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The association between visual ergonomics and visual performance

Are visual well-being and health a mediator in this association or not

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Abstract

The purpose of this study was to investigate if there is an association between perceived *visual ergonomics work conditions, visual well-being and health* and *visual performance* at the Swedish Tax Agency by a digitalized questionnaire. The questionnaire was sent to ninety-four respondents. Out of them, eighty-six participants, 54 women (63%) and 31 men (36 %) answered the questionnaire. Multiple regressions analysis investigated the association between visual ergonomics work conditions and visual performance, with and without visual well-being and health used as a mediator. Screen time outside of work was used as a covariate in all analysis. Descriptive results reported visual ergonomics (M=8.86, SD=2.06), visual well-being and health (M=10.40, SD=11.02) and visual performance (M=15.72, SD=9.51). Results from the multiple regression analysis displayed a significant association between visual ergonomics and visual well-being and health (r^2=.098, β=.254, p<0.05) and between visual ergonomics and self-rated visual performance (r^2=.304, β=.307, p<0.01). When visual well-being and health was used as a mediator, the association between visual ergonomics and self-rated visual performance remained the same (r^2=.310, β=.295, p<0.01). Conclusion drawn from this study was that a reduction in visual performance seemed to occur in isolation from any impact of visual well-being and health.

Keywords: Ergonomics, performance, well-being, multiple regression, mediator analysis

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Sammanfattning

Tidigare forskning visar att det finns en etablerad relation mellan visuell ergonomi och anställdas välmående samt att det finns en etablerad relation mellan visuellt välmående och prestation. Forskning har dock ännu inte har kunnat skildra om och i sådana fall hur den visuella ergonomin påverkar den anställdes visuella prestation. Eftersom det fanns en forskningslucka och en brist på kunskap inom denna specifika forskningsfråga, var det motiverat att utforska dessa fenomen på en djupare plan.

Syftet med föreliggande studie var att undersöka associationen mellan självskattade *visuella ergonomiska arbetsförhållanden*, *subjektivt visuellt välbefinnande* och *självskattad visuell prestation* på Skatteverkets kontor i en mellanstor stad i Sverige. För att besvara syftet användes följande specifika frågeställningar: ”I vilken utsträckning är de visuella ergonomiska arbetsförhållandena associerade med subjektivt välbefinnande?”, ”I vilken utsträckning är de visuella ergonomiska arbetsförhållandena associerade med självskattad visuell prestation?” samt ”I vilken utsträckning är de visuella ergonomiska arbetsförhållandena associerade med självskattad visuell prestation, när subjektivt visuellt välbefinnande fungerar som en medieringsvariabel?”. En elektronisk enkät skickades ut till 94 medarbetare där de fick skatta deras upplevda visuella ergonomiska arbetsförhållanden, deras visuella välmående och deras visuella prestation. För att besvara frågeställningarna användes multipla regressioner samt en medieringsanalys. Skrämtid utanför arbete användes som kovariat i samtliga analyser.

Åttiosex av nittiofyra respondenter besvarade enkäten och den deskriptiva statistiken visade visuell ergonomi (M=8.86, SD=2.06), visuellt välbefinnande (M=10.40, SD=11.02) och visuell prestation (M=15.72, SD=9.51). Vidare visade det statistiska huvudresultatet att det fanns en signifikant association mellan visuell ergonomi och visuell välmående (r^2=.098, β=.254, p<0.05) och mellan visuell ergonomi och självskattad prestation (r^2=.304, β=.307, p<0.01). När associationen medierades av visuell välmående och hälsa var förhållandet detsamma (r^2=.310, β=.295, p<0.01). Slutsatser som togs utifrån studien var att visuell prestation kan försämras på grund av dålig visuell ergonomi, oberoende av ett visuellt välbefinnande. Om det fanns något annat fenomen än visuellt välbefinnande som medierar detta förhållande, ligger det bortom modellen i denna studie.

Nyckelord: Ergonomi, prestation, välmående, multipel regression, medieringsanalys

Preface

First, I would like to acknowledge and thank my supervisor Hans Richter for support, encouragement and interesting discussions during this year. Thanks to also my sample in this study, for taking their time to participate in the study. A final and specific thanks to Evelina Nordin, Melanie Caffrey and Johannes Eriksson for proofreading and support through the whole work process with the thesis.

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Background

Visual ergonomics among office workers

Visual ergonomics is defined as "a science which aims to achieve a good balance between what a person can see and the visual demands of a task. This requires an understanding of the human visual system and an analysis of the visual demands of a task" (Long & Richter, 2014, p. 419). International Ergonomics Association, Technical Committee for Visual Ergonomics (2012) claims that the human visual system can be affected by surrounding elements, such as for example the physical work environment that the human is surrounded by (e.g. illumination, quality of indoor air et cetera). By understanding the relationship between the surrounding elements at the workplace and the human visual processes, the vision is to improve and optimize well-being and performance by understanding the relationship between the surrounding elements at the workplace and the human visual processes (International Ergonomics Association, Technical Committee for Visual Ergonomics, 2012). At the workplace, there are three different environments; Physical, organizational and social (Dul, Bruder, Buckle, Carayon, Falzon, Marras & van der Doelen, 2012). The organizational work environments are e.g. the workplaces management, level of demands and control. The social work environments are e.g. the level of cooperation, social support from colleagues and managers (Arbetsmiljöverket, 2015). The physical environment is e.g. illumination, air and desk height (Anshel, 2005).

A further example of surrounding elements, that interacts with humans and has an impact on the human visual processes, are information technology (IT) devices. The usage of new IT devices at work have increased at a rapid pace recently. Today IT devices, such as stationary and portable computers and smart phones, is a necessity when working in the twenty-first century. Also, in businesses, the usage of computers has increased tremendously the last decades. In the 1980s only 10 percent of the workforce were using computers in the daily work (Anshel, 2005). Today 84 percent of all businesses use digital systems during the workday (Arbetsmiljöverket, 2016). Computers quickly generate and organize large amounts of information and display it on a visual screen. This is a huge difference compared to the historical usage of paper-based tasks during the workday (Anshel, 2005).

The use of visual display units and computers will most likely continue to increase, because the technology is becoming progressively more advanced and cheaper (Anshel, 2005). Hence, this development impacts on us in many ways. According to Stiftelsen För Strategisk Forsknings (2014), at least half of all jobs will be digitalized within 20 years. The more

technology-based our working life becomes, the more knowledge we need of its consequences on visual health and comfort. Such knowledge is currently missing (Stiftelsen För Strategisk Forskning, 2014). Visual symptoms of e.g. eye strain, a common complaint associated with visual display unit work, can be reduced for most parts, if and when optimal visual ergonomics work conditions are prioritized. In order to clarify the management´s responsibility to uphold good visual work conditions and assist them in their efforts to achieve this, The Swedish Work Environment Authority (SWEA) published Belastningsergonomi (in Swedish) "Physical Workload and Ergonomics" (2012) which contains advices and regulations for both employees and employer. It states that technique, work task and organization should be formed in a way to secure employees not being exposed to either psychological or psychical strain that could eventually lead to any illness or diseases (Arbetsmiljöverket, 2012, Ch. 2, §1).

Visual ergonomics and well-being and health among offices workers

World Health Organization (WHO) stated in 1946 that "health is a state of complete physical, mental and social well-being and not merely the absence of illness or infirmity" (International Health Conference, 2002, p. 984). One factor that must be fulfilled, to experience health and well-being in offices, is that the employees also experience visual well-being and health. The common-sense-definition of visual well-being may be equated with someone that is able to carry out a normal amount of visual near work and this without experiencing any symptom of visual discomfort or pain consequently.

A daily work with visual display unit work impact on office employees mental and physical well-being. Kim, Kang, Yoo, Lee & Hong (2016) report in their study that office employees, who are working with computers, show an association between hours of screen work with the risk to develop depressive and anxiety disorders. Introducing a work guideline to organize the daily tasks in a more healthy and balanced way is therefore necessary for these employees since computer work is a source to job stress and is attention- and mentally demanding for these individuals (Kim et al., 2016). Ranasinghe, Wathurapatha, Perera, Lamabadusuriya, Kulatunga, Jayawardana, and Katulanda (2016) has made a study, with aim to describe the prevalence of computer vision syndrome (CVS). CVS are defined by American Optometric Association as a complex of the eye and vision problems which are experienced during use of computers. The study report that their sample, computer office workers in Sri Lanka had a high prevalence of CVS and that female gender, longer duration of occupation, a higher daily computer usage, pre-existing eye disease are significant associated with the presence of CVS. Furthermore, Lindegard, Wahlstrom, Hagberg, Vilhelmsson, Toomingas, and

Tornqvist (2012) report that experienced discomfort with computer work has a relationship with experienced neck- and shoulder problems, such that the more subjective discomfort the more experienced neck- and shoulder problems.

Visual ergonomics and performance among offices workers

Performance refers to a process during which a person achieves something positive, often despite difficulties (Nationalencyklopedin, 2017). Work related performance therefor refers to the work-related activities expected of an employee and how well those activities are executed (Campbell, McCloy, Oppler & Sager, 1993).

The visual performance is the performance of the visual component of the task; For example, the number of words that are being read during a given time, the ability to distinguish and recognize a small target (e.g. alphanumerical character). If the person is surrounded with favorable lighting and with good physical working conditions, he/she can mentally take on the task better, and in the end the total and individual performance will be positively affected (Boyce, 2011; Juslén & Tenner, 2005). According to Boyce (2011) and Juslén and Tenner (2005) the visual ergonomics has an impact on the persons visual performance. The visual performance is also dependent on cognitive performance, task performance and motor performance. Each one of these categories are impacted by visual performance in its own way. These are thereafter impacting the persons general and human performance. Boyce (2011) claims that the human performances with a focus on the occupational health is crucial for the company's profitability. Visually tired and stressed employees who have poor well-being and health will naturally not perform as well. Therefore, good visual ergonomics increases the individual's well-being and importantly, it is good for the long-term performance of the companies where they work (Boyce, 2011).

Performance is a term that is investigated differently in various kinds of studies. Some studies examine the impact of visual functions (e.g. visual acuity, visual field, optical quality), on real tasks or on self-reported performance (Boyce, 2011). Haynes (2008b) established three different ways to examine performance in a workplace. Firstly, equivalent work task can be compared to one another during "good" or "bad" visual work conditions. Secondly, input and output can be measured and compared, between colleagues exposed to "good" or "bad" visual work conditions (e.g. the average number of work file cases related to annual income tax that individual employees can finish in one hour). Thirdly, individual employees in the workplace can be asked to fill out a survey which estimates self-reported level of performance (Haynes, 2008b). There are different and established ways to measure performance in a quantitative

manner. According to Haynes (2008a) there is a general opinion in research contexts; It asserts that there is only one appropriate way to study performance in a workplace; Which is to measure the self-reported performance by having the employee's fill in a survey. The measurement of performance benefits the company and the employees, because it indicates where the company is in relation to its goal and vision. Poor performance may otherwise be a source to mental and physical stress experience. It is therefore important to understand and to measure performance in a workplace (Haynes, 2008a).

Previous research on visual ergonomics and visual performance in offices work

There is a shortage of published scientific studies on the relationship between visual ergonomics and performance at the workplace. However, Radulovic and Hursidic-Radulovic (2012) reports that office employees working a lot with computers (more than 36 hours a week) have higher anxiety, musculoskeletal- and eye problems. They discovered that stretch exercises for the musculoskeletal systems successfully can reduce the musculoskeletal- and eye problems. Radulovic and Hursidic-Radulovic (2012) conclude that a consisting and appropriate exercise and continuous stretching the musculoskeletal system and maintain the quality on the ergonomics computer equipment, could decrease the eye- and muscular problems. In the long run this could reduce the sick leave and enhance the performance at the workplace (Radulovic & Hursidic-Radulovic, 2012). Hadgraft, Brakenridge, LaMontagne, Fjeldsoe, Lynch, Dunstan and Lawler (2016) display in their research that office employees who have meetings standing up and have more face-to face communications instead of sitting down in front of the computer, may also improve their performance, social norms and workload pressures. Madeleine, Vangsgaard, Andersen, Ge and Arendt-Nielsen (2013) reports that employees that are working with computers daily in an office have a negative correlation with reduced performance and musculoskeletal pain. Robertson, Huang and Larson (2016) reported that they found a significant positive relationship between computer use and vision discomfort. Both musculoskeletal and visual discomfort of computer users are also associated with a variety of physical and psychosocial factors, such as workspace, co-worker support and supervisory relations. Robertson et al. (2016) claims that these findings likely interfere with the employee's performance at the workplace.

The previous research within visual ergonomics and visual performance can point out that working in front of a computer both have physical and mental consequences on the employee. These consequences also have a negative impact on the performance at the workplace. The previous study cannot show how or if the visual ergonomics have a direct impact on the

performance on the workplace or if the relationship is based on another phenomenon in between this relationship. There is not much knowledge within this subject, therefor more research is required.

Visual ergonomics, visual performance and visual well-being and health among offices

As stated above, visual ergonomics constitute a crucial part of a workplace physical and mental work environment and has an established impact on an office employee's overall well-being (Dul et al., 2012; Foldspang, Mark, Hjorth, Langholz-Carstensen, Poulsen, Johansson & Rants, 2014). Furthermore, a worker's well-being has an established impact of a worker's level of performance (Dul et al., 2012; Foldspang et al., 2014). A visually deficient workplace may, more specifically, trigger the workers to exert an unhealthy amount of effort to perform to the expected performance level.

If an employee is experiencing a task as mentally exhausting, and if the reward of staying engaged are high or costs of stopping the work are high (e.g. poor performance at work), employee will uphold the performance even when they feel mentally exhausted and experience a strong urge to stop. This strategy is called compensatory effort (American Psychological Association (2011). When the muscles, sensory and/or perceptual functions of the visual system are exposed to high demands beyond what the eyes are evolutionally adapted to cope with, it has consequences for the well-being and health. In biological terms, the work in front of a screen itself is highly unnatural. Examples of such "extra unnatural requirements" are display work under ergonomically inadequate forms (uncorrected visual errors, poor lighting et cetera). A practical example of what is stated above is direct glare. Mork, Bruenech and Thorud (2016) assert when an employee experiences a glare exposure the consequence is that the employee squinting their eyes, in order to compensate for the strong lights to regulate and to reduce the light. By squinting, the employee once again has a good eyesight but on the other hand this compensatory effort tires the body in the long run. But how these kind of "disturbances" as mentioned above, affect well-being, health and work performance are still relatively unknown. In order for poor visual ergonomics to be perceived as a reasonable cause of inconvenience and ill health, it is natural for research to understand what is happening in the body, when it's happening and under what visual conditions. However, there is no established relationship between a workplace´s physical working environment, non-less the visual ergonomics, and the level of performance (Dul et al., 2012).

An assessment of visual ergonomics and its relationship with performance may benefit the workplace, the workers' health and the society in general. If workers claim that they are

experiencing visual stress and as a direct consequence are performing below their standard or alternatively must enlist compensatory effort to perform at the expected level, then this work situation warrants a visual ergonomics intervention. It is therefore motivated to probe in to the relation between visual ergonomics and performance. This understanding will also be a part of contributing to optimize the performance and well-being at the workplace (Dul et al., 2012). In other words, the workers may perform better and simultaneously feel better.

Mediouni, Bodin, Dale, Herquelot, Carton, Leclerc and Descatha (2015) asserts the importance of constantly improving the working conditions for computer office workers who are in compromised positions because their work can otherwise lead to other symptoms of discomfort and health and issues. Supervision of employees using new technology is always necessary. The employee's participation in issues regarding ergonomics is important for a successful occupational health program (Ho, Sung, Yu & Chan, 2014). In the long run this may contribute to significant saving opportunities for the company and for the society in general (Brooks & Pettigrew, 2015).

Problem definition

Previous research reveals two relevant things; There is an established relation between visual ergonomics and the employees' well-being, and that there is an established relation between well-being and performance. What we yet do not know, in a formal sense, is how and/or if visual ergonomics impacts on the employee's visual performance. Since there is a research gap and a lack of knowledge about this relationship or association, it is motivated and necessary to examine this phenomenon deeper.

Aims and research questions

The aim of this study was to investigate the association between perceived visual ergonomics work conditions, subjective visual well-being and health and self-rated visual performance at the Swedish Tax Agency at an arbitrary fixed point in time.

The study investigated three research questions:

1. To what extent is the visual ergonomics work conditions associated with subjective visual well-being and health?
2. To what extent is the perceived visual ergonomics work conditions associated with the self-rated visual performance?

3. To what extent is the visual ergonomics work conditions associated with self-rated visual performance, when subjective visual well-being and health is included as a mediator variable?

Method

Literature review

The study began with a systematic literature search to clarify the knowledge situation in relation to the research questions. The aim of the literature reviews was to compile existing studies investigating the relation between visual ergonomics and performance in workplaces. Databases used for the literature search was PubMed and Web of Science. The literature search was compiled in September 2017. In table 1, the keywords are displayed. The keywords in each search were combined with the Boolean operator. In the first search the operator OR were used between the first and second keyword and between the third and fourth keyword. Between the second and third keyword the operator AND was used. The first search strings were then; Visual ergonomics OR Visual perceptions AND Visual Display Unit OR Computer. This decision was made to make sure some visual were involved but also that there were some display or computer involved in the search. In the second search the Boolean operator OR were used in the whole string. The search string was; Productivity OR Performance OR Efficiency OR Effectiveness. The third search were the same as the second, the Boolean operator OR were only used in the search string; Office worker OR worker OR white-collar worker. In the final search the first, second and third search was combined; (Visual ergonomics OR Visual perceptions AND Visual Display Unit OR Computer) AND (Productivity OR Performance OR Efficiency OR Effectiveness) AND (Office worker OR worker OR white-collar worker) (see appendix 1 for simplified version of the search string).

Table 1. *Keyword in literature search*

Search no.1	Search no.2	Search no.3
Visual ergonomics	Productivity	Office worker
Visual perceptions	Performance	Worker
Visual display unit	Efficiency	White-collar worker
Computer	Effectiveness	

When the final searches were complete, the inclusion criteria; *Written in English or Swedish, peer-reviewed scientific articles, 2012-2017, all journals, available in full text in the*

university's intranet, worker were applied. 21 articles (17 article from the systematic search and 4 found other ways) were included in a quality screening with a help of a modified template taken from Statens beredning för medicinsk utvärdering (SBU) (2014). Issues concerning quality assessment were; *Type of study design, sample, inclusion and exclusion criteria's, response rate, validity and reliability of measurement instruments, adequacy of statistical analyses and a distinct result* (see appendix 2). To be completely sure that the quality screening was completed with as little bias as possible, a tool was created. This tool contained three subqueries which helped the examiner to be as systematic as possible and to not let external factors affect the screening (see appendix 3). The tool contained three sub questions for each main question. To be able to get a "yes" on the main question, all three of the sub question had to be answered with a "yes". To be able to get a "no" on the main question, all three of the sub questions had to be answered with a "no". If the sub question contained both a "yes" and a "no", the main question got answered with a "partly". A further information about the search strategy and article matrix of included articles can be found in appendix 4. The article matrix included author, year, title, aim, sample, loss, study design, data collection method, main findings and quality and generalizability. These categories were selected because they displayed the overall and important parts of the articles. A simplified version of the whole literature review is presented in table 2.

Table 2. *Simplified version of search step*

	1st search	After practical. Screen	High quality	Middle quality	Low quality
Web of Science	1284	12	7	5	0
PubMed	166	5	4	1	0
Another way	4	4	2	2	0
Total	1450	17	11	6	0

Design

This study was conducted with a deductive approach where a cross-sectional association between visual ergonomics work conditions, visual well-being and health and self-rated visual performance was investigated. A deductive approach was used since it is the most common approach when researching relationship between theory and practice in social science. A hypothesis and/or a research question is often formulated based on the researcher´s prior knowledge of the research area (Bryman, 2011). A cross-sectional design collets data at a certain time to retrieve data to be examined to detect established patterns (Bryman, 2011). A

cross-sectional design was chosen since the research questions were specifically asking for associations between visual ergonomics, visual well-being and health and visual performance.

Study population

The sample in this study included office workers (*N*=94) from the Swedish Tax Agency in a town in the middle of Sweden. Their work title were administrators and their work duties were to manage and handle various tax cases. Their work duties require a computer; Therefor most working hours occur in front of a computer, which were the motive why they were chosen as a sample. The sample were selected from the target population; All workers (in the same position as the sample) from Swedish Tax Agency throughout Sweden. The sample sits mainly in open plan offices in a room that is approximately 300-400 square meters. In each room, there is 30-40 employees sitting in pairs of four. Each employee has adjustable desks and uses on average two monitors each, both stationary and portable. The inclusion requirements to participate in this study were to be minimum 18 years old, they had to be employed at the Swedish Tax Agency and working with computer in their daily work. The participants in this study were selected with a convenience sample. This sample recruitment method was chosen because the respondents were geographically close and because it was easy to contact them and to maintain contact with them.

Data collection

Questionnaire

The collection method for this thesis was a digital questionnaire. Hayes (2000) claims that a questionnaire is a good choice if you want to reach a large amount of people and the produced result gives the samples general answer. This was the motive why a questionnaire was chosen as data collection method in this study. The questionnaire was made in the survey tool "Sunet Survey" and were constructed by 22 questions (see appendix 5). The participants got access to the questionnaire through a link that was sent to their work email on 8 January 2018. The respondents work email was found at the Swedish Tax Agency intranet. When the participants clicked on the link they first had to read through a letter with information about this study (see appendix 6). After that, they had to give their consent by clicking "yes" on the first question; *Give your consent*. This question had to be answered with "yes", if not the participants could not proceed to the next page. On the second page the participants had to answer 10 background questions. An example is gender, age and marital status. These questions were multi-choice, for

example gender: a) *woman* b) *man* c) *does not want to define myself*. Questions like age required the participants to type in an answer manually.

On the third page of the questionnaire, the respondents had to answer four (no. 11-13) questions about the perceived visual ergonomics work conditions at their workplace. These questions were custom designed and were answered on a five-point scale. The scale for question no.11 varied between "0 hours" and "40 hours". Question no. 12 and 13 scales varied between "very difficult/bad" and "very easy/good". An example of question was; *How do you perceive your settings on the monitor/displays regarding sharpness, resolution or color*. All the questions from this section were in the next step added together and created a summed index. The minimum possible summed index score was 3 and maximum summed index score was 15. The higher the summed index were, the worse perception of visual ergonomics there was at the workplace according to the respondent. Question no. 14 were initially meant to be a part of the summed index of visual ergonomics but were decided to be excluded since this question were asking about the respondent's own experience of the visual comfort and were therefore asking about something similar to visual well-being and health instead. This question differed from the other questions in this part of the questionnaire, when the other questions asked about actual aspects about the visual ergonomics, such as settings, sharpness et cetera.

On the fourth page of the questionnaire, the respondents had to answer three questions (no. 15-17) which addressed their self-estimated visual well-being and health as based on the experience of their visual symptom. All three questions were taken from Knave, Wibom, Voss, Hedström and Bergqvist (1985) and the questions asked about symptoms concerning eight eye discomforts. These questions were answered with both a frequency of occurrence score and with an intensity of experience score. For an example; *Do you have any of the following eye problems "redness"*. If the respondents answered "no" (0) on the first question, the respondents just went on to the next symptom question in the questionnaire. If the respondents on the other hand answered "yes" (1), the next step was to indicate the frequency (1=occasionally, 2=weekly, 3=daily) and after that, the intensity (1=negligible, 2=slight, 3=pronounced). The eye discomfort index was the sum of the eight various eye symptom scores. A respondent could have a minimum of 0 and a maximum of 56. The higher total, the higher it indicated on more frequency and stronger intensity eye discomfort, and therefore a lower visual well-being and health (Knave et al., 1985).

On the fifth page the respondents had to answer five questions about the self-rated visual performance (no. 18-22). An example of question was; *How do you experience your performance behind the screen, in relation to maximum performance.* These questions were

inspired from previous research in similar studies. These questions got answered with a 11-points scale where 0=very little and 10=very much. Each question was asking about the respondent's opinions at just that occasion, and that's was stated in a short message above the first question. The answered questions got then summed and created a summed index. The minimum score was 0 and the maximum was 50. The higher summed index, the worse visual performance they experienced according to the respondents. The last thing the participants had to do was to click on "send the survey" to conclude the questionnaire.

Pilot study

Bryman (2011) claims that when a convenience sample are used in a study, that it is very important to test the survey with a pilot study before the final survey. To ensure that the questionnaire maintained a high quality a pilot study was sent out to 17 respondents between 9 November 2017– 10 November 2017. The respondents were volunteers in near acquaintances who were minimum 18 years old and worked with computers on a regular basis. The respondents answered the questionnaire and every question had a comment tab below. The respondents in this way had an opportunity to reflect and to give feedback on each question in the questionnaire. Every comment was reviewed and if deemed appropriate specific questions were improved or disambiguated. The statistical software and analysis was tested in IBM Statistical Package for the Social Sciences (SPSS) 22.0 for Windows. Since the pilot study, the questions were changed, for an example Knave et al. (1985) instrument and new questions about visual performance was added. After all these changes, a new pilot study was administrated to one person who worked at an office with regular computer work. This person had no suggestions for how to improve the clarity of the survey.

Data collection from the questionnaire

The final questionnaire was open between 8 January 2018 to 25 January 2018. An e-mail with the link to the questionnaire was sent to all respondents in the study. An e-mail with a purpose to remind them to take part of the questionnaire, was sent on 11 January 2018 and 24 January 2018.

When the questionnaire was closed, the data was transferred to SPSS. To be able to analyse the visual ergonomics, subjective visual well-being and health and self-rated visual performance, every question in the questionnaire needed to be evaluated. In order to measure if a bad visual ergonomics work conditions is associated with a high point in the questionnaire, statement no. 12 and no. 13 needed to be reversed in SPSS. E.g. a 20 indicated on a poor visual

ergonomics work conditions and a 4 indicated on a good visual ergonomics work conditions. Measuring subjective visual well-being and health and self-rated performance followed the same logic. No statement regarding subjective visual well-being and health needed to be reversed but concerning self-rated performance statement 18 needed to be reversed. The summed index for visual ergonomics was treated on an interval scale as an independent variable (*x*) in the following analysis. The summed index for self-rated visual performance was treated an interval scale and as dependent variable (*y*). Visual well-being and health was also on an interval scale and included as a mediator variable (*m*).

Statistical analysis

The analysis was divided in two different parts; Descriptive statistics and inferential statistics. The inferential statistics included the main results and the answer to the research questions in this study. The descriptive statistics were performed to describe the sample based on the background questions and the phenomena's summed indexes. The data's sample (*N*), mean (*M*), standard deviation (*SD*), percent (%), minimum (min), maximum (max), median (Mdn), Mode and contingency tables were used to present descriptive statistics since all data were approximal normally distributed. The scale level of the data determined whether they were presented with mean or median. SPSS was used for all statistical analysis. To investigate and to find an answer to the first, second and third research questions several multiple regressions were performed. Lastly a mediator analysis was performed to specifically answer the third research question. To all analysis the significant level was set to 5% (.05).

Multiple regression

A multiple regression is an analysis that's suitable to explain variables that are associated with the dependent variable to promote an understanding of the underlying process (Brace, Kemp & Sneglar, 2009; Petrie & Sabin, 2009). A multiple regression was chosen as analysis method in study because the research questions were asking about the association between the variables, and since this choice of analysis also made it possible to make predictions.

In this study *gender, age, daily exercise* and *screen time outside of work* were initially chosen as covariates. The covariates were chosen based on previous research where these have been used as covariates or these indexes has differed in their result (Dul et al., 2012; Ho et al., 2014; Mediouni et al., 2015). But since the number of women and men varied in this study, the variable "gender" was determined not to be included as a covariate. A test run of the multiple regression analysis was performed with "age", "daily exercise" and "screen time outside of

work", and neither had "age" or "daily exercise" any effect since these results was not significant. It was therefore determined to use only "screen time outside of work" as a covariate in the final analysis, since this was the only covariate that had a significant effect in the test run of the multiple regression analysis.

To perform a multiple regression analysis there are five terms that should be met or at least identified since this can affect a studies reliability (Borg & Westerlund, 2012; Brace, Kemp & Sneglar, 2009). The first term was that the dependent variables was on interval or ratio level and the independent variable and covariate was on ratio, interval, ordinal level or nominal level. If the variable were on nominal level, then the variable would need to be recoded to either 0 or 1 in SPSS (dummy variable) (Brace, Kemp & Snelgar, 2009). The second term was that the sample size in this study was appropriate in relation to number of variables. This was calculated with the degree of freedom, which can be described as the total number of observation that are free to vary when a statistical measure is calculated (Brace, Kemp & Sneglar, 2009). The calculation could be made by dividing the sample size with 10 or 15 (both are acceptable to use, 10 is more generous and 15 more strict). In this study it meant that the degree of freedom was 8 (86/10=8.6). The third term that should be met was to have a linear correlation between the predictor and criterion variable (Brace, Kemp & Sneglar, 2009) (see table 3). The fourth term was that the data was screened for outliers, normality and homoscedasticity. The fifth and last term was that the data was investigated for multicollinearity, which means that predictors variables was linearly predicted from the each other. To discover multicollinearity, the variance inflation factor (VIF) for each predictor variables was calculated. The rule of thumb is to avoid VIF >10 and a small VIF means there is a considerable part of the variance that can be explained (Borg & Westerlund, 2012). All five terms stated above were met in this study.

Table 3. *Correlations, Pearson's r*

	Visual well-being and health	Visual performance	Visual ergonomics
Visual well-being and health		.257*	.251*
Visual performance	.257*		.439**
Visual ergonomics	.251*	.439**	

* Correlation is significant at the 0.05 level

** Correlation is significant at the 0.001 level

Mediator analysis

A mediator analysis was performed to investigate the third research question. A mediator analysis was used to examine if the independent variable affects the dependent variable through a mediator variable. A mediator is a variable that is in a causal sequence between two variables, whereas a moderator is not part of a causal sequence between the two variables (Baron & Kenny, 1986; Preacher & Hayes, 2004). It is important that each step in the mediator analysis is performed with the exact same analysis (in this case multiple regression) with the exact same covariates.

Baron and Kenny (1986) and Preacher and Hayes (2004) model assumes a three-variable system; which are basically four different analysis and steps that are named *C*, *a*, *b* and *ć* (see figure 1). The first thing was to investigate the association between the independent variable (visual ergonomics) and the dependent variable (visual performance) with a multiple regression with screen time outside of work as a covariate (see path *C* in figure 1). This analysis answered the second research question in this study. The second thing to do was to investigate if chosen mediator variable could be used as a mediator, since there are two terms that should be met for it to work as a mediator (Baron & Kenny, 1986; Preacher & Hayes, 2004). The first term was that it should be a significant association between the independent variable and the mediator variable (Baron & Kenny, 1986; Preacher & Hayes, 2004). In this study the association was investigated with a multiple regression between visual ergonomics and visual well-being and health and screen time outside of work as a covariate (see path *a* in figure 1). This calculation answered the first research question in this study and made sure that the first term was met. The second term that should be met is that it should be a significant association between the mediator variable and the dependent variable (Baron & Kenny, 1986; Preacher & Hayes, 2004). In this study the association was performed with a multiple regression between visual well-being and health and visual performance with screen time outside of work as a covariate (see path *b* in figure 1). This association did not answer any research question but had to be performed since it is a term for the mediator analysis to fully be complete according to Baron and Kenny (1986) and Preacher and Hayes (2004). The next step in the analysis, was to investigate the association with a multiple regression between the independent variable and the dependent variable, with the mediator variable involved and screen time outside of work as a covariate (see path *ć* in figure 1). When this association was performed, the final step was to investigate how and if there was a mediation in the association and this would answer the third research question in this study.

The mediation was analyzed based on comparison the standardized coefficients (β) between *C* and *ć*. If the standardized coefficients (β) were significant in *C* and if it maintained significant in *ć* it would indicate that it did not mediate the association. If on the other hand, the standardized coefficients (β) were not significant in *ć*, it would indicate that the mediator-variable mediate the association between the dependent variable and the independent variable (Baron & Kenny, 1986; Preacher & Hayes, 2004).

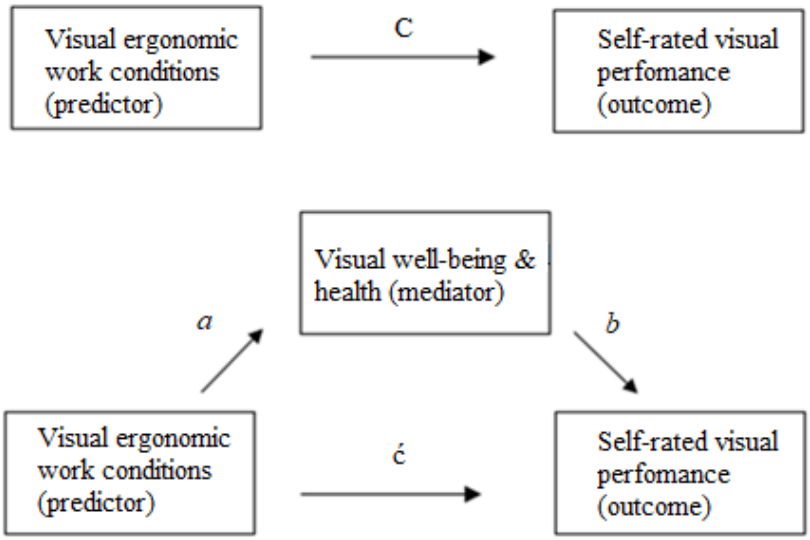

Figure 1. *Simplified version of the analysis*

Ethical considerations

The study obeyed the four principles regarding; *The information requirement, consent claim, the confidentiality and the useful claim* (Vetenskapsrådet, 2011). These principles would be considered to reach a good research ethics. The first term, *the information requirement* was met since every respondent is informed about the thesis and its aim and process. This information was shared in the information letter (see appendix 6) that came along with the survey. The second term, *consent claim* was met since the survey request a mandatory consent before every respondent commence answered the questionnaire. Every respondent was also informed in the information letter about that the participation was volunteering and that they could cancel and exit the questionnaire every step on the way. The third term, *the confidentiality* was met since the questionnaire was confidential and that there are no personal questions asked (except gender, weight and age). Since there were no personal questions, a specific questionnaire could not be traced back to a specific individual. Every respondent was also being analyzed at group

level. The last term about *useful claim* was also met since the data was only used for research purposes. The data was stored decoded until the course was completed and after that all data was destroyed. Every respondent got information about the handling of data in the information letter which came with the survey.

Result

Descriptive statistics

Out of the 94 respondents who received the questionnaire, 86 respondents (91%) answered the questionnaire. The response rate was fairly constant throughout the questionnaires opening period, but the reminders were necessary. 54 women (63%), 31 men (36%) and 1 person (1%) who did not want to define them self in any gender. The age of the participants varies between 23 years old to 64 years old (*M*= 42, *SD*= 12). There was one person who didn't want to fill in the age in this question. For further detailed descriptive statistics from the background questions, see table 4.

Table 4. *Descriptive result of the sample*

	N	Min	Max	*M*	*SD*	*Mdn*	*Mode*
Age (yrs.)	85	23	64	40	12.18	-	-
No. of years at the workplace	86	0	42	11	11.56	-	-
Daily exercise (how often 30min)	86	1	5	-	-	4	4
Sleep quality	86	1	5	-	-	4	4
Screen time at the workplace (1=0h/week, 5=40h/week)	86	1	5	-	-	4.5	5
Screen time outside of the workplace (h/day)	86	0	6	1.31	1.44	-	-

Results from all the 86 respondents answer regarding each phenomenon; Visual ergonomics, visual well-being and health and visual performance are presented in table 5, including minimum, maximum, mean, standard deviation. The table are divided in three columns, one for the total sample and two columns for those who stated themselves as women (*n*=54) and men (*n*=31) in the study.

Table 5. Descriptive result of sum index of the phenomena's

			Total		Women		Men	
	Min	Max	*M*	*SD*	*M*	*SD*	*M*	*SD*
Visual ergonomics	4	13	8.86	2.06	8.87	1.81	8.90	2.47
Visual well-being and health	0	41	10.40	11.02	10.93	11.09	9.81	11.07
Visual performance	5	42	15.72	9.51	15.94	9.69	15.48	9.45

Main results

To answer the first research question; *To what extent is the visual ergonomics work conditions associated with subjective visual well-being and health*, a multiple regression was performed with screen time as a covariate. The model (visual ergonomics and screen time) explains 12% of the variance in the visual-well-being and health and ($F(2,83) = 5.593$, $p = .005$, $r^2 = .119$) (see table 6).

Table 6. A specific description from the result of the multiple regression* (a)

	β	*p*	CI lower	CI upper	Tolerance	VIF
Screen time	.254	.024	.259	3.630	.865	1.156
Visual ergonomics	.157	.160	-.338	2.022	.865	1.156

*Dependent variable: visual well-being and health. Independent variable: visual ergonomics. Covariate: screen-time.

To answer the second research question; *To what extent is the perceived visual ergonomics work conditions associated with the self-rated visual performance*, a multiple regression was performed with screen time as a covariate. The model (visual ergonomics and screen time) explains 30% of the variance in the visual performance ($F(2,83) = 18.158$, $p < .001$, $r^2 = .304$) (see table 7).

Table 7. *A specific description from the result of the multiple regression* (C)*

	β	*p*	CI lower	CI upper	VIF	Tolerance
Screen time	.359	.000	1.076	3.659	.865	1.156
Visual ergonomics	.307	.002	.514	2.322	.865	1.156

*Dependent variable: visual performance. Independent variable: visual ergonomics. Covariate: screen-time.

To perform a complete mediator analysis according to Baron and Kenny (1986) and Preacher and Hayes (2004) the association called (*b*) in figure 2 had to the investigated. In this

study the association between visual well-being and health visual performance (*b*) was analyzed with a multiple regression. The model (visual well-being and health and screen time) explained 24% of the variance in the visual performance ($F(2,83) = 12.827$, $p < .001$, $r^2 = .236$) (see table 8).

Table 8. *A specific description from the result of the multiple regression** (*b*)

	β	*p*	CI lower	CI upper	Tolerance	VIF
Screen time	.434	.000	1.538	4.188	.903	1.108
Visual well-being and health	.122	.232	-.068	.278	.903	1.108

*Dependent variable: visual performance. Independent variable: visual well-being and health. Covariate: screen-time.

To answer the third research question; *To what extent is the visual ergonomics work conditions associated with self-rated visual performance, when subjective visual well-being and health is included as a mediator variable*, there was several multiple regressions performed with screen time as a covariate. The model (visual ergonomics, visual well-being and health and screen time) explained that 31% of the variance in the visual performance non-significantly ($F(2,83) = 12.258$, $p = .433$, $r^2 = .310$) (see table 9), and the visual well-being and health had no effect as mediator. This result regarding the mediation is based on the β, which maintained significant from *C*-analysis to the *ć*-analysis (see table 9 & figure 2).

Table 9. *A specific description from the result of the multiple regression* (ć)*

	β	*p*	CI lower	CI upper	VIF	Tolerance
Screen time	.339	.001	.903	3.574	.813	1.123
Visual well-being and health	.077	.433	-.101	.234	.881	1.135
Visual ergonomics	.295	.004	.445	2.279	.844	1.185

*Dependent variable: visual performance. Independent variable: visual ergonomics. Mediator variable: visual well-being and health. Covariate: screen-time.

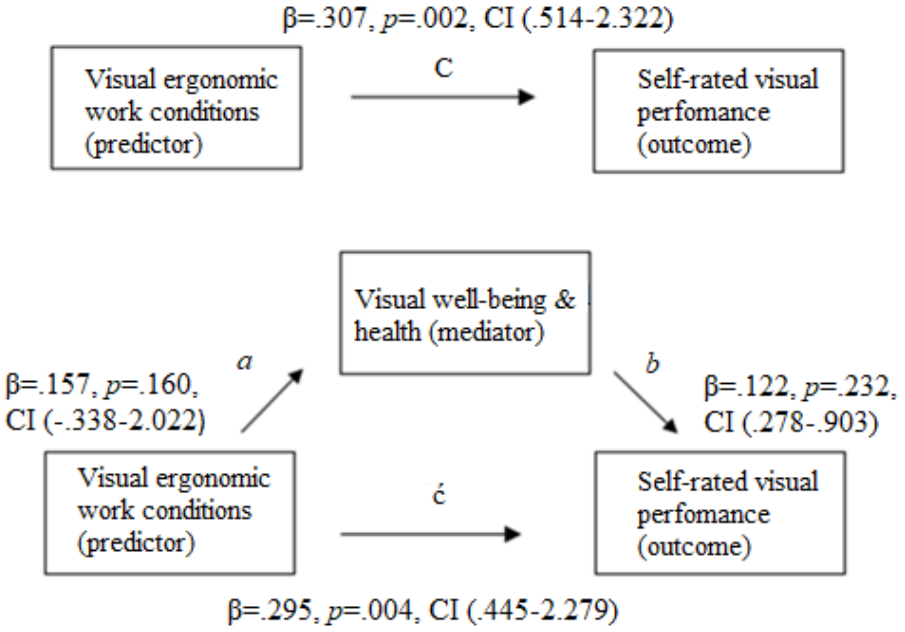

Figure 2. *Simplified version on the result of mediator analysis*

Discussion

Key results

This study aims to investigate if there is an association between perceived visual ergonomics work conditions, visual well-being and health and visual performance. Results from this study indicated that there was a significant association between visual ergonomics and visual well-being and health and between visual ergonomics and self-rated visual performance. When visual well-being and health was used as a mediator the association between visual ergonomics and self-rated visual performance remained the same.

Result discussion

Interpretation of results

According to Anshel (2005), visual symptoms such as eye strain et cetera are a common complaint associated with visual display work. In this study, the establish instrument which were asking about the visual well-being, such as eye discomfort, were from Knave et al. (1985). The results from this study indicates that the workers did have quite good visual well-being. Knave et al. (1985) instrument ranges between 0-56 where the higher, the worse visual well-being and health they have, and the respondents answer ranged between 0-41. Ranasinghe et al. (2016) rapports that female gender has a higher prevalence of CVS than men. This results

and interpretation correspond with the result in this study also where female respondents report to have a more frequency and stronger intensity eye discomfort than men. In this study, there was a significant association between screen time and visual well-being, this result is reasonable since it corresponds with both Ranasinghe et al. (2016) and Robertson, Huang and Larson (2016) arguments. Ranasinghe et al. (2016) reports that a higher daily computer usage has a significant association with the presence of CVS and Robertson, Huang and Larson (2016) demonstrates that it is a significant positive relationship between computer use and vision use. In this study, the respondents use computers between 10-40 hours per week. Ranasinghe et al. (2016) also reports that longer duration of occupation and preexisting eye disease has a significant association with the presence of CVS. This was unfortunately nothing that could be proved in this study, since the questionnaire did not ask the respondents about any preexisting eye diseases.

The significant association between visual ergonomics and visual well-being and health that were found in this study may be reasonable since Boyce (2011) result is similar. Boyce (2011) results show that people that are visually tired have a poorer well-being and health. The results from this study also indicates that there is a significant association between visual ergonomics work-conditions and self-rated visual performance which are equivalent with Juslén and Tenner's (2005) result, which display that visual ergonomics has an impact on a person's visual performance.

Another result from this study display that the association between visual well-being and health and self-rated visual performance remain the same with visual well-being and health as a mediator. This finding is unique since this hasn't been analyzed before. However, a similar study performed by Boyce (2011) shows that employees that are visually tired has a poorer well-being and health, and Boyce (2011) concluded that they naturally do not perform as well because of this.

This study did not find that visual well-being and health had act as a mediator in the relationship between visual ergonomics and visual performance. This finding was a little bit surprising, since previous study surely indicates that these phenomena relate to each other. One aspect that can explain why the visual well-being and health did not have a mediating effect on the relationship between visual ergonomics and visual performance, is that the actual symptom of visual well-being and health not yet has affected the employees. Since, according American Psychological Association (2011) and the theory of compensatory effort, there might be a possibility that the symptom of visual well-being has not been developed yet and that the respondent has not compensated long enough. This study did not ask for any previous eye

problems, and because of this, this aspect cannot be controlled for. Another aspect that also contribute that this matter cannot be controlled for, is the cross-sectional design of this study. If this study would instead have a longitudinal design with several measurement occasions, a more definitive answer how and if visual well-being and health have a mediating effect on the relationship between visual ergonomics and visual performance would have been presented. This because it could have been able to ensure the development of the visual symptoms during a given time during the study.

Method discussion

Strengths of the study

A strength in this study is the response rate, which was high (91%). The higher response rate, the greater the probability is that this study is giving an honest description of how the sample perspective is. A further strength in this study is that the validity and reliability has been kept in mind. One way to make sure to strengthen the validity is to use at least one established instrument. Knave et al. (1985) was used as instrument for measuring visual well-being and health. In the digitalized survey, every phenomenon was separated from each other and written on different pages. This separation was made to keep the questionnaire simple, distinct and comprehensible which therefore also strengthens the validity (Hayes, 2000). To strengthen the reliability in the study, a pilot study was sent out before the actual survey. The pilot study´s aim was to be a declaration of quality since the respondents could give feedback about the pilot survey. The comments were considered, and the survey was edited. An example of editing was instead of asking for time in front of just a computer, a question about screen time was asked instead. For instance, Hayes (2000) claims that a pilot study before the final survey increases the reliability in the study. The reliability of each instrument was also measured using a test called Cronbach's alpha (see table 10). This instrument measures the average correlation between each question in a test and the result of respondents on a scale (Brace, Kemp & Sneglar, 2009). The test gives a measure between 0-1, where 0 indicate that there is no internal reliability and 1 indicate that there is a perfect internal reliability. 0.6 is an established rule of the thumb regarding what's a satisfactory result (Brace, Kemp & Sneglar, 2009; Bryman, 2011). The result regarding Cronbach's alpha, indicate that this study has a quite good internal reliability.

Table 10. *Cronbach's alpha*

Visual well-being and health	Visual performance	Visual ergonomics
.922	.895	.671

Haynes (2008a) claims that there is only one appropriate way to study performance; And that is by self-reporting survey. Since this study chose this method, it can be considerate a strength. But it is important to just clarify; Just because the respondents own rating says one thing, this does not mean that their response is the actual truth. There could have been many different reasons for why they answered like they did. A possible factor that could have affected the completion are underlying variables (Hayes, 2000). The handing out to the questionnaire plays an important role regarding this. By sending out the survey by email and letting the respondents answer online, they could respond on their own terms to the rate and time that best suited them. By chosen this method for handing out the questionnaire, can be considering a strength in this study.

The main ethical aspects of questionnaire studies are how they are administered to the sample and what is done with the findings and results once they have been presented. With these aspects, questionnaire studies have generally relativity few ethical problems comparing to other types of research (Hayes, 2000). The ethical aspects can be considered a strength in this study since there was no problem or obstacle before, during or after the data collection. One reason why no ethical problem arose may be since ethical aspects were taken into consideration from an early stage.

A final strength in this study is that all terms and guidelines to perform multiple regressions and mediator analysis was identified, considered and met. This study had a big enough sample size in relation to the number of variables. The degree of freedom was 8, so there was no problem since this study had one independent variable, one mediator variable and one covariate. All used variables were on suitable scale levels, and there were no distinct outliers that could influence and affect the analysis or result. All used data were approximately normally distributed, and the independent variable and covariate did not correlate with each other (multicollinearity). For the mediator analysis the two terms for the mediator variable was met.

Limitations

The first limitation in this study is the design. This study has a cross-sectional design, which mean there are a lot of things outside of this study that is not controlled for. A cross-sectional study is performed at just one occasion. The results from one of these studies provides a cross-sectional view of the population (all workers in the same work position as the sample). These studies can only give information about phenomenon at a specific time. Since it can only provide information from one specific occasion, the study can rule out any correlations and

only confirm associations. In any cross-sectional study, no the background variable cannot be controlled for. Another limitation in this study is that it is a risk of a bias in the responses. Response bias means that the respondents answer is distorted in the way the respondent think is beneficial (Hayes, 2000). This cannot be ruled out in this study, since the questionnaire raised areas that might be perceived as sensitive and maybe the respondents believed the answer and results would affect them later at the workplace (based on if the workplace result was "good" or "bad"). Response bias can emerge automatically when respondents want to see the positive aspects in themselves and try to become socially accepted (Hayes, 2000). The sample in this study was selected trough convenience sampling. This can affect and risk that the generalizability of the result in this study is limited. When a convenience sample is used in a study, it is not possible to ensure a fully representative study sample (Bryman, 2011). Therefore, the results in this study are not entirely possible to generalize to all workers at the Swedish Tax Agency. Previous research in the exact area is very limited. Previous research has focused on different perspectives, so this lack of this knowledge became problematic in both the implementing of the literature review, background and to interpret the result in this study. Also, this was problematic when trying to understand if and how the result is reasonable or not, since there isn't a lot of research to compare with.

The survey in this study included two things which can be considerate weaknesses, which both were due to the human factor. The first thing was that statement no. 11 "*I ditt arbetsliv, hur många timmar arbetar du framför en bildskärm i snitt varje vecka?"* with a response interval between 1-5, where 1 indicated on 0 hours per week and 5 indicated on 40 hours per week, was formulated in a different way in the final questionnaire, not intentionally. The statement was instead of average per week asking the average per day, and this error could have affected the respondents in a negatively way since the question and response interval did not corresponded. This error was pointed out quickly, and an additional e-mail with explanation was sent to all respondents.

One other thing in the survey which may be considered as a weakness is that question no. 14 did not need to be a part of the final questionnaire, but it was anyway. The initial thought was that this question would be a part of the summed index of visual ergonomics, but it got deleted from this index since the question differed from the other questions in the index. When handing out questionnaire to people it is important that is short but capture the important parts. It is important to maintain the respondents focus, and you do that by having as few questions as possible (Bryman, 2011). Regarding this, one extra question (e.g. no 14) which could have been deleted before the final questionnaire, could have affect the sample focus and desire to

answer. The possibility of this happening in this study are minimum, since the respondent rate was high.

One aspect that can be considered as a limitation in this study is that parametric analytical methods were used. Jamieson (2004) claims that parametric analytical methods cannot be used when having variables on ordinal scale, but only on interval or higher. Carifio and Perla (2008) is opposing Jamiesons (2004) finding and assert that Likert question or items may well be ordinal but when consisting of sum index across of many items, the variable is then interval scale. If the sum index is therefore on interval scale, then doesn't matter whether to use parametric or non-parametric analytical methods. Norman (2010) draw the conclusion based on empirical literature dating back nearly 80 years, that parametric analytical methods can be used on ordinal scale with a small sample size, with unequal variances and/or with non-normal distributions. This is an intensive debate and the outcome and point of view in this study are based on the researcher's perspective, the research fields and belief.

Based on the strengths and limitations in this study, the statistical power needs to also be addressed. Statistical power is the ability of the procedure to discriminate accurately between situations where the null hypothesis is true to situations where the null hypothesis is false (Borg, Kemp & Sneglar, 2009). Statistical power is influenced by several factors. The aspects that would indicate that the power would be low, is that the study's sample size only was eighty-sex and the design in this study. The design of this study was cross-sectional which indicate on a lower power. Design that's indicate on a higher power are longitudinal or experimental studies (Borg & Westerlund, 2012). With these aspects stated above, this study statistical power would indicate to be quite low.

Implications from the study and additional research

This study itself and the result is essential for both the employees, employer and for the society in general. The results and knowledge about visual ergonomics, visual well-being and health and visual performance can help the manager to understand the extent of the problems and how the relate to each other. It can also help the individual to understand how important good visual ergonomics is, since it can affect several other aspects. Since this study indicate that poor visual ergonomics affects the visual performance in a negative sense, it may be a reasonable thought that association also has other mental effects such as stress. If you cannot perform as much as you or your employer would like to, this can likely act as a stressor which in the long run can affect the individual in a broader perspective. If you know that you do not perform as well as you should, it may well also affect the individual self-esteem and self-confidence. Another

theory about the effects that may occur when you experience a bad visual ergonomics for example the sharpness of the screen and you cannot really see it clear, it may cause the individual to strain the eyes even more to compensate for the lack of visual ergonomics, to maintain the performance level. This compensation may also have both physical effects (since the eye gets tired) and mental effects (since the focus are to maintain the compensation and not on the task). Overall, all these alternatives may create a negative spiral downward with more consequences as previously thought.

The society in general are getting more digital in a pace that we barely can keep up with. With this, the workplace is also getting more technology-based and we do not know a much about its visual, mental och physical consequences (Stiftelsen för Strategisk Forskning, 2014). The Swedish Work Environment Authority (SWEA) has published several regulations with support from the Work Environment Act (1977:1166) which are founded to assist the employer and employees about their requirements and responsibilities regarding the work environment (Arbetsmiljöverket, 2012, Ch. 2, §1). Based on the shared responsibility between the employer and employees to establish and maintain a good working environment in all aspects, and since we do not know a lot about the visual, mental and physical consequences from the technology – studies such as this may have an essential meaning and may also be significant in further studies in similar areas.

In this study one mediator (visual well-being and health) was tested, and it turned out it didn't mediate the association between perceived visual ergonomics work conditions and visual performance. This result does not rule out that there might be something else that can mediate the association. To fully understand the association between these phenomena's, further information about the respondents could be needed; Such as sleeping habit and/or previous eye problems since these were not investigated in this study. Another angle that should be explored is to investigate this phenomenon, but not in a subjectively matter but with an experimental design. It would be very interesting to attain deeper knowledge about measurement with an experimental design and then investigate if its results are consistent with the results obtained in this study.

Conclusion

Results from present study indicate that visual performance may be impaired due to poor visual ergonomics without the impact of neither good or bad visual well-being and health at office work. Then what is the reason why visual performance decreases when visual ergonomics is

poor (if visual well-being and health is not involved)? Well, if the respondent has poor visual sharpness, inadequate color rendering, bad focus et cetera on their screens, means that it will take longer than usual for the respondent to perform their work on the screen. This means that it takes "longer than normal" and that it is basically completely independent of visual well-being and health. If there is any other phenomenon than visual well-being and health that acts as a mediator in this relation, it is beyond the model in this study.

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Appendix 1. Results from the literature searches

Databases	Searches	No. articles
Web of Science	Visual ergonomics OR Visual perceptions AND Visual Display Unit OR Computer	737,765
	Productivity OR Performance OR Efficiency OR Effectiveness	4,766,039
	Office worker OR worker OR white-collar worker	219,997
	(Visual ergonomics OR Visual perceptions AND Visual Display Unit OR Computer) AND (Productivity OR Performance OR Efficiency OR Effectiveness) AND (Office worker OR worker OR white-collar worker)	1284
	After applying the inclusion criteria's	12
Pub Med	Visual ergonomics OR Visual perceptions AND Visual Display Unit OR Computer	706,412
	Productivity OR Performance OR Efficiency OR Effectiveness	1,494,336
	Office worker OR worker OR white-collar worker	25753
	(Visual ergonomics OR Visual perceptions AND Visual Display Unit OR Computer) AND (Productivity OR Performance OR Efficiency OR Effectiveness) AND (Office worker OR worker OR white-collar worker)	166
	After applying the inclusion criteria's	5 (1 double)
Total:		17

Appendix 2. Quality screening

Författare:	Datum för granskning:
År:	Art.no:

	JA	NEJ	DELVIS
Har studien ett begripligt syfte och/eller frågeställning?			
Har studien ett lämpligt urval kopplat till frågeställningen och/eller syftet?			
Har studien passande inkluderings-/exkluderingskrav kopplat till frågeställningen och/eller syftet?			
Finns det en klar och formulerad bortfallsanalys?			
Är studiens reliabel/valid?			
Är datainsamlingen precist beskriven?			
Har en lämplig statistisk metod/analys använts?			
Är resultatet klart beskrivet?			
Total poäng:			

Total bedömning av kvalité:		
0–5 poäng, **låg**	6–11 poäng, **medel**	12–16 poäng, **hög**

Appendix 3. Tool for quality screening

Har studien ett begripligt syfte och/eller frågeställning?

- Är syftet och/eller frågeställningen en logisk följd av introduktionen? (Ja/Nej)
- Är syftet och/eller frågeställningen avgränsad och tydlig? (Ja/Nej)
- Är det rimligt att få fram ett svar? (Ja/Nej)

Har studien ett lämpligt urval kopplat till frågeställningen och/eller syftet?

- Kan urvalet svara syftet och/eller frågeställningen? (Ja/Nej)
- Beskrivs urvalet på ett precist sätt? (Ja/Nej)
- Är urvalet lik mål- eller undersökningspopulationen? (Ja/Nej)

Har studien passande inkluderings-/exkluderingskrav kopplat till frågeställningen och/eller syftet?

- Beskrivs inkludering- exkluderingskravet på ett klart sätt? (Vilka de är, varför)
- Stämmer inkluderingskravet överens med syftet och/eller frågeställningen? (Ja/Nej)
- Stämmer exkluderingskravet överens med syftet och/eller frågeställningen? (Ja/Nej)

Finns det en klar och formulerad bortfallsanalys?

- Redogörs det för bortfallet i metoden/resultatet? (Ja / Nej)
- Redogörs det för bortfallet i en tabell? (Ja / Nej)
- Resoneras bortfallet i diskussionen? (Ja / Nej)

Är studiens reliabel/valid? (vid kvant)

- Har instrumenten hög reliabilitet? (Minst Cronbach's 0,75)
- Beskrivs/diskuteras något av intern eller extern validitet? (Ja / Nej)
- Mäter instrumentet det syftet och/eller frågeställningen efterfrågar? (Ja / Nej)

Är studiens reliabel/valid? (vid kval)

- Ger insamlingstekniken information om det fenomen vi vill studera? (Ja/Nej)
- Beskrivs det om att det framtagna resultatet stämmer överens med resultat från tidigare studier av samma fenomen (Ja/Nej)
- Beskrivs det om att det framtagna resultatet stämmer överens resultaten med resultat från mätningar med annan metod/teknik? (Ja/Nej)

Är studiens reliabel/Valid? (Vid randomiserade)

- Diskuteras det något om intressekonflikter? (Ja/Nej)
- Diskuteras det något om ekonomiskt intresse i resultatet? (Ja/Nej)
- Diskuteras det något om jäv, bindningar et cetera? (Ja/Nej)

Är datainsamlingen precist beskriven?

- Skulle datainsamlingen kunna replikeras? (Ja / Nej)
- Beskrivs datainsamlingen i klara steg? (vart, när, hur)
- Beskrivs datainsamlingsmetoden på ett klart sätt? (vilken typ, omfattning av frågor)

Har en lämplig statistisk metod/analys använts?

- Beskrivs analysgången tydligt? (Ja / Nej)
- Lämnar analysmetoden ett svar som besvarar syftet och/eller frågeställningen? (Ja/ Nej)
- Är analysen riktigt utförd? (Ja / Nej)

Är resultatet klart beskrivet?

- Lämnar resultatet svar på syftet och/eller frågeställningen? (Ja / Nej)
- Är resultatet lättbegripligt? (Ja / Nej)
- Presenteras resultatet på ett begripligt sätt? (Ja / Nej)

3 Nej= Nej	**1 Ja/ 1 Nej= Delvis**	**3 Ja= Ja**

Appendix 4. Detailed overview of including articles

Author, year	Title	Aim	Sample	Loss	Study design	Data collection method	Main findings	Quality and generalizability
Afzal, A., Al-Subaiee, F. S., & Mirza, A. A, 2016	The Attitudes of Agricultural Extension Workers towards the Use of E-Extension for Ensuring Sustainability in the Kingdom of Saudi Arabia	Estimate the attitude of workers towards the use of E-extension and to control for the connection between the extension workers and their attitude towards the use of E-extension	230 extension workers in Kingdom of Saudi Arabia	65% (149)	Cross-sectional study, Quantitative	Questionnaire	Computer training and computer skill impacts positive attitude towards E-extension	Q= Middle G= High
Barut, C., Kiziltan, E., Gelir, E., & Kokturk, F. 2013	Advanced Analysis of Finger-Tapping Performance: A Preliminary Study	Explain the time course of average intertap-interval and the patterns of variation in left and right hands of right-handed subjects using the Tan Tong Finger-Tap system	38 male University students	3	Cross-sectional study, Quantitative	Single-finger-tapping test	Pattern of temporal difference in the intertap-interval can provide more trustworthy results in studies that evaluate the effects of working conditions, working hours and hand performance	Q= Middle G= Middle

Brooks, K. A., & Pettigrew, T. 2015	Exploring No-Cost Opportunities for Public Sector Information Systems Energy Efficiency: A Tennessee Application	Aims to serve as a proof of concept regarding occasions for cost savings through computer power organization policies	615 Central Office Computers	0	Longitudinal study, Quantitative	Networked computers	Strategic power management can have both positive and negative impacts on energy consumption, network security, productivity, worker and state budgets.	Q= Middle G= High
De Cocker K, De Bourdeaudhuij I, Cardon G, Vandelanotte, C. 2016	The Effectiveness of a Web-Based Computer-Tailored Intervention on Workplace Sitting: A Randomized Controlled Trail	Define the effects of objectively measured standing time, sitting time and pauses from sitting	213 desk-based workers	0	Randomized controlled trail, Quantitative	Web-based interventio n	Computer tailoring for sitting behavior and its possible use in public health promotion, and effects of the tailored condition were larger to the general and control conditions.	Q= High G= Middle
Hadgraft, N. T., Brakenridge, C. L., LaMontagne, A. D., Fjeldsoe, B. S., Lynch, B. M., Dunstan, D. W., Lawler, S. P. 2016	Feasibility and acceptability of reducing workplace sitting time: a qualitative study with Australian office workers	Investigate office workers' opinions of barriers to reducing sitting time at work	20 office workers	0	Qualitative	Semi-structured interviews	Having a knowledge of the health effects of prolonged sitting and having a supportive organizational culture are important for improving motivation for change	Q= High G= Middle
Jay, K., Brandt, M., Sundstrup, E., Schraefel,	Effect of individually tailored biopsychosocial	Explore the effect of an individually intervention strategy,	752 laboratory technicians	10%	Single-blind randomized controlled	Physical-cognitive-mindfulne	Increasing employee physical and mental capacity, motor/ mobility control- and cognitive	Q= High G=High

M. C., Jakobsen, M. D., Sjogaard, G., & Andersen, L. L. 2014	workplace interventions on chronic musculoskeletal pain, stress and work ability among laboratory technicians: randomized controlled trial protocol	effect of company policy ergonomics and effects on exercise initiatives on stress, chronic musculoskeletal pain and work disability.			design, Quantitative	ss training or follow company policies for 10 weeks at the worksite	training at the workplace may represent a useful approach for reducing chronic pain, stress and work disability in laboratory technicians.	
Jimenez Barbosa, I. A., Boon, M. Y., & Khuu, S. K. 2015	Exposure to Organic Solvents Used in Dry Cleaning Reduces Low and High Level Visual Function	Explore the experience to occupational levels of organic solvents is associated with neurotoxic symptoms and visual deficits in the perception	68 (33 dry cleansers, 35 non-dry-cleaners)	0	Randomized controlled trial, Quantitative	Questionn aire, Munsell Hue 100 test, letter visual-search task	Exposure to occupational levels of organic solvents is associated with neurotoxicity. This is associated with both high and low level visual deficits such as the perception of global form and motion, but not visual performance.	Q= Middle G= Middle
Kim, T., Kang, M.-Y., Yoo, M., Lee, D., & Hong, Y.-C. 2016	Computer use at work is associated with self-reported depressive and anxiety disorder	Investigate the association between computer work time and self-reported anxiety and depressive disorder	50,032 workers in South Korea	1182	Cross-sectional study, Quantitative	Questionn aire	A high amount of computer at work are associated with anxiety and depressive disorder.	Q= High G= Middle

Lindegard, A., Wahlstrom, J., Hagberg, M., Vilhelmsson, R., Toomingas, A., & Tornqvist, E.W. 2012	Perceive exertion, comfort and working technique in professional computer users and associations with the incidence of neck and upper extremity symptoms	Explain the association between; Perceived comfort and perceived exertion and working with the frequency of neck and upper extremity symptoms	853	204	Longitudinal study, Quantitative	Questionnaire	There was a strong association between high perceived exertion and the development of shoulder/neck, and hand/hand symptoms. An association between neck pain and poor perceived comfort.	Q= High G= High
Madeleine, P., Vangsgaard, S., Andersen, J. H., Ge, H.-Y., & Arendt-Nielsen, L. 2013	Computer work and self-reported variables on anthropometrics, computer usage, work ability, productivity, pain and physical activity	Compile an analysis on both long and short-term pain and work-related variables	690	4310	Cross-sectional study, Quantitative	Questionnaire	Pain perception were reported by only women. Analyses confirmed the complex interplay between work ability, pain perception, productivity and anthropometrics.	Q= High G= Middle
Mediouni, Z., Bodin, J., Dale, A. M., Herquelot, E., Carton, M., Leclerc, A., Descatha, A. 2015	Carpal tunnel syndrome and computer exposure at work in two large complementary cohorts	Estimate the association between computer usage and CTS	4817 workers	1763	Longitudinal study, Quantitative	Health examination, questionnaire	CTS is more common among workers in non-computer related workplaces	Q= High G= High

Radulovic, B., & Hursidic-Radulovic, A. 2012	Frequency of musculoskeletal and eye symptoms among computer users at work	Investigate the frequency and relation between eye symptoms and musculoskeletal symptoms	49 workers	0	Cross-sectional study, Quantitative	Questionnaire	Exercises for stretching musculoskeletal system and using ergonomic computer gear can improve productivity and decrease sick leaves	Q= Middle G= Middle
Ho, W.-Y., Sung, C. Y. Y., Yu, Q.-H., & Chan, C. C. H. 2014	Effectiveness of computerized risk assessment system on enhancing workers' occupational health and attitudes towards occupational health	Sum up the research in two studies, regarding reduce body distress and mental fatigue and enhancing workers' occupational health	1500 in Hong Kong	1389	Longitudinal study, Quantitative	Questionnaire, interview	Workers' input and incorporation of ergonomics into the management are important for successful operation of occupational health programs	Q= High G= Middle
Irmak, A., Bumin, G., & Irmak, R. 2012	The effects of exercise reminder software program on office workers' perceived pain level, work performance and quality of life	Define the efficacy of the exercise program on office workers' perceived work performance, pain level and quality of life	39	0	Randomized controlled trial, Quantitative	VAS, WRFQ SF-36, Stretching exercises	Exercise is effective in reducing pain. It had no effect on quality of life and work performance.	Q= Middle G= Middle
Kingston, D. C., Riddell, M. F., McKinnon, C. D., Gallagher, K. M., &	Influence of Input Hardware and Work Surface Angle on Upper Limb Posture in a Hybrid	Explain the effect of work surface angle and input hardware on upper-limb posture when using a hybrid	14	0	Trial, Quantitative	Two hardware types and two workstatio	A recommendation is that use horizontal- surface computer for typing and to use a sloped-surface tablet for intermittent reading tasks.	Q= High G= High

Callaghan, J. P. 2016	Computer Workstation	computer workstation				n slopes across three common computer tasks		
Ranasinghe, P., Wathurapatha, W. S., Perera, Y. S., Lamabadusuriya, D. A., Kulatunga, S., Jayawardana, N., & Katulanda, P. 2016	Computer vision syndrome among computer office workers in a developing country: an evaluation of prevalence and risk factors	Estimate the prevalence of CVS and its associated elements	2210	290	Cross-sectional study, Quantitative	Questionnaire	Higher daily computer usage, Female gender, pre-existing eye disease, longer duration of occupation, use of contact lenses, not using a VDT filter and higher ergonomics practices knowledge were significant associated with the presence of CVS.	Q= High G= High

Robertson, M. M., Huang, Y.-H., & Larson, N. 2016	The relationship among computer work, environmental design, and musculoskeletal and visual discomfort: examining the moderating role of supervisory relations and co-worker support	Study the factors of computer use, psychosocial factors, workspace design and organizational ergonomics resources on visual- and musculoskeletal discomforts and their effect on the health and safety	1724	465	Cross-sectional study, Quantitative	Questionnaire	Significant connection were found between psychosocial factors and computer use of co-worker support and guiding relations with musculoskeletal and visual discomfort.	Q= High G= Middle
Dul, J., Bruder, R., Buckle, P., Carayon, P., Falzon, P., Marras, W. S., & van der Doelen, B. (2012).	A strategy for human factors/ergonomics: developing the discipline and profession.	Deliver an image of the future of the human factors/ergonomics (HFE)	findings of the Future of Ergonomics Committee	0	Qualitative study	Interviews, email exchange	Suggest a joint world-wide HFE expansion plan, in which the IEA takes a leadership role	Q= High G= High
Juslén, H., & Tenner, A. (2005).	Mechanisms involved in enhancing human performance by changing the lighting in the industrial workplace	Study what happens when the lightning is shifting at an industrial workplace	Old field studies in industrial environments	0	Retrospective study	Field studies	Ten mechanisms that contribute to the increase of human performance after improving the lighting. (visual comfort, visual performance, interpersonal relationships, visual ambience, biological clock, job satisfaction,	Q= High G= High

							stimulation, problem solving, the halo effect, and the change process)	
Boyce, P. R. (2011).	On measuring task performance	Defines the methods that can be used to measure task performance and demonstrates them by reviewing what is known about the impacts of illuminance and light source spectral power distribution on task performance	real tasks field studied	0	Quantitative study	Field studies measured in laboratory	Being clear about what kind of performance has been measured and how those measurements were made is the first step in understanding what the results mean and to what purpose they might helpfully be put.	Q= Middle G= High
Haynes, B. P. (2008a	An evaluation of the impact of the office environment on productivity.	To describe the effects of the office environment on its workers perceived productivity.	Two dataset (1418 in total)	In total: 5138	Longitudinal study, Quantitative	Questionn aire	The social environment has the greatest effect on office productivity	Q= Middle G= High

Appendix 5. Questionnaire

Jag ger mitt samtycke

Ja

Bakgrundsfrågor

1. **Kön**
   - Kvinna
   - Man
   - Vill inte definiera mig själv
2. **Ålder**
   - Skriv själva
3. **Civilstånd**
   - Gift
     Sambo/Partner
   - Singel
   - Änka/Änkling
4. **Hur länge har du haft ditt nuvarande jobb?**
   - Skriv själva
5. **Längd?**
   - Skriv själva
6. **Vikt?**
   - Skriv själva
7. **Hur ofta ägnar du dig åt någon form av vardagsmotion i sammanlagt minst 30 minuter?**
   - Mer sällan än 1 ggr/mån
   - 1 ggr/mån
   - 2-4 ggr/mån
   - 2-3 ggr/vecka
   - 4 ggr eller fler/vecka
8. **Har du gått till en optiker de senaste 2 åren för att uppdatera styrkan på dina glasögon alternativt prova ut ett par nya glasögon eller kontaktlinser?**
   - Ja
   - Nej
   - Vet inte
9. **Hur upplever du din sömnkvalitet?**
   - Mycket dålig
   - Dålig
   - Sådär
   - Bra
   - Mycket bra
10. **Utanför ditt arbetsliv, hur många timmar skärmtid har du per dag?**
    - Skriv själva

Visual ergonomi

11. **I ditt arbetsliv, hur många timmar arbetar du framför en bildskärm i snitt varje vecka?**
    1. [ ] 0 timmar
    2. [ ]
    3. [ ]
    4. [ ]
    5. [ ] 40 timmar

12. **Hur upplever du att du har att hitta skärpan när du läser texten på bildskärmen?**
    1. [ ] Mycket svårt
    2. [ ]
    3. [ ]
    4. [ ]
    5. [ ] Mycket lätt
13. **Hur upplever du dina inställningar på bildskärmen/bildskärmarna gällande skärpa, upplösning eller färg?**
    1. [ ] Mycket dålig
    2. [ ]
    3. [ ]
    4. [ ]
    5. [ ] Mycket bra
14. **Hur upplever du att din synkomfort på din arbetsplats är?**
    1. [ ] Mycket dålig
    2. [ ]
    3. [ ]
    4. [ ]
    5. [ ] Mycket bra

Subjektivt visuellt välmående

15. Har du något eller några av följande ögonbesvär? Om ja på något besvär, fortsätt då med att besvara hur ofta det förekommer och svårighetsgraden?

			16. Förekomst			**17. Svårighetsgrad**		
Symtom	**Ja (1)**	**Nej (0)**	**Enstaka gånger (1)**	**Varje vecka (2)**	**Dagligen (3)**	**Obetydliga besvär (1)**	**Måttliga besvär (2)**	**Uttalande besvär (3)**
Sveda i ögonen								
Ögonklåda								
Gruskänsla								
Ögonvärk								
Ljuskänslighet								
Rödögdhet								
Tårögdhet								
Torrhet i ögonen								

Prestation

Följande frågor undrar om din visuella prestation just nu

18. **Hur upplever du din prestation bakom bildskärmen, i relation till maximal prestation?**
    0 [ ] Väldigt liten
    1 [ ]
    2 [ ]
    3 [ ]
    4 [ ]
    5 [ ]
    6 [ ]
    7 [ ]
    8 [ ]
    9 [ ]
    10 [ ] Mycket hög

19. I vilken utsträckning blir du tvungen att avbryta bildskärmsarbete, för att du känner besvär från ögonen?

0 [ ] Väldigt lite
1 [ ]
2 [ ]
3 [ ]
4 [ ]
5 [ ]
6 [ ]
7 [ ]
8 [ ]
9 [ ]
10 [ ] Väldigt mycket

20. I vilken utsträckning upplever du att du utför mindre bildskärmsarbete än vad du skulle vilja, på grund av bristfällig synkomfort?

0 [ ] Väldigt lite
1 [ ]
2 [ ]
3 [ ]
4 [ ]
5 [ ]
6 [ ]
7 [ ]
8 [ ]
9 [ ]
10 [ ] Väldigt mycket

21. I vilken utsträckning upplever du att du är begränsad i hur länge du orkar utföra bildskärmsarbete, på grund av bristfällig synkomfort?

0 [ ] Väldigt lite
1 [ ]
2 [ ]
3 [ ]
4 [ ]
5 [ ]
6 [ ]
7 [ ]
8 [ ]
9 [ ]
10 [ ] Väldigt mycket

22. I vilken utsträckning upplever du att kvaliteten på ditt bildskärmsarbete är lägre än vad det borde vara, på grund av bristfällig synkomfort?

0 [ ] Väldigt lite
1 [ ]
2 [ ]
3 [ ]
4 [ ]
5 [ ]
6 [ ]
7 [ ]
8 [ ]
9 [ ]
10 [ ] Väldigt mycket

Appendix 6. Letter to respondents

Hej,

Jag heter Sofia Sundin och studerar Masterprogrammet i Arbetshälsovetenskap vid Högskolan i Gävle. Inom programmet bedriver jag nu mitt examensarbete och utför då en studie. Syftet med studien är att bidra med en ökad förståelse för arbetshållanden, i form av visuell ergonomi och prestation och dess förhållande till varandra. Inklusionskriteriet för att delta i studien är att du är anställd och arbetar vid bildskärm under ditt dagliga arbete, samt att du är minst 18 år gammal. Föreliggande enkät är helt frivillig och du kan när som helst avbryta ditt deltagande genom att stänga ned enkäten. Din anonymitet garanteras genom att inga personliga frågor kommer att ställas och dina svar kommer inte kunna spåras tillbaka till dig. Insamlingsmaterialet kommer endast att användas till uppsatsen och inga obehöriga kommer att ha tillgång till materialet. Datamaterialet kommer att behandlas i ett statistikprogram och analyseras sedan på gruppnivå. Allt datamaterial kommer att raderas efter att kursen är avslutad.

Enkäten innehåller 22 frågor och tar cirka 10 minuter att besvara. För att påbörja och därefter medverka i studien krävs det att du ger ditt samtycke.

Vid eventuella frågor eller funderingar, kontakta gärna mig!

Vänligast,

Sofia Sundin
Mail: **********
Tel: **********

Handledare:
Hans Richter
Mail: **********