ranging from 1 (*uncomfortable*) to 5 (*comfortable*). The questionnaire is made up of 7 scales and has good reliability and validity (Vischer & Fischer, 2005). In the current study, the Cronbach's alpha was .918. The Air Quality scale has 3 items (Cronbach's alpha = .890, e.g. *Air freshness*), Thermal Comfort has 4 items (Cronbach's

alpha = .782, e.g. *Temperature comfort*), Spatial Comfort has 8 items (Cronbach's alpha = .851, e.g. *Furniture arrangement in your workspace*), Privacy has 3 items (Cronbach's alpha = .871, e.g. *Telephone privacy at your desk*), Lighting Quality has 4 items (Cronbach's alpha = .836, e.g. *How bright lights are*), Office Noise Control has 3 items (Cronbach's alpha = .901, e.g. *Specific office noises; voices and equipment*) and Building Noise Control has 3 items (Cronbach's alpha = .616, e.g. *Noise from the air systems*). Also, two general items are given about functional comfort and overall satisfaction (i.e. *Please rate whether or not this space helps you do your work* and *How would you rate your overall satisfaction with this building*?). Total scores were calculated for the BIU, by scoring the items and adding the scores. After a check for normality, it was shown that the variable (M = 109.5, SD = 18.0, Min = 53.0, Max = 152.0) was normally distributed (see Table A1). For the current study the questionnaire was translated to Dutch twice and combined to a single translation by two researchers from this study. This translation was translated back to English by two different researchers from this study, who also came to a single combined translation. The Dutch and English translations were compared by all researchers and final changes were made to the Dutch translation, to come to a valid Dutch translation of the BIU (see Appendix 2).

Job complexity was measured using part of a scale of the Work Design Questionnaire (WDQ). The WDQ was developed to investigate work- and job design and has good reliability and validity (Morgeson & Humphre, 2006). The WDQ has 87 items and uses a five-point scale, ranging from 1 (*strongly disagree*) to 5 (*strongly agree*). It is made up of 4 scales, namely Knowledge Characteristic, Task Characteristics, Social Characteristics and Work Context. For the current study, items of 4 subscales of the Knowledge Characteristic scale were used to measure job complexity, i.e.; Job Complexity, which has 4 items (Cronbach's alpha = .734, e.g. *The job requires that I only do one task or activity at a time*), Information Processing which has 4 items *(*Cronbach's alpha = .890, e.g. *The job requires that I engage in a large amount of thinking*), Problem Solving which has 4 items (Cronbach's alpha = .889, e.g. *The job often involves dealing with problems that I have not met before*) and Skill Variety which also has 4 items (Cronbach's alpha = .890, e.g. *The job requires me to use a number of complex or high-level skills*). Job complexity scores were calculated by (reverse) scoring and adding

the items of the selected four subscales of the Knowledge Characteristics scale. The Cronbach's alpha for the total of these 4 subscales was .818. After a normality check, it was shown that the variable (*M* = 61.7, *SD* = 8.9, Min = 26.0, Max = 80.0) was normally distributed (see Table A1). The part of the questionnaire used in the current study was translated to Dutch in the same way the BIU was translated to Dutch (see Appendix 3).

Data analyses

Analyses were done using Statistical Package for Social Scientists, standard version 23.0 (SPSS 23.0; IBM SPSS Statistics). All moderation analyses were done with PROCESS (Hayes, 2013), an add-on program in SPSS. *P*-values of < .05 (two-sided) were considered statistically significant. Sex and age were added as covariates for all analyses.

Violations of the assumption of normality were assessed for all continuous variables with z-Skewness, z-Kurtosis and Kolmogorov-Smirnov statistics. Variables were standardized to check for outliers. To test for homogeneity of variance, Levene's Statistic was assessed with ANCOVA (see Table A2). Interactions between office type and the covariates were also assessed with ANCOVA, to test for homogeneity of regression (see Table A3). There were no violations of the assumptions. Because sex and age did not interact with office design, analyses were done without interaction terms.

Several independent t-tests were performed to assess baseline differences in cortisol concentrations between the open-plan and the traditional office condition for functional comfort, job complexity and age. A Pearson Chi-square test was performed to assess a baseline difference in the distribution of men and women across office type. There were no baseline differences in sex, age or job complexity between the open-plan and the traditional office condition (see Table 1). However, there was a baseline difference for functional comfort of employees between the open-plan and traditional office condition (see Table 1).

Table 1

Analyses to check for baseline differences across office type for the variables used in this study

Variable	*Office-design*	*n=131*	*M*	*SD*	*Min*	*Max*	*t*	*df*	*sign. (2-sided)*
Sex	Open-plan	57	-	-	-	-	1.378[a]	1	.240
	Traditional	63	-	-	-	-			
Age	Open-plan	57	36.8	11.7	18.0	62.0	.581	129	.562
	Traditional	63	38.0	12.0	22.0	64.0			
WDQ	Open-plan	57	61.3	9.0	26.0	80.0	.525	129	.601
	Traditional	63	62.1	8.9	33.0	74.0			
BIU*	Open-plan	57	104.8	16.3	66.0	152.0	3.015	129	.003
	Traditional	63	114.0	18.5	53.0	147.0			

[a] Parameter for variable calculated with Pearson Chi-Square test
* $p < .05$

Preliminary ANCOVA analyses were done to investigate the relationships between functional comfort, job complexity and cortisol concentrations. Firstly, functional comfort was entered as independent variable and cortisol concentrations as dependent variable. Secondly, job complexity was entered as independent variable and cortisol concentrations as dependent variable. Furthermore, preliminary ANCOVA analysis was done to investigate the relationship between office type and functional comfort. Office type was entered as independent variable and functional comfort as dependent variable. Sex and age were entered as covariates for all preliminary analyses.

To investigate whether cortisol concentrations are higher for employees who work in an open-plan office than for employees who work in a traditional office, ANCOVA analysis was performed. Office design was entered as independent variable, cortisol concentrations as dependent variable and sex and age as covariates.

To test for an interaction effect between office type and functional comfort on cortisol concentrations the variables were entered in PROCESS. Office type was entered as independent variable, cortisol concentrations as dependent variable and functional comfort as moderator. Sex and age were added as covariates. To explore the interaction effect, simple slopes for the conditional effect of office type on cortisol concentrations were investigated at one SD above and below the mean of functional comfort. To test for an interaction effect between office type and job complexity on cortisol concentrations the variables were also entered in PROCESS. Office type was entered as

independent variable, cortisol concentrations as dependent variable, job complexity as moderator and sex and age as covariates. To explore the interaction effect, simple slopes for the conditional effect of office type on cortisol concentrations were investigated at one SD above and below the mean of job complexity.

Results

Preliminary analyses

Results from the ANCOVA's showed that functional comfort ($F(1,129) = .000$, $p = .991$, partial $\eta^2 = .001$) and job complexity ($F(1,129) = .419$, $p = .519$, partial $\eta^2 = .057$) were not related to cortisol concentrations. However, results showed that employees reported different levels of functional comfort between the open-plan and the traditional office condition ($F(1,127) = 10.080$, $p = .002$, partial $\eta^2 = .074$). Functional comfort was lower for employees in open-plan offices ($M = 104.8$, $SD = 16.3$) than for employees in traditional offices ($M = 114.0$, $SD = 18.5$). To investigate the office ergonomics for which functional comfort was lower in the open-plan offices compared to the traditional offices, post-hoc ANCOVA analyses were performed for all subscales of functional comfort. The subscales 'Thermal comfort' ($F(1,127) = 8.325$, $p = .005$, partial $\eta^2 = .062$), 'Air quality' ($F(1,127) = 11.397$, $p = .001$, partial $\eta^2 = .082$), 'Office noise' ($F(1,127) = 13.755$, $p = .000$, partial $\eta^2 = .098$), and 'Privacy' ($F(1,127) = 11.053$, $p = .001$, partial $\eta^2 = .080$) were related to office design. However, the subscales 'Building noise' ($F(1,127) = 3.088$, $p = .081$, partial $\eta^2 = .024$), 'Spatial comfort' ($F(1,127) = .080$, $p = .778$, partial $\eta^2 = .001$), 'Lighting comfort' ($F(1,127) = 2.093$, $p = .150$, partial $\eta^2 = .016$), and 'General comfort' ($F(1,127) = 2.127$, $p = .147$, partial $\eta^2 = .016$) were not related to office design.

Office design

Results from the ANCOVA showed that cortisol concentrations were not different between employees in the open-plan offices and employees in the traditional offices ($F(1,127) = .013$, $p = .909$, partial $\eta^2 = .000$). However, results showed that the covariate age was related to cortisol concentrations ($F(1,127) = 4.275$, $p = .041$, partial $\eta^2 = .033$). Post-hoc regression analysis showed that higher cortisol concentrations were associated with older age ($\beta = .183$, $t(129) = 2.114$, $p = .036$).

The ANCOVA also showed that men and women did not differ in their cortisol concentrations ($F(1,127) = .556$, $p = .457$, partial $\eta^2 = .004$).

Functional comfort and office design

Results from the moderation analysis showed that there was a marginally significant interaction effect[1] between office type and functional comfort on cortisol concentrations ($b = .006$, $se = .003$, $t(125) = 1.718$, $p = .088$) (see Figure 1). However, simple slope analyses showed that for participants who reported low levels of functional comfort (-1SD), cortisol concentrations were not different between the open-plan office condition and the traditional office condition ($b = -.111$, $se = .086$, $t(125) = -1.300$, $p = .197$. For participants who reported high levels of functional comfort (+1SD), cortisol concentrations were also not different between the open-plan office condition and the traditional office condition ($b = .1024$, $se = .090$, $t(125) = 1.144$, $p = .255$). Furthermore, the moderation analysis showed that cortisol concentrations were marginally different between employees in the open-plan offices and the traditional offices ($b = -.653$, $se = .380$, $t(125) = -1.719$, $p = .088$). Results showed that cortisol concentrations were marginally lower for employees who reported higher levels of functional comfort ($b = -.015$, $se = .009$, $t(125) = -1.711$, $p = .090$).

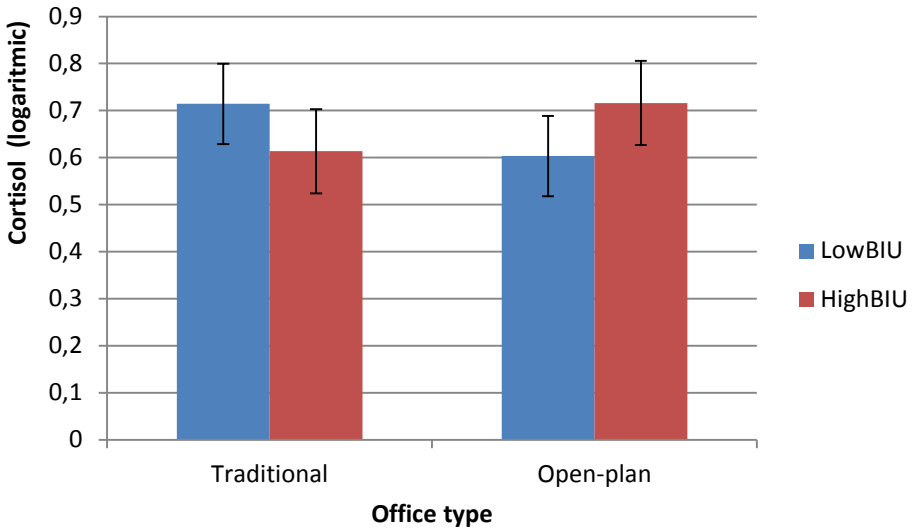

Figure 1. The relationship between office type, functional comfort (BIU) and cortisol concentrations

[1] When not controlled for sex and age, $b = .005$, $se = .004$, $t(125) = 1.511$, $p = .133$

Job complexity and office design

Results from the moderation analysis showed that there was no significant interaction effect between office type and job complexity on cortisol concentrations (b = .002, se = .007, $t(125)$ = .275, p = .784) (see Figure 2). Simple slope analysis showed that for participants who reported low levels of job complexity (-1SD), cortisol concentrations were not different between the open-plan office condition and the traditional office condition (b = -.020, se = .085, $t(125)$ = -.237, p = .813). For participants who reported high levels of job complexity (+1SD), cortisol concentrations were also not different between the open-plan office condition and the traditional office condition (b = .013, se = .085, $t(125)$ = .153, p = .879). Furthermore, the moderation analysis showed that cortisol concentrations were not different between employees in the open-plan and traditional offices (b = -.118, se = .420, $t(125)$ = -.281, p = .778). Results showed that functional comfort was not related to cortisol concentrations (b = -.002, se = .017, $t(125)$ = -.104, p = .918).

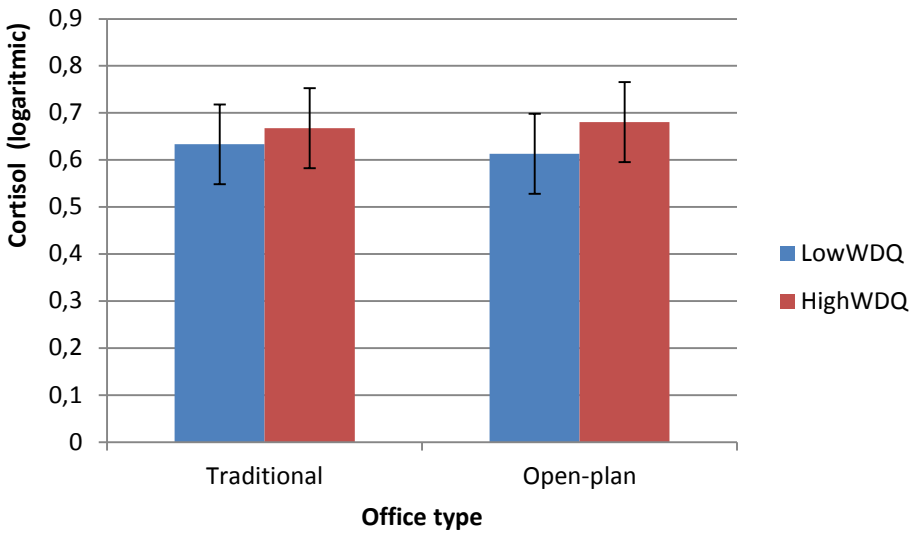

Figure 2. The relationship between office type, job complexity (WDQ) and cortisol concentrations

Discussion

The current study was not able to detect a difference in cortisol concentrations in hair of employees working in open-plan versus traditional offices. Although studies showed associations between office design and the experience of strain (Davis et al., 2011; Seddigha, Berntsonb, Danielsona, & Westerlund, 2014) and associations between the experience of strain and cortisol concentrations (Davenport et al., 2006; Kalra et al., 2007; Faresjö, Jullander, Götmalm, & Theodorsson, 2014; Karlén et al., 2011), there is inconsistent literature on the direct relationship between psychosocial working environment and cortisol levels (Hansen, Larsen, Rugulies, Garde, & Knudsen, 2009). The inconsistency in findings might be explained by the different work-environmental stressors that these studies investigated (e.g. job demands, organisational changes, leadership, social support, job satisfaction, shift-work). Studies show that not all environmental stressors are equally associated with higher cortisol levels (Dickerson, & Kemeny, 2004). The absence of a relationship between office design and cortisol levels of employees could therefore firstly be explained by the possibility that office design is not directly related to cortisol concentrations in hair.

Secondly, the absence of a direct relationship between office design and cortisol concentrations could be explained by the possibility that cortisol concentrations in hair are not representative of the experience of strain. Several studies did not find a relationship between hair cortisol concentrations and measures of strain in individuals (Van Uum et al., 2008; Dettenborn, Tietze, Bruckner, & Kirschbaum, 2010; Stalder et al., 2010; Dowlati et al., 2010). For example, a study showed that cortisol levels in hair were positively correlated with strain in pregnant women (Kalra, et al., 2007). However, this result was not reproduced in a similar, larger sample (Kramer et al., 2009). Likewise, a review, of 208 studies, reported several studies that showed increases in strain in response to acute environmental stressors (Dickerson, & Kemeny, 2004). However, the acute environmental stressors in these studies were not able to activate the HPA-axis. Similar to these studies, the results of the current study showed that employees working in an open-plan office reported lower levels of functional comfort compared

to employees working in a traditional office. However, employees working in an open-plan office did not show higher cortisol concentrations then employees working in a traditional office. These results may indicate that the experience of strain due to office design is not sufficient as stressor to elicit cortisol responses. Research should expand on the association between the experience of strain in employees and cortisol in hair to understand individual differences in cortisol responses to chronic work-environmental stressors.

Lastly, the absence of relationship between office design and cortisol concentrations in hair can be explained by the Social Self-Preservation Theory (Dickerson, & Kemeny, 2004). It is possible that office design as stressor did not meet the conditions, suggested by the theory, necessary to elicit differences in cortisol concentrations. A review showed that not all environmental stressors equivalently lead to heightened cortisol responses (Dickerson, & Kemeny, 2004). The review showed that only stressors with certain characteristics were associated with higher cortisol concentrations. In line with the Social Self-Preservation Theory, the review showed that cortisol responses were higher when stressors induced social-evaluative threat (Dickerson, & Kemeny, 2004). Furthermore, stressors that were not under the control of the participants and subsequently threatened a specific goal towards a desired outcome were related to higher cortisol concentrations (Dickerson, & Kemeny, 2004). For some employees the open-plan office design might have met the conditions proposed by the Social Self-Preservation Theory, whereas for other employees the open-plan office design might not have met these conditions. The employees who did not experience the open-plan office design as a threat to the social self-esteem and as uncontrollable would not have had higher cortisol concentrations. The different appreciation by employees of the open-plan office design as stressor might partially explain the absence of a relationship between office design and cortisol concentrations in the current study. Research should further investigate cortisol concentrations in hair and the association with individual differences in the appreciation of the open-plan office design.

The current study did not show a moderating effect of functional comfort on the relationship between office design and cortisol concentrations in hair. Results did show a

marginally significant interaction effect of functional comfort and office type on cortisol concentrations. However, results also showed that there was no relationship between office type and cortisol concentrations for participants with scores of one SD below and above the mean of functional comfort. Moreover, it should be noted that when sex and age where not added to the analyses as covariates, this trend towards moderation was non-significant. That the current study did not find a moderating effect of functional comfort could be explained by the possibility that a negative appraisal of functional comfort by employees is not a sufficient stressor to elicit higher cortisol concentrations. Other studies likewise showed no relationship between negative affect in response to psychosocial and environmental stressors (e.g. cognitive tasks, public speaking, noise exposure) and changes in cortisol levels (Dickerson, & Kemeny, 2004).

Finally, the current study did not show a moderating effect of job complexity on the relationship between office design and cortisol concentrations. These results are not in line with other studies that showed interaction effects between office design and measures of job complexity on work-related outcomes (Duffy, 2000; Block & Stokes, 1989; Carlopio & Gardner, 1992; Seddigha et al., 2014). The differing results might partially be explained by the different operationalisations of job complexity between these studies. For example, a study showed an interaction effect of need for concentration and office design on the amount of distraction and strain in employees (Seddigha et al., 2014). Another study showed an interaction effect of job type (i.e. managerial or clerical) and office design on environmental satisfaction of employees (Carlopio & Gardner, 1992). Furthermore, a study showed an interaction effect of task complexity and office type (i.e. private versus non-private) on environmental satisfaction of employees (Block & Stokes, 1989). These studies used single indicators (i.e. job type, need for concentration, task complexity) to operationalize job complexity. Conversely, the current study investigated a composed score of several aspects of job complexity; namely self-reported job complexity, self-reported amount of information processing, need for problem solving and needed skills. The inconsistencies in results may be explained, because single indicators are

thought to represent underlying constructs less accurate than composite scores of several scales measuring the same underlying construct (Gerbing, & Anderson, 1988).

In the current study it was expected that cortisol concentrations in hair of employees would reflect strain as a result of office design. However, the relationship between office design and cortisol in hair might have been confounded by other stressors in the lives of employees (e.g. death or sickness of close relatives or friends, divorce). Cortisol in hair gives an indication of cortisol concentrations of an individual over a predetermined period of time, while strain due to office design reflects only partially the time period covered by hair cortisol (Staufenbiel et al., 2012; Steinisch et al., 2014). Other stressors in the lives of employees, that were present in the time-period covered by the hair cortisol measurement, could also have caused strain and consequently have effected cortisol concentrations in hair. For example, a study has shown that individuals who had experienced serious life events had increased hair cortisol concentrations, compared to individuals who did not report experiencing serious life events (Karlén et al., 2011). Further research should consider the influence of these confounding stressors in the lives of employees, because they might suppress the association between office design and hair cortisol.

Furthermore, in the current study there were several methodological problems that could have led to random error. Firstly, studies showed that there might be an impact of hair pigmentation, cosmetic treatments (i.e. hair dyeing) and personal hygiene (e.g. frequency of hair washing) on cortisol concentrations (Bennett, & Hayssen, 2010; Sauve et al., 2007; Hamel et al., 2011), possibly leading to distortion of the measurements of cortisol concentrations. Secondly, the current study included employees from a range of different companies, which led to differences, other than office type, in the working environment of the employees (e.g. differences in organisational structure and culture, style of management or company size). Although the inclusion of many different companies added to the generalizability of the results of this study, these differences between the companies might have reduced the power to detect an effect. Lastly, the subjective assessment by employees of functional comfort may have led to variability in functional comfort scores that was not caused by actual differences in the office ergonomics.

For example, anchoring effects would have led employees to judge the functional comfort of the office ergonomics compared with their previous office environments (Robins, Fraley, & Krueger, 2007). For some employees this would have meant that their functional comfort scores were not accurate representations of their office ergonomics. Employees from a previous work environment with bad office ergonomics would have judged the functional comfort of their current office ergonomics higher, whereas employees from a previous work environment with good office ergonomics would have judged the functional comfort of their current office ergonomics lower.

In conclusion, the results from the study suggest a possibility that employees in open-plan offices do not experience more strain than employees in traditional offices. However, these results are preliminary and the possibility of a relationship between office design and cortisol concentrations cannot be completely refuted. Further research on cortisol concentrations in hair of employees as an indicator of strain due to office design is needed, before valid conclusions can be drawn. It would be interesting for further, exploratory research to investigate individual differences in the appreciation of the open-plan office design and the specific conditions under which the open-plan office design might elicit changes in cortisol levels. For example, it might be interesting to investigate whether certain personality traits are related to negative appraisal of the open-plan office design and to higher cortisol concentrations. Additional research is needed on work-related stressors and their conditional relationship with subjective and physiological strain in employees. With this knowledge companies can ensure effective implementation of the open-plan office design and aid successful redesign from traditional offices to open-plan offices, while causing minimal strain on the employees who work in the offices.

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Table A1

Tests for normality assumptions

Variable	*z-Skewness*	*z-Kurtosis*	*Kolmogorov-Smirnov*
Age*	.556	-.802	.157
WDQ*	-.843	1.862	.064
BIU*	-.258	.070	.067
Cortisol	3.074	11.988	.255
Cortisol Logarithmic*	.364	.849	.093

Note. Normal distribution when: z-Skewness < 1.96, z-Kurtosis < 1.96, Kolmogorov-Smirnov > .05
*Normally distributed variable chosen for analyses

Table A2

Preliminary ANCOVA for test of assumption of homogeneity of variance

Variable	*Levene's Statistic*	*df1*	*df2*	*sign.*
Office type	.025	1	129	.875
Office type corrected for sex	.004	1	129	.952
Office type corrected for age	.041	1	129	.839

* $p < .05$

Table A3

Preliminary ANCOVA for test of assumption of homogeneity of regression

Interaction term	*F*	*df1*	*df2*	*sign.*
Office type x Sex	.014	1	127	.905
Office type x Age	2.997	1	127	.086

* $p < .05$

Appendix 1[2]

Traditional office	**Characteristics**
1. Cell office	Single room office
Architectural features:	Rooms along the façade of the building offering every room access to a window; consequently, long corridors that connect small offices to each other distinguish the plan layout.
Functional features:	Most of the amenities are found within the room. The office work is characterized by independence and is of concentrated nature.
2. Shared room office	2 to 3 people share a single room
Architectural features:	Workstations are often freely arranged in the room, sometimes with screens or other divisional elements to provide privacy at the individual workstation. Roommates share a window or windows.
Functional features:	Most of the amenities are normally found outside the shared room office. The shared room office for team-based work often has work facilities in the room. People sharing a room tend to have similar work assignments. The team-based shared room office is characterized by interactive project work.
Open plan offices	**Characteristics**
3. Small open plan	4 to 9 persons/room
4. Medium-sized open plan	10 to 24 persons/room
5. Large open plan	> 24 persons/room.

[2] Table from: Danielsson and Bodin (2008)

Architectural features:	A shared room with workstations that are often freely arranged in groups. Screens between different workstations reduce noise and provide some privacy at the individual workstation. There are no individual windows.
Functional features:	Sometimes amenities can be found at the individual workstation. Employees mainly work individually, with routine-based work and low levels of interaction.
6. Flex office	No individual workstation
Architectural features:	Often an open plan office, though not a defining feature, the flex office includes “backup spaces” that enable concentrated work, private phone calls, meetings, etc. Dimensioned for < 70% of the workforce to be present simultaneously; based on expected illness, work outside the office, etc.
Functional features:	Depends on good information technology to enable employees to choose workstation freely—in the office as well as outside the office. Shared amenities in common spaces. No ability to “personalize” the workstation.
7. Combi office	Employees spend > 20% of their time at workstations other than their “own,” team-based work.
Architectural features:	No strict spatial definition, but the combi office does contain individual workstations in either an individual room or an open plan office. There is access to “backup spaces” that enable work activities that cannot take place at the personal workstation, such as specific work functions, full-time project rooms, meeting rooms, etc.

Functional features:	Teamwork and the sharing of common amenities define this office type. The office work is independent in its character, as well as interactive with colleagues in teamwork. The teams move around in the office on an "as-needed basis" to take advantage of a wide range of common facilities. Shared work facilities in common spaces.

Appendix 2

Building-In-Use (BIU) Assessment questionnaire

Datum _____

Op de volgende pagina's vind je een aantal eenvoudige vragen over je werkomgeving. De antwoordmogelijkheden hebben een schaal van 1 tot en met 5, waarbij 1 oncomfortabel en 5 comfortabel betekent. 3 is neutraal. Geeft u a.u.b. één antwoord per vraag. Beantwoord alstublieft elke vraag en overleg niet met collega's totdat u de vragenlijsten heeft voltooid.

Temperatuur comfort:

1	2	3	4	5
Oncomfortabel				Comfortabel

Hoe koud het wordt:

1	2	3	4	5
Oncomfortabel				Comfortabel

Hoe warm het wordt:

1	2	3	4	5
Oncomfortabel				Comfortabel

Temperatuur veranderingen:

1	2	3	4	5
Te vaak				Constant

Ventilatie comfort:

1	2	3	4	5
Oncomfortabel				Comfortabel

Luchtfrisheid:

1	2	3	4	5
Muffe lucht				Frisse lucht

Luchtstroom:

1	2	3	4	5
Stil				Goede circulatie

Afleiding door geluid:

1	2	3	4	5
Te afleidend				Comfortabel

Hoeveelheid achtergrondgeluiden:

1	2	3	4	5
Teveel geluid				Comfortabel

Specifieke geluiden (stemmen, gereedschappen):

1	2	3	4	5
Teveel geluid				Comfortabel

Geluid van de ventilatiesystemen:

1	2	3	4	5
Teveel geluid				Comfortabel

Geluid van de lichten:

1	2	3	4	5
Teveel geluid				Comfortabel

Geluid van buiten het gebouw:

1	2	3	4	5
Teveel geluid				Comfortabel

Meubelcomfort in jouw kantoor/werkplek:

1	2	3	4	5
Oncomfortabel				Comfortabel

Grootte van jouw kantoor/werkplek:

1	2	3	4	5
Oncomfortabel				Comfortabel

Opslagruimte in jouw kantoor/werkplek:

1	2	3	4	5
Oncomfortabel				Comfortabel

Toegang tot gereedschappen/materialen:

1	2	3	4	5
Oncomfortabel				Comfortabel

Plek voor persoonlijke opslag:

1	2	3	4	5
Inadequaat				Adequaat

Informele ontmoetingsplaatsen:

1	2	3	4	5
Inadequaat				Adequaat

Ruimte voor samenwerking met collega's:

1	2	3	4	5
Inadequaat				Adequaat

Ruimte voor ontmoetingen met bezoekers:

1	2	3	4	5
Inadequaat				Adequaat

Visuele privacy:

1	2	3	4	5
Oncomfortabel				Comfortabel

Privacy om een gesprek te voeren:

1	*2*	*3*	*4*	*5*
Oncomfortabel				Comfortabel

Privacy om te telefoneren:

1	2	3	4	5
Oncomfortabel				Comfortabel

Elektrische verlichting comfort:

1	2	3	4	5
Oncomfortabel				Comfortabel

Hoe fel het licht wordt:

1	2	3	4	5
Oncomfortabel				Comfortabel

Schittering van de lichten:

1	2	3	4	5
Oncomfortabel				Geen

Toegang tot daglicht:

1	2	3	4	5
Inadequaat				Adequaat

In het algemeen, zou je zeggen dat de werkplek je helpt of hindert bij het uitvoeren van je werkzaamheden?

1	2	3	4	5
Moeilijker				Makkelijker

In het algemeen, hoe tevreden ben je met de fysieke omgeving waarin je werkt?

1	2	3	4	5
Ontevreden				Tevreden

Appendix 3

(partial) Work Design Questionnaire (WDQ)

Knowledge Characteristics:

- **Werk complexiteit**

Het werk vereist dat ik één taak of activiteit tegelijk doe (reverse)

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

De werktaken zijn eenvoudig en ongecompliceerd (reverse)

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk bestaat uit relatief ongecompliceerde taken (reverse)

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk bestaat uit het doen van relatief eenvoudige taken (reverse)

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

- **Informatie verwerking**

Het werk vereist dat ik toezicht houd op een heleboel informatie

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist dat ik veel moet nadenken

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist dat ik zicht houd op meer dan één ding tegelijk

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist dat ik veel informatie analyseer

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

- **Probleem oplossen**

Het werk bestaat uit het oplossen van problemen die geen duidelijk juist antwoord hebben

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist dat ik creatief ben

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk bestaat vaak uit het omgaan met problemen die ik nog niet eerder ben tegengekomen

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist unieke ideeën of oplossingen voor problemen

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

- **Vaardigheden variatie**

Het werk vereist een variëteit aan vaardigheden

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist dat ik gebruik maak van een variëteit aan vaardigheden om mijn werk te voltooien

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist dat ik een aantal complexe of hogere-level vaardigheden gebruik

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*

Het werk vereist het gebruik van meerdere vaardigheden

1 2 3 4 5

Helemaal mee oneens *helemaal mee eens*