When Knowing Is Not Enough: Promoting Ergonomic Awareness by Use of Ambient Information Systems

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ABSTRACT
This article is the result of a bachelor's project within the field of Information and Communication Technology (ICT). The project had a duration of a semester. Our main focus was on how the use of Tangible User Interfaces (TUI) - and more specifically - Ambient Information Systems - can help remind office workers of their own ergonomic conditions within an office work environment. By using a taxonomy on ambient information systems by Pausman and Stasko for a theoretical approach, as well as conducting interviews and questionnaires for a practical approach, we were able to define the fundamental attributes of our design concept, giving focus on key design aspects. Furthermore, we used this knowledge to construct a fully functional prototype we tested on possible end users, with the results discussed in relation to related work.

RESUME
Denne artikel er resultatet af et bachelorprojekt inden for området Informations- og Kommunikationsteknologi (IKT). Projektet havde en varighed på et semester. Vores hovedfokus var, hvordan bruger af Tangible User Interfaces (TUI), og mere specifikt Ambient Information Systems, kan hjælpe med at påminde kontorarbejdere om deres egne ergonomiske forhold, inden for et kontormiljø. Ved at benytte os af en taksonomi inden for ambient informationssystemer, af Pausman og Stasko, for en teoretisk tilgang, såvel som udførslen af interviews og spørgeskemaer for en praktisk tilgang, har det været muligt at definere fundamentale egenskaber til brug i vores designkoncept, med fokus på visse hovedaspekter. Endvidere har vi brugt denne viden til at konstruere en fuld funktionel prototype, som vi testede på mulige slutbrugere, med resultaterne diskuteret i forhold til relateret arbejde.

MOTIVATION
Our motivation for conducting research within the field of ergonomics is founded in a universal need for solving ergonomic problems in an office work environment. We are familiar with this problem since we have experienced the consequences that can occur by prolonged work at a computer without taking breaks. Besides that, we have family members struggling with injuries such as tennis elbow or pain in the lower back, that have occurred because of ergonomic problems at work.

We saw this as an opportunity to improve these conditions while obtaining a better understanding of what office related work requires.

General Terms
Measurement, documentation, design, experimentation, human factors.

Keywords
Ergonomics, Ambient Information Systems, Peripheral Attention, Office Work Environment.

Note to Readers
Please note that all quotations from Danish sources (i.e. websites, interviews, questionnaires etc.) have been translated into English by the authors of this article.

1. INTRODUCTION
Ergonomics is a scientific discipline that has been around for many years now, originally focusing on the safety for factory workers. Nowadays, it is a discipline that has grown to include all kinds of work forms. [34] describes different factors in the science of ergonomics, as well as the general physical and mental characteristics of work, like posture, stress, repetition, and so on. This information showed us which main areas that had to be taken into consideration when trying to define what ergonomics is about.

In Denmark, The Danish Work Environment Authority (DWEA) has established a set of specific rules known as The Working Environment Act (WEA)[3]. This act states that all Danish companies have a commitment to follow the rules set by the DWEA and at the same time it acts as a working tool used for improving work environments. In the descriptions of office work, the Danish Work Environment Authority has made a directory [3] which helps the companies making a WEA with the goal of taking ergonomic factors into account - which also means that the DWEA has made a list of the most important rules the company has to follow. An example of this is working at computer screens for which the directory states:

"The employer must make sure to organize work at computer screens such that the daily work is regularly interrupted by different work or - if not possible - interrupted by breaks so that harmful health related issues are avoided."[3]

This is followed by several other rules like how the company must pay for a visual examination to see if the employee needs special glasses for use at a computer (which the company must pay for as well), or how the desk, chair or monitor must be positioned ideally.

So what health related issues are caused by bad ergonomics, and how can one avoid them? Healthycomputing.com has a thorough list of specific conditions like carpal tunnel syndrome, wrist tendonitis and trapezius myalgia [7] as well as a list of how these conditions arise. They also have a list of stretching exercises which - according to their website - will help prevent the medical conditions, as well as a guide of how to construct the work environment properly. Wyatt et al. [38] had researched on students' use of laptops at schools and how bad the ergonomics involved when using the laptops is. They propose a list of observed health issues consisting of problems with eyes, head and neck, shoulders, elbows and arms, forearms, wrists and hands, hips, legs, knees, feet and ankles, and the upper and lower back. This is followed by a list of proposals on how to handle these issues no matter when and where the students are working. All this can be cut down to the fact that including some kind of variation in the work methods can prevent the health issues in bad ergonomics, which is part of what we want to research.

Realizing how difficult it is to remember good ergonomics, we chose to use ambient information systems as our way of interacting with people. Ambient information systems are a way to provide users with information that we monitor with little to no conscious effort. Just like windows reveal the weather outside and provides an approximation of the time of day, or first impressions can be deduced by smells, ambient information systems are designed to make certain information in our environment peripheral to our main focus of attention [14]. As such, using this technology, our goal is to make office workers attentive to their ergonomics without interrupting their work flow.

This article has taken its base in a banker's office environment. This environment is a challenge ergonomically because of the consistent costumer contact as well as it being in an open office space, where the workers have a high amount of working hours sitting at their desks without being made appropriately aware of their own work routines.

2. RESEARCH QUESTION

Is it possible, with the use of ambient information systems, to help remind office workers of their current ergonomic work conditions?

3. RELATED WORK

In the field of improving ergonomics, there has been various suggestions as how to do so. For instance, there are several different kinds of ergonomic furniture and office accessories available and in use. When speaking of ergonomic furniture and office accessories, we are referring to e.g. multipositionable chairs, adjustable desks, wireless headsets, and ergonomic keyboards and computer mice [36]- which are all adjustable according to people's individual needs.

Several software solutions have has also been made, trying to make people remember to take breaks or use exercises in order to help stretching, like ActiveClick [1] which automatically clicks and drags objects on the screen; Albion StopNow! [32] which reminds you that you need a break in order to prevent repetitive strain injuries; Stretch Break [27]which reminds you to take a stretch break and shows you how to stretch properly. Morris et al. [17] have done research on how to use software interactivity to enhance ergonomic typing breaks. As such, they have made a software system in which camera tracked game-based interactivity is the key to improve ergonomics, called SuperBreak. SuperBreak was trying to improve software solutions by using camera tracking instead of mouse clicking, using the keyboard or stepping away from the computer, by taking the breaks in front of the computer while playing a game making you physical active.

The option of combining the furniture with modern technology has opened new doors as to how it is possible to help people's individual ergonomic needs, enabling ways which were previously unattainable. By using physical artifacts as the main way of reminding users of their ergonomic situations, it is possible to avoid interruptions of workflow - which is often seen in software-only solutions by e.g. popups on the screen. Daian et al. [4] from the University of Technology Eindhoven, proposed the Sensitive Chair as a possible way of combining software and physical artifact. In this project, force sensors were used to measure users' sitting postures and then use the data in a physical artifact. This physical artifact would face the users if their sitting posture was adequate, and it would turn its back to the users if the sitting posture was inadequate - all of it while using sounds to inform the users of what is going on.

Another example of these mixtures of software and physical artifacts (which will be referred to as Tangible User Interfaces, or TUI) is the Ambient Orb [2]. The Ambient Orb is a ball-shaped artifact which changes its inner color according to its configurations, such as checking market stock movements. As such, the Ambient Orb will start out yellow and turn green if stock prices are going up, and it will turn red if stock prices are plummeting. Other kinds of ambient media is the ambientROOM [11] which is a different approach compared to the Ambient Orb, since it is not a single physical object, but the entire room being a complete interface for processing information in the background of awareness. As such, there is no clear definition of when an object is ambient - whether it is an entire room or a simple ambient fixture [11].

These two examples of TUI are what Ishii [10] calls *ambient media*. This ambient media describes the kinds of interfaces that are used to smooth the transition of users' attention between background and foreground information. Within the topic of TUI, Fishkin [5] proposed a taxonomy that focuses on the dimensions of embodiment and metaphors which would unify previous frameworks for TUI systems, also stating that the more a TUI system is full-level in both dimensions, the more it is tangible and even shows how it can accommodate and locate *calm technology*. Mark Weiser and John Seeley Brown [37] call this ambient media *calm technology* and explain that it is about engaging both the center and periphery of our attention and how it moves back and forth between these two.

Hemmert [9] has done research in this field to investigate in what way it is best to get attention from users through ambient technology. As such, he has tested three different approaches on mobile phones, these being shape change, vibration and weight shifting, and he concludes that embodied systems could be an effective approach to notifying users through ambient technology.

Another approach to testing how ambient information systems work most effectively is by Haller et al. [6], who did research on how to properly interrupt people in an office environment with the goal to improve their sitting posture. They use three different prototypes to see which way is the most effective: an icon on the computer (graphical feedback), a physical agent that moves (physical feedback), or a vibrating chair (vibrotactile feedback). Another way to inform users ambiently is the use of lighting, according to Occhialini et al. [26]. In this explorative research, Occhialini made an ambient display using dynamic light patterns on the walls of class- or meeting rooms, with the purpose of reminding speakers of how much time they have spent talking. Pousman and Stasko have proposed a taxonomy made of four patterns of design [28] used as a tool for designing ambient information systems. We will use this taxonomy, which also means that there will be a more detailed description of its use.

As discussed earlier, the WEA gives a set of rules for the ergonomics in an office environment [3]. One of the rules that we were inspired to have our system supporting, was ensuring proper variation and breaks in the daily work routines. As described, many have already tried to support good ergonomics in the office work environment through the use of the adjustable chairs, tables and other appliances; however, those solutions that have influenced our project were those that applied TUI and more specifically ambient technology. The most inspiring were the work of Daian [4] and Haller [6] who both used some kind of physical feedback as means of communication to make the users aware of their own (sitting) posture. Our solution should, however, use this type of feedback to make users aware of their variation of work routines (or lack thereof). Like [4, 17], we will apply the use of taking breaks as part of our design, but not incorporate the use of exercising (as a part of it), since the sole purpose of our design is to make the users aware without encouraging them to take action, as it may seem inappropriate in a bank office environment.

4. METHODS

In order to get a better understanding of how ergonomics affect people in their work environment, we interviewed a professional ergotherapist about general ergonomics as well as a bank employee - who is in charge of the ergonomics in said bank - so that we could get some insight of how it works in practice. We also made an online questionnaire to get inside information from desktop workers. In this section, we will describe our findings.

4.1 Questionnaire

Using the knowledge from DWEA [3], Healthycomputing [7]and Wyatt [38] about ergonomics, we started questioning what we actually knew. We made an online questionnaire and sent out the questionnaire to the Danish companies Tieto A/S, Sparekassen Hobro, BM Autoteknik A/S and Paschal Danmark A/S as well as Aarhus University. The reason for sending out the questionnaire to companies from different professions is to see if there are any differences between what kind of work you do and ergonomic health issues. Our main point of focus in the questionnaire was to get an idea of how common ergonomic health issues are as well as getting the office worker's own oppinion on the matter of ergonomics. Furthermore, we also wanted to know if the workers were willing to spend time on exercises during their working hours, and their oppinion on what kind of solution would be favourable to them (e.g. preventive, informative or direct action).

As such, we made this questionnaire [20] with both open and closed concise questions to try to avoid misunderstanding. The form of the questionnaire's was similar to an interview, starting with introductory questions, phasing into information-seeking questions about the workers' own experiences with ergonomic issues, ending in open questions about how they would like a future system to assist them.

Our questionnaire [25] gave us 42 unique responses, and made us able to get a realistic picture of how widespread various issues are. As such, we were able to notice the following tendencies:

- 55% experiences health issues from office work.
    - 91% of the people with health issues have worked at an office for at least 10 years.
    - 82% of the people with health issues work at an office for at least 60% of their daily work time.
    - 43% of the people with health issues can feel it several times every week.
- 76% work in an open office environment
- 93% want a preventive solution.
- 48% would want to do exercises during work hours to prevent injuries.
- 86% say exercises must last a maximum of 5 minutes per session.

Considering these tendencies, we can now conclude that 55% of people working in office environments are subject to damages in their health - especially if they have been working for more than 10 years. It is notable, however, that not all of the injured workers spend most of their time in office environments and it is possible they have been injured by other means. An interesting fact here is about half of the workers who have had injuries feel pain several times every week. It is also interesting that 76% work in an open office environment which means we have to be aware of the fact that some people may not want to do stretching exercises in front of other people. This also closely relates to the fact that only half of the people would want to do exercises during work hours. This means we have to closely consider whether we want to make a system that forces people into exercises, or in some other way make people stop sitting at their computers. If, however, we want to promote exercises, most users note that they only want to do exercises for 5 minutes, which could become a problem in order to work out properly. Finally, nearly everybody wants a preventive solution which means our system must be able to somehow track the users' work routines.

4.2 Interview with Professional Ergotherapist

We made an interview with an ergotherapist in order to check up on the validity of our earlier findings, as well as to obtain more expert knowledge on ergonomics in office environments. We made an interview guide [23] in order to keep our focus during the interview on what we specifically wanted to know [12]. Our interview would be described as being semi structured [31] , since we had made a manuscript to keep us focused on what we wanted to know as well as having pre-planned questions at first, and then turning to explorative questions to get more details when necessary. This was done in order to get as much information as

possible so that we would be sure to have proper knowledge to compare with our earlier findings and questionnaire. The interview was done over the phone by the request of the ergotherapist and lasted for 39 minutes [22].

When we asked the ergotherapist whether she works exclusively as a consultant or if she treats people as well, she told us about one of her days at work, *"[...] some of the people I talked to have had pain in their necks and backs [...] and I asked them if they have used the offer of free consultations with a physiotherapist, and they told me they had thought about it but didn't have the time for it."* This could mean that people are well aware of the ergonomic possibilities around them - they just seem to forget it or prioritize differently. She also noted that people seem to not use what they have at their disposal, *"[...] Provided that people use it. You know, you can have the best items at your disposal but if you for some reason do not get it adjusted to you, or if you sit so that it does not fit you, that is how it is."*. This could indicate the fact that people tend to forget the ergonomics at their work place, which leads to not adjusting their chairs or tables to accommodate their individual needs.

We asked the ergotherapist if it means that the people who use the computers should avoid repetitive work, to which she answered, *"Yes. It is called RSI, repetitive strain injuries, and it has been an issue for many years. [...]"*, after which she states that it is often caused by typing or doing precision work on a computer. When asked how to avoid this, she said, *"[...] you need to take some breaks. Just microbreaks where you just sit around and you stop typing, lift your hands, and then do a few stretches or something else for the body. Stand up and move around. So you could say that the physical layout (of the office) has to be able to adapt to each individual. "*. This lead to our next question, concerning if there are any special methods or exercises that should be considered to improve ergonomics, to which she told us, *"Well, you could say if you want to use a general word that the most important thing is variation. It it is the most important part of it. [...] and what is variation? It is the way in which you work, the amount of time spent at a computer, the type of work you are doing, all that sort of things."*. This keyword, *variation*, can be compared to the list of possible ways of treatment as proposed by Wyatt [38] which was described earlier. Good ergonomics in an open office environment also applies to how sounds are handled, *"[...] depending on whether you sit in a place where you cannot interrupt too much because that is an important factor if you are in an open office."* which means to us that if we want to use sounds we have to be aware of how much it can be an annoyance more than an aid - not just to the user of our system but also to everyone in proximity of the user.

Since Wyatt [38] and Healthycomputing.com [7] mentioned using stretching exercises to help prevent ergonomic injuries, we asked for the ergotherapist's opinion on the matter, and she told us that *"I think it is a really good idea to make people used to doing a few stretching exercises every day. [...] stretching is really good because it prevents muscle tension"*, which confirmed that the use of exercises is in fact a proper way to help prevent injuries. About preventing the injuries from happening at all, the ergotherapist said, *"Prevention is definitely the way. It is quite obvious. Besides, the law states that you have to prevent people from getting ergonomically related injuries at work"*, which is consistent with the information from DWEA and our questionnaire findings.

As such, the most important finding from our interview with the ergotherapist is how changing the entire work routine is the best way to improve ergonomics. Stretching is a good idea, but it is not sufficient in the long run. Office workers need to get away from their usual routines of sitting in their adjustable chair typing on a keyboard, e.g. by taking breaks, going for a coffee run more often, or getting some more paper for the printer - all of which are small routines that apply to what the ergotherapist describes as being *variation* - the keyword for proper ergonomics.

4.3 Interview with Bank Administrator

Similar to the interview with the ergotherapist, we had a interview [21] with a bank employee from Sparekassen Hobro. This was also an open-ended interview [19] with the purpose of understanding a bank employee's daily work practice, the bank administrator's handling of ergonomics in work environment, and possible issues within this area.

When asked if the employees wanted to be informed on how they could avoid injuries that occur through bad ergonomics, the bank administrator answered, *"They already know what they can do to avoid these injuries, it is just something they forget while working"* which supports the information from the ergotherapist about how people are well aware of how to maintain good ergonomics, they just forget it. Seeing how workers seem to forget what to do, the administrator also stated that the bank spends a lot of money on buying adjustable desks and chairs in order to fulfill the needs of the workers with injuries, but she has come to a realization: *"It does not help to buy them ergonomic products if they do not use them properly."* This could also be due to the fact that the workers simply forget good ergonomic practice.

Unlike the SuperBreak solution [17], the bank manager states that using a software application would be of an annoyance if the solution had a pop-up function: *"We agreed, I think, that it would be unpopular.[...] Another aspect is that they are in the middle of something and it is really annoying when something pops up right in the middle of everything."* Here we could consider developing a concept that is not on the employee's computer screen, but in the physical environment of employee's office similar to the use of physical feedback in Haller et al. [6] and the Sensitive Chair [4]. Even further supporting this consideration is that it would also be good if *"[...] you could ignore it [the given solution to remind the user] if you were talking on the phone or doing something important at the given moment."*

What also support the results from the questionnaire are the ergotherapists thoughts about a preventative solution: *"... you do not stand up until your back hurts. If you had something that was preventative then you might actually avoid experiencing pain in the back."* and *"The ideal scenario is if we could fix the problem, before it appears"* since in the later explorative part of the the interview the employee mentions that: *"We actually have a big of problems with ergonomics [...] we have many people that are going to massages and chiropractors and have pains in their lower backs and all those sort of things. So it is a very important subject."* meaning that ergonomics is an important issue and that both the company and the workers could benefit from a preventative solution. This could prevent the employees from experiencing injuries and pain and thus prevent the company from spending resources on treatments of these injuries.

4.4 Specification of Requirements

We know from the questionnaire that 76% of people are working in an open office arrangement, which means that our prototype should not annoy or in other ways interrupt the work of other people. This means we have to take care if we want to use sound as a way of notifying people. However, according to our ergotherapist, our bank administrator and the research done by Daian [4], one should be very careful about the use of sound as a notifier as it will often lead to frustration among users and people close to the user.

We also found, from our interview with the bank administrator as well as from related work, that several sound based software solutions already exist but mostly are of annoyance because of the way they interrupt the workflow of the users by popups. Our design must therefore make sure not to disrupt or decrease work efficiency. This can also be seen as a reason for making the system ambient since ambient technology is supposed to be calm [37], yet be able to catch the user's attention when needed. This, of course, depends on which technology is used for seeking attention since vibrotactile feedback, as promoted by Hemmert [8], is mostly considered as frustrating, whereas shape changing [9] or light indication [27] can be effective, calm technologies. Using a physical, ambient agent is also inspired by the research made by Daian's sensitive chair [4] as well as Haller's research[6].

The bank administrator let us know that people are well aware of how to be ergonomically responsible, they just keep forgetting it, which means we could quit the idea of teaching people stretching exercises, and instead focus on *reminding* them of good ergonomics. This is closely related to the software-only solutions previously described with the timed popups for reminding people to take a break. Seeing as how the Sensitive Chair project put sensors in a chair to measure if people were sitting in it, we believe that they lack the ability to register if the computer is still being used. Our ergotherapist stated that people have to get away from the computer in order to be thoroughly ergonomically responsible, which means that people could still be semi-responsible by raising their desks and working standing by not performing none computer related work. The Sensitive Chair [4] did not take this into account, which we believe we have to seeing as - according to the bank administrator - some people are using their chairs and desks properly but still are not ergonomically responsible. A solution to this would be to include an activity checker to see if anyone is typing on the keyboard or if the mouse is being moved or clicked. With this information, we are now able to make a list of requirements that our design should include. It should:

- Be an ambient system in order to avoid frustration, yet create awareness.
- Make the user aware of the fact that he should leave his desk for a break.
- Include an activity notifier for checking activity on the user's computer, in case of users standing while working.
- Have a clear, but high, level of abstract feedback information to the user in the form of shape change, lighting, or both.
- Be a design whose sole purpose is to remind users of what they already know about ergonomics and stretching exercises.
- Not disrupt or decrease workflow efficiency since this is a cause of annoyance and frustration.
- Aesthetically pleasing and fit naturally into the user's work environment.

5. CONCEPT AND DESIGN

5.1 Design Ideas

This part of the article investigates our different design approaches, and uses a specified taxonomy in order to better understand the different aspects of designing ambient information systems, and to get an idea of what to expect of a design concept.

With our list of requirements and inspiration from related work, we started designing different concepts.

5.1.1 First idea – Balloon

Through the works of Hemmert (et al.) [9], it was concluded that making artifacts seem alive is a different way of designing. It is a different way of understanding an artifact, and it can be used efficiently for awareness. Through that, we came up with the idea of having a small balloon expand slowly during a 40 minutes interval, which is an optimal work time followed by a 5 minutes break [34]. In this way, the office users will be able to see a change of shape in the artifact, which should trigger an alarm

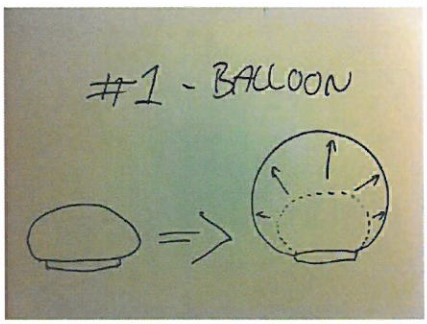

Figure 1 – Balloon idea

making the users remember to take a short break.

5.1.2 Second idea – Twister

Our second idea is also greatly inspired by the works of Hemmert. This time, it is a prism-shaped artifact that will slowly twist its own body, as to make an abstract reference of how their back is will be hurt if they sit in a bad position (se figure 2). This will also adhere to the 40 minute rule we referred to earlier. If the users choose to ignore the twist (or they simply do not see it) an internal red light will start increasing in strength. At the beginning, it will be a hardly noticeable light indication, but after a short while, the light will increase until you will have trouble ignoring it.

Figur 2 - Twister idea

5.1.3 Third idea – Ambient Agent with a monitor

Our third idea is an ambient agent with a small monitor on it (figure 3). The shape of the artifact is determined as to allow it to be used no matter the angle of perspective. The monitor will stay neutral and darkened so the users will not notice it at all. After a while, a small light indication will start lighting up, from the bottom of the artifact. After 40 minutes of this, the monitor will turn itself on with a big warning sign. The warning sign will flicker slowly, and change into a drawing of a person sitting at a desk with some obvious back ache.

A different take on this last idea was to make it personalized by having the users use it as a portrait. We also discussed using vibration as a way of getting the user's attention. However, according to Hemmert [9] and Haller [6], vibration could in the end annoy people more than it can help them, which can lead to people not want to use the product.

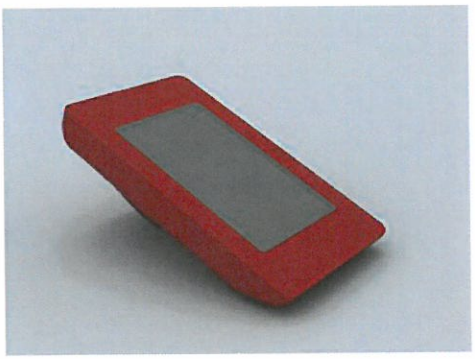

Figure 3 - Ambient agent with display

Using the taxonomy of ambient information systems by Zachary Pousman and John Stasko [28] from Georgia Institute of Technology, it is possible for us to define both our preferred design for relaying information, and our preferred physical aesthetics.

6. TAXONOMY OF AMBIENT DISPLAYS

This is a review of the taxonomy of ambient information systems. Here we will discuss the four key design aspects of the taxonomy and what they represent. It is also important for us to describe the four models and what they represent - so that later on we will be able to use it in our discussion and analysis. We will discuss our preferred taxonomy based on information from our interviews, questionnaires and related work, and then compare and evaluate three of our design ideas with our preferred taxonomy.

It is important to note that the taxonomy is a tool for product designers to plot their intentions about the purpose of the ambient information systems within the four design aspects, which all range from low to high:

Information Capacity
This aspect shows how much information the designer wants to communicate to the user. Ambient information systems with a physical display of information often have a low *information capacity*, whereas those that have information represented by displays (e.g. LCD or similar) often tend to have a high *Information Capacity*.

Notification Level
This aspect focuses on the users' attention to the system. The scale of attention is divided into five categories: *user poll (low), ignore, change blind, make aware, interrupt* and *demand attention (high)*. Physical displays are typically not in the levels *make aware, interrupt, demand attention* and it is but the fewest ambient information systems that reach the *demand attention* level.

Representational Fidelity
This aspect represents levels of abstraction of the system information communicated to the user. The lowest level is often represented symbolically (e.g. abstract symbols) typically found in physical displays, whereas the highest level of representation is indexical (e.g. maps).

Aesthetic Emphasis
This aspect is concerned with how much focus a designer had on a the aesthetics of a system and is therefore perceived from a subjective point of view. The focus in the aesthetics of the system range from the lowest - where the designer puts information conveyance at a higher priority than aesthetics - to the highest, being mostly focused on high aesthetics, often with the loss of information capacity.

6.1 Preferred Taxonomy

Through our findings based on interviews, questionnaire and earlier discussions of related work, we came up with the following preferred taxonomy which is our suggestion for an ideal solution.

Based on what we know from [21, 22]; i.e. that *variation* in work habits is the most important factor for good ergonomics, and that it is only necessary to inform the users of *when* it is time to change their work routine and not needed to explain to them *why* they should do so, since the workers know how and why they should put variation into their work routines. It is also important to continuously remind the users that they should switch between different working routines, postures and to take breaks, since that is a part of putting variation into work habits. With these preferences, the *information capacity* scale of our preferred taxonomy would be one which is the lowest in the *information capacity* scale, since we only need to make a reminder for the user that has to make sure not to interrupt their work routines until necessary. Related work showed this was possible by a simple change of color of lamps, which means it is possible to keep

information capacity at a low while still conveying relevant information.

The ideal *notification level* should range from *change blind* to *make aware*, since the design should have the properties of being easy to ignore, but yet be noticeable enough to catch the user's attention without disrupting his or her workflow. The reason for this is also based on the fact that even though people are aware of good ergonomics, they need to be reminded of it, which indicates that while working, the employees forget about ergonomics and were not aware of when they should take breaks or put variation in their work routines. As such, we need to be able to notify users not only by different means but also at different levels. Based on related work, this could be done by using lighting, vibration, change of shape, weight shifting, software solutions or sound. However, as mentioned in Haller et al. [6], using vibro-tactile feedback would often interrupt the user's workflow, and even annoy the users and put the system notification level at the *interrupt* level. The final product should therefore increasingly remind the users of their ergonomics to a degree that does not interrupt them and disrupt their workflow.

The preferred *Representational Fidelity* was also influenced by the *Aesthetic Emphasis* since our intentions concerning the physical shape of the product are that is should be simple and being able to fit in the right context - which in our case was a bank office context, since the bank employee mentioned that the product must be aesthetically pleasing [21] in order for the bank to have interest in acquiring a product such as what we proposed. The product shall therefore have a high *Aesthetic Emphasis* focusing on the aesthetics of the product within context rather than work of art.

The high focus on aesthetics and the fact that our design should have a simple shape meant that our preferred *Representative Fidelity* should be at low to somewhat low (e.g. symbolic) level. The symbolic representation should be clear for the user to understand - what the product tries to communicate - but only to the extend that other people who do not know of the product purpose would not understand what the feedback represents.

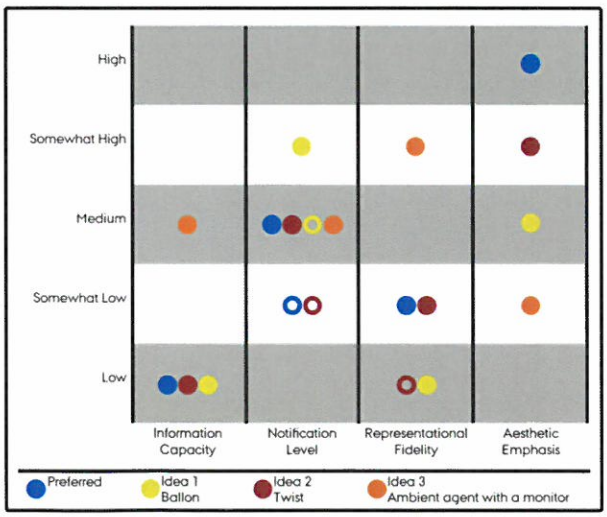

Figure 4 - Ideas used in the taxonomy

6.2 Analysis of the Design Ideas

See figure 4 which shows use of the taxonomy on our ideas. We chose idea 2, Twister, after evaluating the four design aspects individually comparing the different ideas to our preferred taxonomy. While looking at the information capacity aspect of the taxonomy, it was clear that we wanted to communicate a small amount of information through our physical agent. The only idea which was different in this aspect was idea 3, Ambient Agent, which was meant to both make the user aware of the dangers of his/her current ergonomically working condition and teach them how to achieve good ergonomics. This proved unnecessary since we through our research [21, 24] was able to conclude that the users were already aware of how to achieve good ergonomics but only needed to be reminded of paying attention to their current situation.

The taxonomy does not support the use of transition between levels within the notification level design aspect which meant that we added a start marker (empty circle) and an end marker (filled circle) for some of our ideas at the notification level, meaning that we wanted our preferred solution to begin notifying at a somewhat low level and gradually transitioning into a medium notification level, at which point Twister and Ambient Agent hit the mark with idea 1, Balloon, ending up on a somewhat high notification level, since its expansion of volume makes it difficult to ignore when at its end stage, which means it disrupts the user's work flow in an unwanted way. The Twister achieves the wanted evolution of notification by only changing its shape with its twist but without the change in volume.

The representational fidelity we wanted was at a somewhat low level, which might seem odd considering how a higher level of representational fidelity means it will be easier for the user to understand the information communicated. This choice, however, was because of the simplicity of what we were trying to communicate and the fact that we did not want to make it obvious to every person to decipher what we were communicating, as it could make the user embarrassed. The reason that Twister was chosen in this design aspect, and not Balloon, is that with its twist, the user begins to draw symbolical, abstract parallels to how someone imagines the twist on his/her back and spine when it hurts, whereas Balloon, with its expansion, does not make the user draw parallels that might relate to what is being communicated.

The last of the four design aspects is aesthetic emphasis, which is a somewhat subjective aspect since you cannot define what looks and feels aesthetically pleasing. However, our interview with the bank administrator told us that the physical appearance of a design can define whether or not it will be used by a certain company, which is why we tried to get as high an aesthetic emphasis as possible. With the Ambient Agent, we would be high on the representational fidelity since it has a small display which would produce drawings or even instructions, which is quite different from the abstract understanding described in the taxonomy. Balloon, with its simplicity, is pleasing to observe at first glance but when it expands it becomes a quite undesirable balloon shaped artifact, which might not fit into certain places of use, like a bank with its streamlined design. Twister, like Balloon, is a simple piece of office accessory, but where Balloon adds a more undesirable look through its evolution, Twister adds more style, and becomes somewhat of a piece of art.

7. CONCEPT

Based on our choice of idea to work on – the Twister - we present a conceptual idea for a scenario of the concept in use. As noted earlier, we are inspired by the use of a physical agent in the line of sight of the user.

7.1 Scenario of the Concept in Use

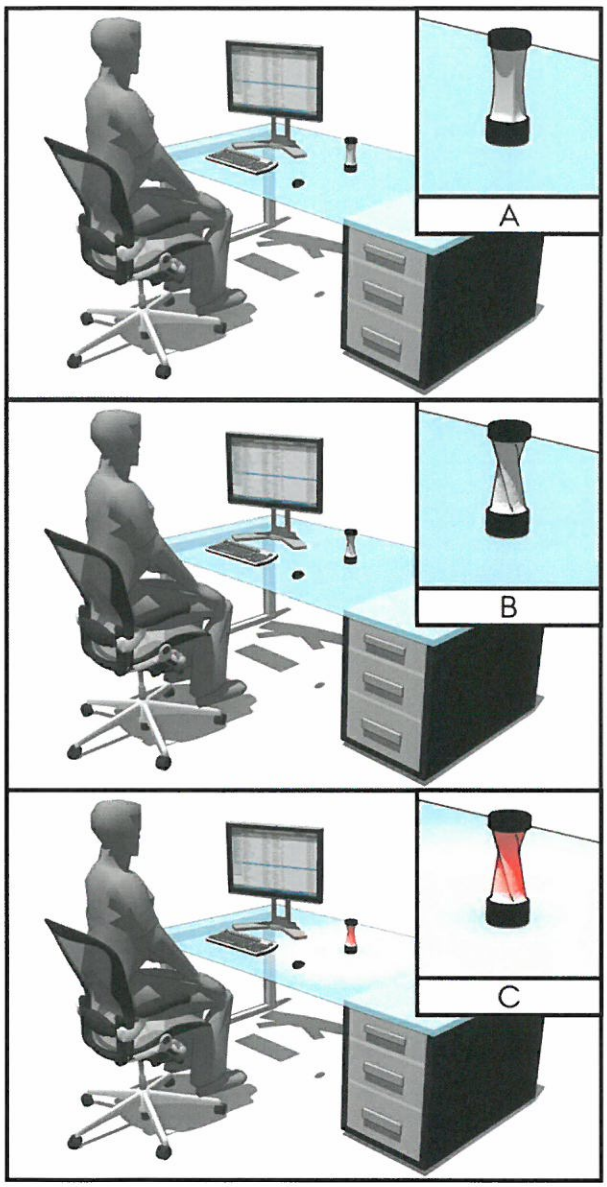

Figure 5 - Scenario of the concept in use

Figure 5 shows a scenario with the purpose and use of the system. At the beginning of the use, situation A, the user sits in his chair, and starts working on his computer. As soon as the user sits, a force sensor in the chair registers it and sends the information wirelessly to the physical agent on the table, and when the user starts using the mouse or keyboard, an activity notifier sends input to the physical agent as well. After working a while, the physical agent starts twisting (B), indicating that the user has been sitting there for some time. Even if the user stands up, the activity notifier will still know if the computer is used, and that means the physical agent will keep twisting. However, if you stand up or take short breaks, the Twister will "reward " the user with bonus time for doing some kind of variation in the work routine. Before the twist is at its full, the light will turn on (C) and begins to increase in intensity, to warn the user that he/she really needs to get away from the computer for a while. If the user keeps working, the agent will ultimately stop twisting and stay in a twisted position, and the lights will stop increasing in intensity, and wait for the user to react and walk away from the work station.

7.2 Arguments for the Concept

In our concept there are certain key elements that have been included in order to fulfill our previously stated requirements:

- Wireless force sensor in chair
- Activity notifier
- The physical agent's indicators

We use the force sensor in the chair in order to measure when the users are sitting in their chairs. Since we know that the most important thing when working with computers is to get away from them and take a break, we choose to use a single force sensor to measure whether or not users are sitting. This can be compared to Daian's approach [4] where they use multiple sensors in order to measure precise sitting postures and then convey it to the user, which is none-essential compared to the purpose of our design concept – reminding people of what they already know.

Seeing as variation is the key word in good ergonomics, shifting posture from sitting to standing – and back again - should be rewarded in some way. However, as mentioned earlier, we still have to register if there are any uses of the computer while people are standing up. This is why we are using an activity notifier to register if there is any activity going to the computer from e.g. mouse or keyboard. It is important to note that this activity notifier should not log any information, and only register inputs – not which kinds of inputs, since it could become a security risk if the notifier was keylogging sensitive bank information.

As mentioned earlier, we use the twisting, physical agent in an indicating way directly inspired by related work from [4, 6, 9], with the change shape from [9], using low-disruptive feedback from [6] and using a physical agent by [4, 6], with the design being based on the taxonomy, and the light indication was inspired by [2, 26].

8. THE PROTOTYPE – DESIGN AND TEST

After evaluating our various ideas and concepts by use of the inspiration from related works and the use of the taxonomy, we were able to construct a prototype to test our thoughts and findings.

8.1 The Prototype

The prototype is divided into three main elements of which the first two are used for gathering relevant information about the user's status, and the last elements is a feedback agent representing the information to the user.

The first element is a force sensor placed in the user's chair. The

sensor will detect if the user is sitting or standing and thereafter send this input as wireless information to the feedback agent.

The second element is software, written in python script, which notifies the feedback agent on whether the user is or is not using the computer by mouse or keyboard. The information is sent to the feedback agent through a USB-cable and only telling the agent if the computer is used, but for security purposes not how or what it is being used for.

With the help of the two types of information the feedback agent will be able to know if user is either working or taking a break and even know if the user is working in one out of three categorized working statuses: sitting and working on the computer, sitting but not working with the computer, and standing and working with the computer.

The feedback agent's purpose is to passively notify the user if he/she has repetitively been in the same working status past a specific work period. These work periods are intervals at either 40, 20 or 6 minutes that can be preselected through a switch before turning on the feedback agent. Each work period has a pause period, with a pause period of 5 minutes for 40 minutes of work, 2 minutes for 20 minutes of work and 10 seconds for 6 minutes of work. These work and pause period setups are chosen from [4, 34] that have defined how long a break should be to be most effective and still give the user an effective workflow. With the use of Twister in the taxonomy evaluation, the feedback agent will then begin to twist after the user has been in the same work status for a time of over half of the selected work period, and is fully twisted when reaching the selected work period. Complimenting the representation of the twist is the red light that begins with its lowest intensity at the time of three fourths of the selected work period, increasing the intensity of light slowly, until it is at the maximum at five fourths of the selected work period. Whenever the user leaves the chair and computer to take a break, the feedback agent will be notified of this action and will at an interval of 20 seconds gradually reset itself back to its original physical position and intensity of light. The red color for the light was chosen because the its symbolism and traits described in [18].

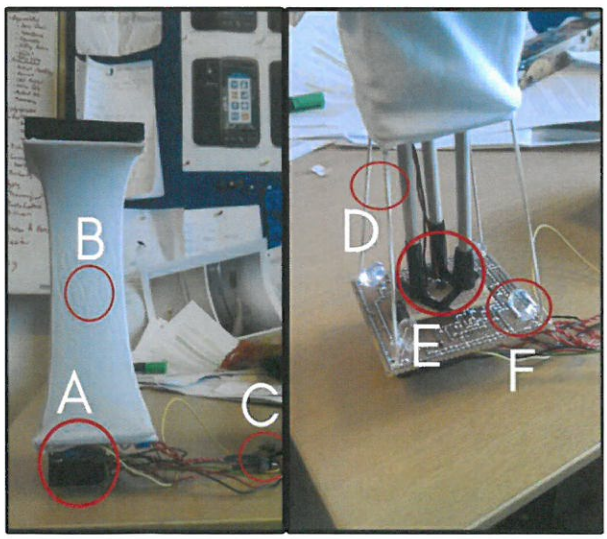

Figure 6 - Elements in the prototype

As seen in figure 6, the prototype consists of a servo-engine (A), stretchable material used as casing for the twisting effect (B), a switch for choosing work period settings (C), stretchable material used to support the shape (D), a rotating surface connected to the servo motor (E), and LEDs for the light feedback (F). Besides this, there is also an ATMEGA-8 microcontroller containing software for the physical agent, a wireless receiver used for getting input from the force sensor and a USB-connection for getting input from the activity-notifier as well as providing power to the physical agent.

8.2 Prototype Testing and Feedback

The purpose of the prototype tests is to figure out if the prototype actually makes users aware of their own ergonomics through the use of its change of shape and intensity of light, without breaking their workflow, and see if they will act as expected from the two different types of feedback from our system. Furthermore, we want to see if people will actually take a break or just ignore the prototype, and we would like to place the testing in different contexts – solo work and collaborative work. We tested the collaborative work with a student from Aarhus University, and the solo work with the bank administrator.

8.2.1 Testing Collaborative Work Environments

The purpose of testing the prototype with a student was to get a basic idea of its potential, and to check if the student was aware of the change of shape and lighting when in a collaborative work situation. The setup was simple; we placed the prototype next to the student's computer as we described in the scenario. One of the authors would sit next to the student while they would work on a project together. The tests were videotaped and are available at [29, 30].

The test was a mixed success. The student did not notice the prototype until one of the authors let the student know that the prototype was at its maximum. The author, however, did notice the lighting change during its test. There are several factors that might explain why the student did not notice the prototype. First, we were not seated optimally. The author was placed between the student and the prototype, sometimes blocking the student's line of sight. Second, the position of the prototype was not ideal. The prototype was placed on the table between empty soda bottles roughly the same size as the prototype, which could make it harder for the student to spot it.

What we learned from this first test was that in a collaborative environment the prototype needs to be placed prominently. Even though a lot of things are going on and projects need to be made, ergonomics are still an important factor when working at a computer. We also learned that if the user is without direct line of sight to the prototype, he will not spot the change of shape or lighting. This could mean that if the user was e.g. piling up documents on his table, blocking the view of the prototype, he would never notice it. This could mean that using some sort of indication like sound or vibration might be a good idea after all in certain work conditions.

8.2.2 Testing Solo Work with Bank Administrator

In the second test session, the filtering dimensions of the prototype [13] were mainly on the interactivity and appearance. In this test we focused on observing if the prototype's notifying elements, light and shape change, would get the tester's attention,

and if so, at which times the tester's attention was drawn respectively towards and away from the prototype's feedback. Another goal of the observation was to find the exact angle at which the prototype's twist would be registered by the user, as well as the level of light intensity from the prototype at the moment it catches the bank administrator's attention. The test and observation was performed in an isolated environment within the bank administrator's home and lasted for 30 minutes. Equipment used for the test was the prototype placed at the administrator's desk but was not connected to computer at the desk. The test was performed by using a Wizard of OZ [31] method where all input sent to the feedback agent was given by one of the two observers.

During the test, the bank administrator only changed focus when the prototype began to show the red light, which occurred only twice in the test. This focus shift, which occurred immediately, did not keep the bank administrator's attention for more than a few seconds before shifting back to the current activity. Another interesting part of the test was the fact that the bank administrator took breaks immediately after the prototype began to show light.

The second part of the session was an open discussion of the test where the bank administrator was asked about the interaction with the prototype (i.e. feedback). Other topics in the discussion were the prototype's appearance and physical shape, and how it would fit in a bank office environment. The feedback session took 17 minutes and was recorded [25].

When asked if the prototype's feedback was annoying in any way, the administrator answered, *"In the beginning I could easily work without it bothering me. But the redder it became, the more I could see it from the corners of my eyes. So it works quite well [...] and I could still continue reading."* thus stating the fact that the light was not annoying, but still made the bank administrator aware. This also meant that the prototype's feedback was within the administrator's requirements, *"The importance is that you can still work even if it is lid, but still, through the corner of your eyes, notice it."* However, when specifically asked about the physical feedback, the participant said that she did not notice the twist: *"I could not actually see the twist. It was when the light lid that I noticed it"*. Discovering that the prototype's physical twist was not the cause of the administrators' shift of attention, but instead the initial indication of the increasing red light was interesting. Although it was proved by Haller et al. [6], that the physical feedback would be the least disruptive way of notifying users, our prototype's physical feedback did not even catch the participant's attention and therefore had less of an effect than originally intended.

The prototype's intention was easily understood by the participants, since, *"Those who will use this device already know what to do about their ergonomics and therefore know what it is trying to tell them"*, which could also mean that the type of people who would use this kind of product are willing to change their work habits and awareness of their own ergonomics. The bank administrator also commented, *"When it lights up I would not think: what did the ergotherapist tell me? So, when it lights up and I notice it, I would think that there is something and I will be aware of stuff, like, is there something with my arm and so on. Then I might begin doing some other kind of work with my hands or if I had a pain in my back then I would stand up for a bit..."* which states that the prototype's purpose to make the user aware of their ergonomics in their work routines was met. However, even if the prototype only conveys that the user has worked in the same setting for a specific period of time, it is surprising how the effect makes the users reflect on the aspects of their work routines.

As a preventative tool against ergonomic health issues caused by lack of variation, the participant stated *"This is a good idea, and I could easily imagine this company using it within the areas of improving our work environment and the ergonomics"* and, *"The argument would be that we could save payments from physiotherapists and sick leaves. That would be my argument for us to buy these."* this sums up the ideal purpose for both the employees and the company, and is a goal that other projects like the SuperBreak [17], Sensitive Chair [4] and Haller et. al. [6] have tried to solve. We could even go so far to say that it has the potential to fulfill one of the requirements stated by the DWEA.

When asked about the appearance of the prototype, the bank administrator was shown 3D renderings (figure 7) of our preferred design at which point the bank administrator clearly pointed out the prototype's physical size*"[...] if I came bringing that [Twister], then I could not buy it, since it does not fit into our work environment [...] That is because it is too big and is a monstrosity"* and therefore its current physical size would influence whether or not the bank would buy this type of solution. *"It clearly will, if it is a big monstrosity, because the design means something. Of course, in a streamlined environment the [physical] design plays a role."* The bank administrator then commented on the 3D renderings, *"if it looked like that then it wouldn't be an issue, since it fits in nicely in our work environment, then it would be the price that defines whether or not I would be allowed to purchase it"* We should therefore in our future design iterations keep the physical appearances of the system in mind. This verifies our earlier decision from our used taxonomy with a focus on high aesthetic emphasis, but where the aesthetic requirements in our prototype are not fully met, our renderings were an adequate medium for conveying our design vision. Even if the physical design is of great importance, the bank administrator also pointed out, *"This is not the essential reason for buying these tools."* and again mentioned the arguments why the company should acquire this kind of solution.

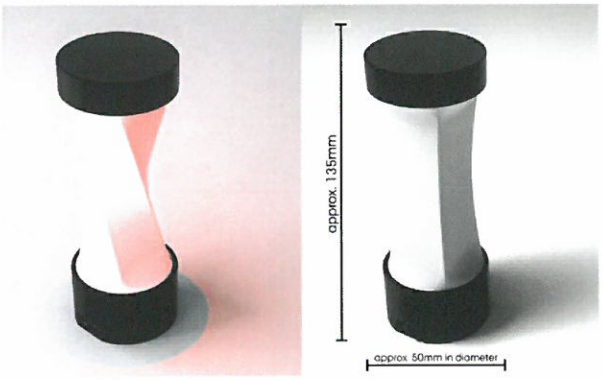

Figure 7 - Renderings of prototype

Both during the observation and the discussion, the participant stated that it was too early for the red light to begin increasing its intensity. The light should only begin *"...just before it was about to go wrong"*, and thereby notifying the user with the increasing red light. In a 40 minutes work period configuration, the lighting should occur closer to 35 minutes instead of the prototype's original configuration of 30 minutes into the work period.

9. AMBIENT INFORMATION SYSTEMS AND ERGONOMICS

The process of developing a design concept for an Ambient Information System in an office work environment has proven to be a challenge. This has been emphasized by several discussions upon the categorization of the concept as an ambient display, and the methods used that influenced our decision of the design concept and evaluation of our prototype.

Ishii, Matthews and Weiser have done research in these areas for the last 20 years, and [35, 11] describes how computations shift towards three directions: to our bodies (wearable), into the environment like the AmbienROOM, and the *ambient fixtures*, which are ambient displays that can be distributed throughout architectural spaces. On a project like this, it required a lot of research to realize how to utilize the many advantages of these systems. We believe that in our project, the ambient fixtures are most definitely the best approach, since we want to remind people of proper ergonomics through a trigger. As such, we could compare our concept to that of an alarm clock, or a dashboard in cars, seeing how those are also based on peripheral information at first, turning to insisting on getting the users' attention when the alarm triggers, if there are engine troubles or if the user has been working at a desk for a certain amount of time.

9.1 Discussion of Prototype and Process

At the empirical research part of our design process, we could have considered interviewing more experts (physio- and ergotherapists) within the field of ergonomics, as well as more bank employees in order to get more precise data describing the need for and concerns about ergonomics within an office work environment. However, seeing as how the information we found on the Internet, articles about ergonomic issues and interviews all conveyed almost the same information, no matter the source, it is plausible that we would have received the same information from other experts. Although the questionnaire gave us a good understanding of the status of workers in office environments, having only 42 unique replies could be argued as not being enough to make a generalization. We believe, however, that 42 replies to mundane questions in order to get a basic understanding of general ergonomic understanding is sufficient - especially considering how a lot of our design choices are not directly based on the questionnaire, but the feedback from interviews.

Similar to the questionnaire, it can be argued that we could have made more tests of the prototype in order to get more feedback. However, this is still an early iteration and further testing would be part of our future work. Even though the tests were few, they still gave us results to further analyze and evaluate, such as the effectiveness of the feedback of the system and the aesthetics of the physical size and shape of the agent.

9.2 Discussion of Concept

We have worked in the direction of utilizing the environment, thereby using the office environment to aid the user in his/her self awareness and ergonomics. Our design concept is like the Water Lamp [11], developed for use in open-space environments with several people, since office workers usually work in open offices. This also means that there is a need for the concept to take into account the fact that different people need to use the same solution, which means the concept must be adaptable - such as seen with adjustable desks and chairs. This was also backed up by our interview with the ergotherapist who revealed the same fact. In our project, we have made this a possibility by having our prototype include three different settings; short work time, medium work time, and long work time.

The amount of time spent before the activation of feedback, and the length of time each break should last, are based on earlier works and findings by Swanson and Sauter [34] - stating that intervals of 40 minutes of work followed by 5 minute breaks will improve work performance. These intervals should be discussed in a later iteration as whether proper or not. This is a valid discussion considering the fact that [34] is from 1990, which is a long time ago considering the technological evolution, and with research by Daian et al. [4] - stating that the intervals should consist of 20 and 40 minutes with a short break, or 60 minutes intervals with a long break - from 2007. Further research of related work and further collaboration with experts in the field of work space ergonomics (physio- and ergotherapists) could provide us with the relevant knowledge to find this. Our approach to setting the interval was based on the fact that both articles talked about 40 minute intervals, and the ergotherapist from our interview said that microbreaks and variation are useful as well.

More types of input (e.g. sitting posture) could be considered being integrated into our concept in later iterations in order to get more specific input. However, this would require us to reevaluate our preferred taxonomy since there would more information that has to be relayed through our physical agent. This would also bring up the discussion about if more relayed information would improve the user's ergonomics and whether a large capacity of information that has to be relayed through a simple physical agent, with a low representative fidelity, can create confusion with users about what they have to be aware of, instead of letting the user be reminded of a few areas of ergonomics. If a physical agent with high information capacity and low representational fidelity is to convey a lot of information, it might turn out being more disruptive than at first intended, since it would have to convey a

lot of information in a limited amount of ways, which could lead to the users spending more time on deciphering the agent than on of doing what it is trying to say.

If our design concept were analyzed through the use of Fishkin's taxonomy [5] we could place our design concept at the *environmental* level. The input is given through typing on the computer keyboard, moving the mouse and sitting on the force-sensor which is sent to a developed feedback agent that converts it into representative output (in this case, a physical and light feedback). All of the input and converted outputs of the system occurs in, and is a part of, the user's work environment, thus being *environmental*.

Our preferred notification level of our design concept mapped in Pausman and Stasko's taxonomy is an area of interest and discussion since the level should change between *change blind* and *make aware*. Matthews et al. [15, 16] argues through previous related research that different notification levels can be achieved by various methods of transitions, where *"Repetitive and very gradual animations are appropriate for change blind transitions[...]"* and *make aware* can more appropriately be obtained through use subtle techniques like *"[...]updating small pieces of the display abruptly"*. However arguing with examples of transitions of other studies the article states, *"Further research is needed to determine the best way to transition changed data in peripheral displays"*. Seeing as there is a lack of related work on how to utilize the right transitions, we used two different approaches. Firstly, we took inspiration from other ergonomic ambient information systems, and secondly, we tested different types of feedback through prototyping.

10. CONCLUSION

Through the process of our bachelor's project, we have been able to develop an early iteration design concept of an ambient information system used to help remind office workers of their current ergonomic work conditions. Within this process, Pausman and Stasko's [34] taxonomy was used to define the fundamental attributes of our design concept, giving focus on key design aspects of an Ambient Information System.

The initial research of related work within the field of ergonomics, both in general and specifically in an office environment, provided essential data to support finding specific topics in interviews with experts in both fields. The initial research also provided inspiration for design decisions in an analytical approach. The analytical approach was a suitable alternative for a more practicable approach like early prototyping. However this could not cover all the advantages of the practical approach, as we later discovered in our prototyping sessions.

The use of interviews as the means of empirical research revealed the importance of variation in an office work environment to avoid injuries such as RSI, and if compared with related work of Ambient Information Systems, the interviews also reveals potential of applying such systems within this type of environment.

11. FUTURE WORK

Areas to consider for the future work with the current concept are to explore other ways of creating physical feedback, since the application of a steady twist motion did not have the desired effect of increasingly attracting the user's attention. Even though the physical twist was not as effective as intended, it is still noted from Haller et al. [6] that physical agents are less disruptive and a plausible solution for giving feedback within an office work environment. In general, we believe ambient information systems need more research on how to get peoples' attention within its environmental context.

Furthermore, Daian et al. [4], notes that a physical agent is preferred above a screen based application that uses pop-ups. Relevant to the research of physical feedback solutions is the design of the physical shape of the system. Mentioned by the bank administrator, this will be a significant factor if a company like a bank would apply this solution as utility in their employees' daily work routines.

Another area to consider is more testing and further development of the prototype. To see if our prototype helps people, we would need to test it for several months, every day, on the same person. It would also be relevant testing the prototype in a complete collaborative work environment, like an actual open-office bank environment, to see the level of interruption and annoyance to other users than the intended.

12. ACKNOWLEDGMENTS

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