UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
FACULTAD DE
DISEÑO INDUSTRIAL

DESARROLLO DE ESTRUCTURA de INTERFAZ INTUITIVA PARA SOFTWARE DE EVALUACIÓN ERGONÓMICA

Tesis Profesional que para obtener el título de Diseñador Industrial
Presenta

Guillermo Ignacio Munguía Velazquez

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DR. Luis Equihua Zamora

Y la Asesoría de:
MDI. Ana Paula García y Colomé
MDI. Vanessa Sattele Gunther
MDI. Gustavo Victor Casillas Lavín
MDI. Mauricio Moyssén Chávez

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NOMBRE MUNGUIA VELAZQUEZ GUILLERMO IGNACIO No. DE CUENTA 310220570

NOMBRE TESIS ESTRUCTURA DE INTERFAZ INTUITIVA PARA SOFWARE DE EVALUACION ERGONOMICA.

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DESARROLLO DE

ESTRUCTURA de INTERFAZ INTUITIVA

PARA SOFTWARE DE EVALUACIÓN ERGONÓMICA

DEVELOPMENT OF AN INTUITIVE INTERFACE STRUCTURE FOR ERGONOMIC EVALUATION SOFTWARE.

Por Guillermo Munguía Velazquez y Pontus Rang-Roslund en colaboración con el proyecto Smart Textiles for Sustainable Work Life en la Universidad de Skövde.

Con la coordinación de:

Ing. Peter Thorvald

Ing. Aitor Iriondo Pascual

Ing. Dan Högberg Ing.

Ari Kolbeinsson

He aquí la culminación de una etapa única en mi existencia y el principio de nuevos caminos por explorar.

A mis padres, abuelos y familiares por toda su paciencia y apoyo incondicional; los mejores mentores de la vida y los pilares principales que forman parte de mi esencia. Valoro mucho su esfuerzo, gracias por siempre darme la libertad de ser quien soy.

A la Universidad Nacional Autónoma de México por abrirme sus puertas y a sus profesores por compartir sus conocimientos y enseñanzas que contribuyeron a mi formación como profesional.

A la Universidad de Skövde y su gente que me acogió y que me brindaron una experiencia incomparable de autoconocimiento y crecimiento.

Y por supuesto a todas las personas que son y fueron parte de este gran camino, gracias amigos por escucharme, por sus consejos y sobre todo, por tener fé en mi.

Descripción y Antecedentes

El proyecto presentado a continuación se llevó a cabo en la Universidad de Skövde en Suecia durante el semestre de primavera 2018 por medio del Programa de Movilidad de la Facultad de Arquitectura de la Universidad Nacional Autónoma de México. Se logró gracias a la colaboración de Pontus Rang-Roslund, colega de la Universidad, así como a la coordinación de los examinadores Peter Thorvald y Aitor Iriondo Pascual en conjunto con los supervisores Dan Högberg y Ari Kolbeinsson, miembros de la Universidad de Skövde.

Se desarrolló dentro del programa *BACHELOR DEGREE PROJECT IN PRODUCT DESIGN ENGINEERING* por la Universidad de Skövde, el cual contiene las bases y la estructura para su desarrollo. Dentro de los aspectos que el programa contribuyó a mi formación como profesional fue el trabajar de manera independiente realizando actividades vinculadas al desarrollo de productos por medio del entendimiento de bases científicas y métodos de trabajo que generaron habilidades y criterios de un trabajo autónomo y creativo que daban lugar a la identificación, formulación y solución de problemas dentro de un periodo asignado. Así como la capacidad para reunir, valorar y usar conocimientos e información de manera sistémica y crítica cuando se diseñan, modelan y evalúan propuestas para dar solución a problemas que surgen durante el desarrollo de un producto. Las sesiones colaborativas de trabajo aportaron la apertura al debate de información, problemas, métodos, y soluciones a través de aptitudes orales, visuales, de escritura, descripción y argumentación. También se contribuyó a la madurez para identificar necesidades para un futuro desarrollo de conocimientos y habilidades personales.

Surgimiento y Desarrollo

El proyecto *Intuitive Interface Structure for Ergonomic Evaluation Software* (*IISEES*) surgió como consecuencia del proyecto *Smart Textiles for Sustainable Work Life* (*STSWL*), lo cual permitió además una colaboración con diversas compañías como *Hultafors Group AB*, *Volvo Cars AB*, *Volvo Trucks AB*, *Scania CV AB*, *Feelgood Svenska AB* y *Avonova Sverige AB*.

STSWL parte de la necesidad de generar un sistema para medir, visualizar y evaluar los esfuerzos físicos de los trabajadores que realizan actividades en la línea de producción de empresas automotrices como *Volvo Cars AB*, *Scania CV AB* y otras. **El objetivo es la prevención de lesiones musculares de trabajadores durante jornadas laborales en cadenas de producción industrial y de construcción**. De esta forma las compañías se comprometen con el cuidado de la salud de sus trabajadores para invertir en el aumento en la productividad de la empresa, al igual que ofrecer una mejor calidad de trabajo para sus operarios.

La raíz de esta problemática se debe a las posturas no favorables para el cuerpo a causa de dos factores principales: primero, las dimensiones del área de trabajo o el equipo con el que se labora, lo cual propicia esfuerzos físicos exagerados, que rebasan las capacidades físicas de los trabajadores; segundo, dichos trabajadores no ejecutan adecuadamente las actividades asignadas.

Una manera de prevenir las lesiones musculares es por medio de información ergonómica, la cual debe ser obtenida y procesada por especialistas en ergonomía, así como por entrenadores físicos, quienes serán los encargados en capacitar e instruir a los obreros para que ejecuten las actividades asignadas. De la misma manera se diseñará y adecuará el entorno laboral de acuerdo a las necesidades de dichos operarios. Antes de llevar acabo las actividades de capacitación y modificación del entorno laboral, los ergónomos y entrenadores deberán llevar a cabo las evaluaciones físicas ergonómicas necesarias, mediante la observación directa de los trabajadores. De esta manera se analizan las posturas que ejecutan; con base en la información obtenida será posible evaluar el nivel de riesgo y las posibilidades de lesiónes físicas en dichos operadores. Actualmente se apoyan de métodos ergonómicos como *OCRA, OWAS* y *RULA*[1]. Estos permiten visualizar el riesgo de lesiones gracias al análisis de magnitudes físicas tales como velocidad, ángulos, tiempo y fuerza que se ejercen en distintas áreas del cuerpo durante la ejecución de actividades laborales.

El uso de una sola metodología para analizar todos los datos ergonómicos que este proyecto insta es impensable. Este requiere un análisis que abarque observaciones en períodos, ritmos y ciclos, así como el estudio de diferentes secciones del cuerpo, cosa que una sola metodología no podría abarcar. Por lo cual el proyecto *STSWL* con el propósito de incorporar diversas variables necesarias para un estudio de dicha magnitud, generó un nuevo sistema basado en la recopilación de diversas técnicas ergonómicas, al cual se le nombró *STEM*[2]. Su empleo permite durante una sesión de trabajo la obtención de valores con mayor precisión necesarios para una averiguación en la prevención de lesiones físicas. Todos los datos son extraídos mediante sensores que posteriormente se registran (producto del proyecto *STSWL*). Los sensores se colocan en las prendas de los trabajadores, las cuales consisten en textiles que se ajustan a la complexión de los operarios, esto con la finalidad de extraer los datos de manera exacta. Cada valor es almacenado en un servidor para posteriormente reorganizar dicha información y tener así la posibilidad de acceder a ellos por medio de un programa con hojas de trabajo.

Inicialmente toda esta información era presentada en bruto, lo cual dificultaba su análisis. Esto nos permitió identificar la necesidad de presentar los datos recabados de manera que los usuarios (ergónomos y entrenadores) la puedan visualizar de manera adecuada y utilizarla sin complicaciones para desarrollar evaluaciones físicas ergonómicas.

La solución que daba respuesta a esta problemática fue mediante el empleo de interfaces. Esto brindaría la posibilidad de reinterpretar la información obtenida en los sensores de una manera clara y entendible para facilitar su lectura y así eficientar la labor del especialista en ergonomía y del entrenador con conocimientos ergonómicos para la prevención de lesiones físicas. De este modo el proyecto *IISEES* surge

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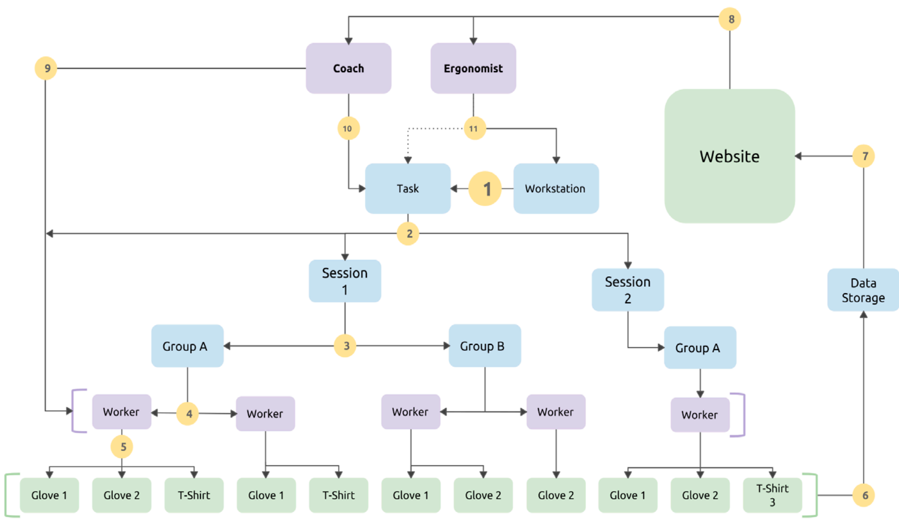
[1] *Ver métodos de evaluación ergonómica, "Ergonomic Evaluation Methods" (trabajo explicado en el capítulo 2 pag. 53 de este volumen).*

[2] *Ver "Smart Textiles Evaluation Method" método de evaluación ergonómica desarrollado por la Universidad de Skövde, "Ergonomic Evaluation Methods" (trabajo explicado en capítulo 2 pag. 55 de este volumen).*

con la finalidad de desarrollar una interfaz que permita tanto a ergónomos y entrenadores cubrir la necesidad de integrar, organizar y clasificar información ergonómica para su estudio, análisis y comparación.

Con el propósito de comprender el sistema en donde se desarrolló el proyecto, el diagrama presentado a continuación en la figura 1 ilustra los elementos presentes en el contexto y su correlación. Se sitúa en una



[Fig. 1] Diagrama de interacción del contexto.

estación de trabajo (***workstation***), llamada línea de producción o de ensamble en la cual hay una serie de **tareas** (***task***) que cubrir en un periodo al cual se le denomina **sesión de trabajo** (***session***) donde intervienen **grupos** (***group***) conformados por cierta cantidad de **obreros** (***worker***) designados a ejecutar la encomienda. Cada trabajador posee ya sea una **playera** o **guantes** (***T-shirt, glove***) con sensores con la finalidad de registrar su actividad para ser almacenada en una **nube** (***data storage***) y posteriormente presentarse por medio de un **sitio web** o **aplicación** (***Website***) a **ergónomos** (***ergonomist***) y **entrenadores** (***coach***) y así generar un análisis o reporte.

Una vez identificada la problemática del proyecto, los usuarios involucrados y sus necesidades preliminares, se propuso una estrategia de diseño con un periodo de desarrollo asignado que consistía en abordar y desglosar los puntos clave que arrojarían soluciones a los requerimientos solicitados. La primer parte de dicha estrategia contemplaba una investigación preliminar con el propósito de obtener un amplio conocimiento en el área de desarrollo de interfaces por medio del entendimiento de los usuarios, su contexto, necesidades, aspiraciones y dificultades.

Dentro del análisis se encontró que el diseño de interacción es fundamental para la generación de un producto accesible de fácil uso, entendimiento y aprendizaje para proveer una experiencia agradable y disfrutable para el usuario dentro del campo de diseño de interfaces apoyada en principios de psicología, arte y diseño.

La parte que se relaciona con el aspecto psicológico en el diseño de interacción va encaminada a el entendimiento de la percepción con el fin de comprender el modo en el que el hombre reinterpreta la información de su entorno por medio del análisis de los procesos cognitivos que se desarrollan a partir de esta, Así como el estudio del comportamiento humano para facilitar una interacción provechosa entre el usuario y el producto que propicie experiencias positivas al cumplir con sus necesidades. De modo que al entender los procesos cognitivos, es posible predecir el comportamiento humano en la toma de decisiones, brindándonos así la oportunidad de anticiparnos a las acciones y por consiguiente generar soluciones satisfactorias de diseño.

Una vez comprendida la relación que hay entre el desarrollo de interfaces y la interacción, fue necesario profundizar en el campo de *Human Computer Interaction*[1] (*HCI*) ya que en esta área de esudio se examina la interacción existente en el intercambio de información mediante un software entre los individuos y las computadoras. El objetivo de esta área es generar una comunicación clara y eficiente para disminuir errores y brindar satisfacción al usuario mediante el análisis de las acciones posibles, las que están sucediendo, y las que están por suceder durante una interacción entre humano-máquina.

Partiendo de *HCI* nos encontramos con dos ramificaciones que se

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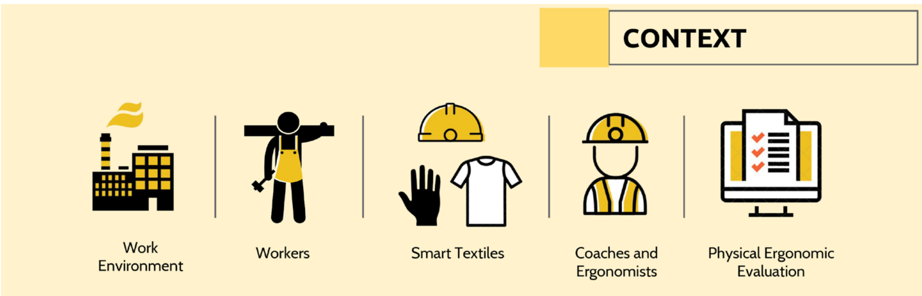
[1] *Ver "Human Computer Interaction" (trabajo explicado en el capítulo 2 pag. 45 de este volumen).*

tomaron en consideración debido a su aportación al proyecto: *User Experience*[1] (*UX*) y *User Interaction*[2] (*UI*), las cuales funcionan de manera complementaria, dado que *UI* se enfoca en el diseño de la interacción del comportamiento aplicado al sistema de la interfaz y *UX* se enfoca en el diseño de productos, procesos, servicios, eventos y entornos tomando como prioridad el brindar calidad y disfrute de la experiencia para el usuario.

Al indagar más en el terreno de *UI*, nos percatamos que para promover una interacción provechosa se requiere un buen entendimiento del ser y su relación con el medio en el que se desarrolla la problemática. Para esto, el área tiende a analizar todo el contexto a través de la identificación y definición de los usuarios involucrados en donde sus funciones y motivaciones son reconocidas, asimismo, tanto las actividades realizadas como herramientas y objetos utilizados en el entorno son determinadas, así como el flujo de información presente, de modo que se genera una comprensión del sistema que vincula la interacción del conjunto de todos los elementos mencionados. Los resultados provenientes de dicha investigación nos brindan ingresos de elementos de información del sistema o contexto que se definen como *inputs*



[Fig. 2] Representación del contexto del proyecto en el que se contempla el área de trabajo donde laboran trabajadores haciendo uso de sensores que brindan información a ergonomistas y entrenadores para realizar análisis ergonómicos.

(entradas de información) para que posteriormente generar *outputs* (salidas de información) que buscan dar soluciones que respondan a estos. La aplicación de esta investigación durante el análisis de nuestra

[1] *Ver "User Experience" (trabajo explicado en el capítulo 2 pag. 52 de este volumen).*

[2] *Ver "User Interaction" (trabajo explicado en el capítulo 2 pag. 50 de este volumen).*

problemática amplió el acercamiento y entendimiento del contexto (figura 2), permitiéndonos formular respuestas más acertadas respecto a las complicaciones presentes.

Por otro lado el área de *UX* está fundamentada en principios de usabilidad que garantizan eficiencia, efectividad, facilidad de uso y capacidad de aprendizaje en las soluciones de diseño para generar la satisfacción del ser. La manera en la que dichos principios fueron alcanzados fue por medio de la aplicación de métricas y evaluaciones con usuarios aplicadas a las propuestas de diseño generadas luego de la recolección de la investigación preliminar que abarcaba información afin al campo de desarrollo de interfaz, un estudio empírico mediante observaciones y entrevistas a ergonomistas o personal vinculado al área, así como la recopilación de información respecto a los diversos tipos de evaluaciones ergonómicas físicas requeridas en el proyecto. De este modo el estudio previo permitió recolectar información cualitativa, así como la extracción de necesidades y deseos para identificar las características más importantes del producto, su configuración, contexto y restricciones para generar propuestas que posteriormente serían evaluadas con usuarios de acuerdo a los principios de usabilidad. En dichas pruebas principalmente se verificaba que los requisitos planteados fuesen cumplidos, además se consideraba el tiempo de demora al ejecutar una actividad y si esta se concretaba o no.

Cabe aclarar que la manera en que la información recabada fue reinterpretada y clasificada para puntualizar las especificaciones del proyecto y así proceder con la generación de conceptos, fue por medio del análisis de los datos en cuatro secciones:

- Requerimientos de Datos: estos correspondían a actividades e información solicitada por ergónomos y entrenadores, por ejemplo, el querer conocer el valor de alguna variable en específico como la fecha de ejecución de alguna prueba, el tiempo, el resultado de la evaluación entre otras.

- Requerimientos Funcionales: eran aquellos que representaban las operaciones que se efectuaban en el sistema de tal forma que podían ser convertidas en acciones y controles de la interfaz, por ejemplo la tarea de imprimir un reporte, el ejecutar un reporte.

- Requerimientos de Negocio: esta sección se englobó dentro del plan de trabajo para el desarrollo del producto.

- Requerimientos Técnicos: este punto consideró el tipo de la plataforma de software que se utilizaría para el producto.

De tal modo que la clasificación de las necesidades descubiertas fue la siguiente:

- Requerimientos de Datos: conocer el tiempo transcurrido, observar el comportamiento de cada variable a lo largo del tiempo, usar el mínimo de pasos para realizar acciones, generar una estructura para la información que fuera de lo general a lo particular (jerarquizar), simplificar la visualización de la información por medio de elementos gráficos, observación de las evaluaciones ergonómicas e identificación de usuarios.

- Requerimientos Funcionales: comparación de información, exportar documentos a archivos PDF, evaluación de elementos por medio de colores, barra de menú, presentar una barra/caja de visualización de datos con botones.

- Requerimientos de Negocio: cumplir con los alcances de acuerdo al plan de trabajo.

- Requerimientos Técnicos: diseño de interfaz para formato de tablet y computadora de escritorio para el producto.

La fase de investigación tuvo como finalidad la identificación de patrones de comportamiento que reconocían motivaciones y objetivos de los usuarios. Dichos patrones de comportamiento fueron vinculados con *Creation of Personas*[1] (Creación de Personajes) con el objetivo de determinar necesidades al sintetizar información obtenida en el estudio previo. Posteriormente los personajes fueron introducidos dentro de una narrativa llamada *Creation of Scenarios*[2] (Creación de Escenarios) para dar forma a la fase de definición de requerimientos[3]. *Creation of Scenarios* sirvió para reconocer las exigencias de cada tipo de usuario, el cual era descrito en una historia que narraba una experiencia ideal desde la perspectiva del personaje, enfocandose en su manera de pensar y comportarse. Esto indentificó la conexión entre usuarios y la estructura del diseño para posteriormente generar conceptos de la propuesta.

Esta pauta definió el rumbo del proyecto en la fase de generación de conceptos, los cuales fueron evaluados con especialistas en el área de de ergonomía y de desarrollo de interfaces, para posteriormente ser filtrados hasta obtener la opción que mejor cubriera los requerimientos previstos. Dicho concepto permitía el registro de trabajadores para generar una sesión y facilitaba la visualización de datos ergonómicos en tiempo real dirigida a entrenadores para asesorar y dar apoyo a los mismos. Además la propuesta posibilitaba a ergonomistas el comparar y evaluar los datos datos generados a partir de las sesiones de trabajo. Fue necesario someterla a pruebas de usabilidad con usuarios por medio de un proceso iterativo con la finalidad de exponer errores para ser corregidos y así continuar con una siguiente valoración. Esto generó una evaluación formativa con la que se mejoraba la propuesta después de finalizar cada prueba.

Con el apoyo de modelos de papel generados e impresos a partir de un programa de diseño de prototipaje de interfaces se ejecutaron las evaluaciones ya que el proceso era rápido y no requería un gran costo. Esto beneficiaba al proyecto en cuanto ahorro de tiempo y ejecución debido al dinamismo que ofrecía al interactuar con usuarios como también al modificar el concepto. Como resultante, la propuesta final arrojó una interfaz flexible y óptima que cubría las necesidades. Dicha propuesta (figura 3) incorporaba 3 secciones en su menú principal:

Create Session (Crear Sesión) : en este apartado los trabajadores a evaluar eran registrados y añadidos, para dar comienzo a una nueva sesión en el área de trabajo. Dicha sección correspondía a entrenadores

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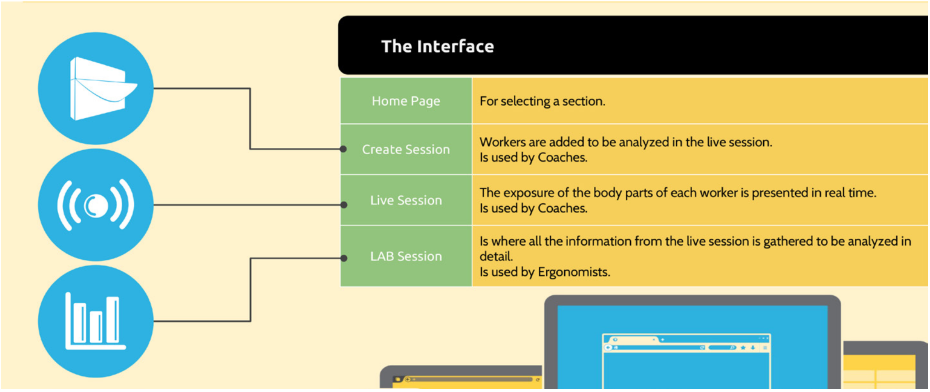
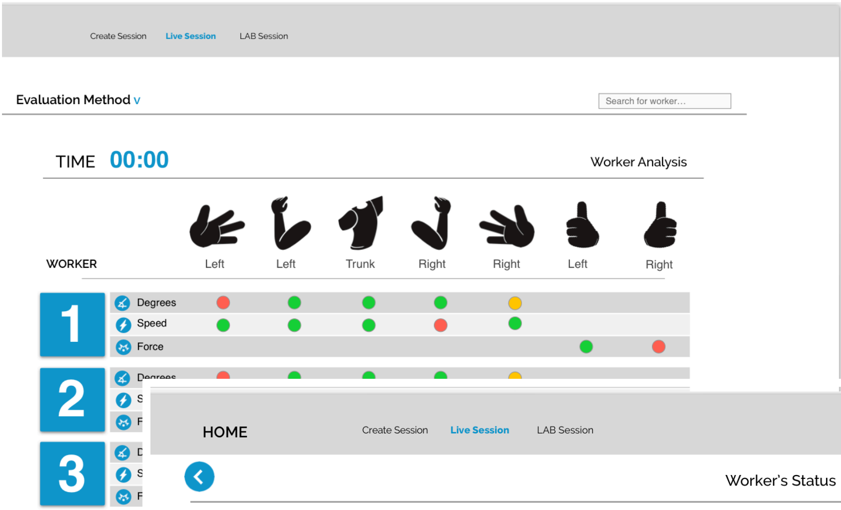
[1] *Ver "Creation of Personas" (trabajo explicado en el capítulo 2 pag. 68 de este volumen).*

[2] *Ver "Creation of Scenarios" (trabajo explicado en el capítulo 2 pag. 70 de este volumen).*

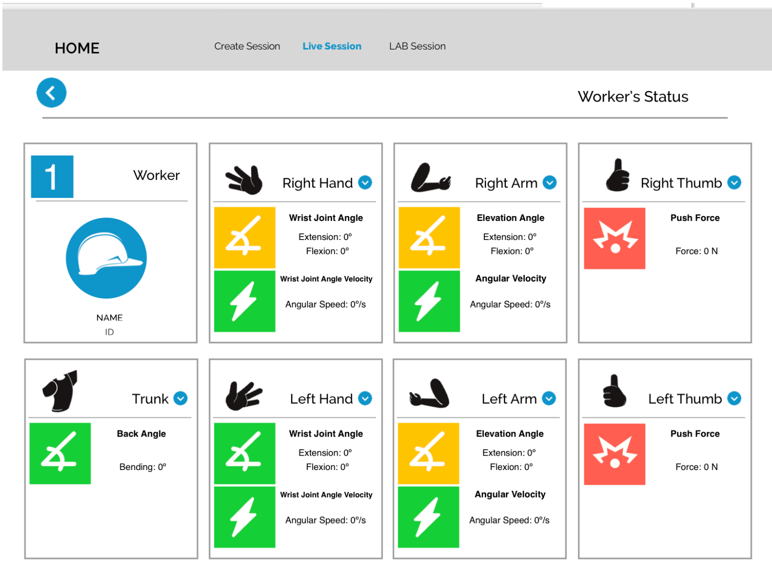
[3] *Ver "Validation Scenario" (trabajo explicado en el capítulo 3 pag. 78-81 de este volumen).*



[Fig. 3] Representación de las secciones de la interfaz.



[Fig. 4] Visualización general de la sección "Live Sesic

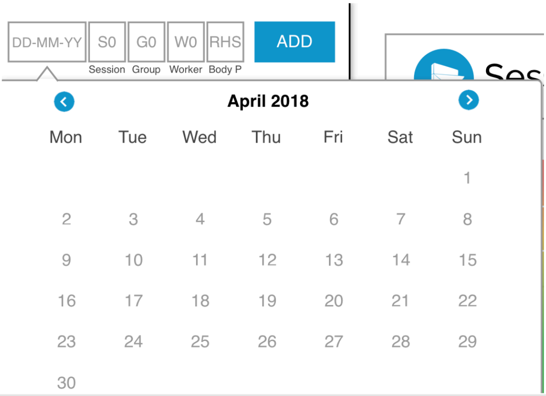


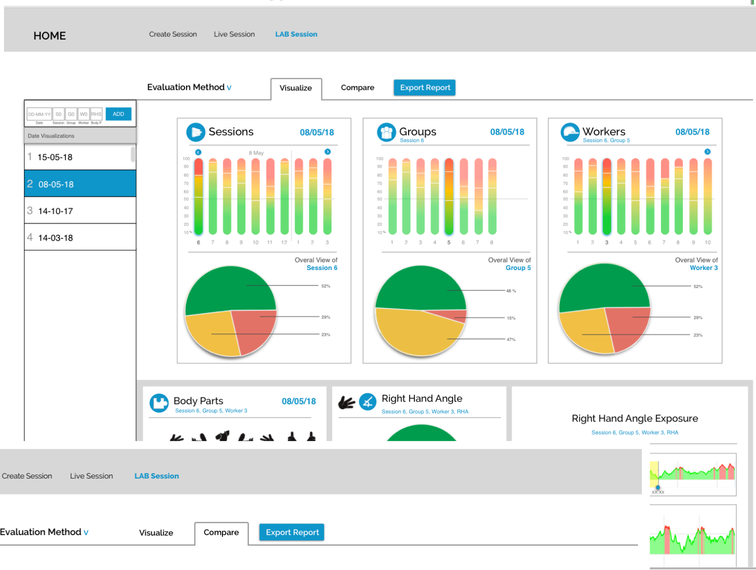
[Fig. 5] Visualización del estado de un trabajador en l sección "Live Sesic

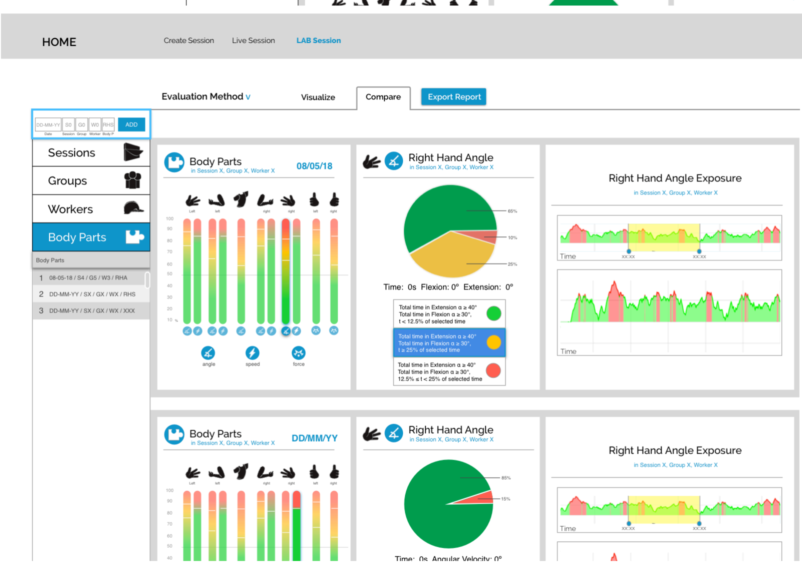
[Fig. 6] Ingreso de datos para su análisis en la sección "Lab Sesion".

[Fig. 7] Visualización de datos en la sección "Lab Sesion".

[Fig. 8] Comparación de datos en la sección "Lab Sesion".







debido a su interacción directa con los operarios.

Live Session (Sesión en Vivo): esta parte también se dirigía a entrenadores, con la finalidad de monitorear los datos en tiempo real durante una sesión de trabajo y así coordinar a los obreros (figura 4). El usuario era capaz de observar por medio de una tabla las partes del cuerpo de cada trabajador (figura 5) con sus respectivas magnitudes para evaluar si alguna sección presentaba algún riesgo.

LAB Session (Sesión en Laboratorio): es aquí donde todos los datos de las sesiones de evaluaciones ergonómicas eran registrados por fecha (figura 6) y presentados de modo que los ergónomos podían hacer un análisis exhaustivo, comparar datos, partiendo desde datos generales a datos en específico (figura 7 y 8) para posteriormente intervenir en la adecuación del espacio de trabajo en caso de identificar algún problema o patrón que produjera riesgos a largo plazo en la salud de los operarios.

El desarrollo de este proyecto tuvo como producto la propuesta de una interfaz que ofrecía una estructura de datos de información ergonómica. Sin embargo el trabajo requiere seguimiento para poder desarrollarse en su totalidad. Haría falta la programación de la propuesta con la finalidad de ser presentada en los dispositivos requeridos.

Conclusiones

La manera en que se abordó el proyecto fue por medio del uso de una metodología enfocada en el desarrollo de interfaces. Esta metodología consistía en la recolección de información que sirviera de base para el desarrollo de un producto que diera solución a las necesidades de los usuarios. De esta manera toda la información generada a lo largo de la metodología era sintetizada partiendo de lo general a lo particular. Para esto, se contempló un plan de trabajo que involucró alcances con tiempos asignados, técnicas y metodologías acorde a las características del proyecto que definían sus objetivos, el estudio preliminar de temas relacionados principalmente con el desarrollo de interfaces, el entendimiento de los usuarios y su entorno, la generación de conceptos partiendo de un análisis de necesidades y la evaluación de dichos conceptos que conducían a una propuesta final. Es por eso que el planteamiento de la problemática de un proyecto posibilita su comprensión para posteriormente fijar las metodologías y técnicas que se adapten a sus características, facilitando así el proceso de diseño.

Durante todo el proyecto se contempló un proceso iterativo que facilitó la corrección de errores durante cada etapa de desarrollo, esto brindó flexibilidad para continuar con el proceso de diseño. De este modo se obtuvieron resultados concretos y específicos de la información requerida que condujeron a una buena propuesta de diseño sin que ésta perdiera los puntos clave del proyecto.

Pese al plan de trabajo formulado, durante el desarrollo de éste surgieron diversas problemáticas que no se tenían contempladas. Un ejemplo de esto fueron ejemplo de esto fueron las dificultades manifestadas al momento de llevar a cabo la investigación empírica que abarcaba entrevistas a usuarios y observaciones. Se consiguieron 6 entrevistas, sin embargo solo 2 fueron dirigidas a ergónomos involucrados directamente con el proyecto debido a su disponibilidad limitada y su ubicación en otra ciudad. El haber entrevistado más usuarios directos hubiera arrojado información más a detalle sobre métodos ergonómicos de evaluación, problemas, experiencias y comentarios personales respecto a su trabajo y la labor que desempeñan y por ende una disminución de errores al presentar la generación de conceptos. La solución que se abordó para extraer más información respecto al tema fue la de conducir las entrevistas a usuarios indirectos, es decir, fueron dirigidas a usuarios cercanos con conocimientos en al área de ergonomía y diseño de interfaces, en este caso, profesores pertenecientes a la Universidad de Skövde. Asimismo se realizó un cuestionario dirigido a ergonomistas y se subió a través de un foro, sin embargo no se obtuvo respuesta alguna por parte del foro, dificultando así la recolección de información.

Por otro lado, las observaciones de la investigación empírica fueron analizadas por medio de grabaciones realizadas en una línea producción, en las que se examinaron los roles de los usuarios involucrados, las herramientas utilizadas, el tipo de información manipulada y su flujo, así como la secuencia de acciones realizadas. Esta fase permitió esclarecer el entendimiento del sistema. Es posible que se hubiese tenido un mejor acercamiento a la problemática de haber realizado las observaciones en el área de trabajo en lugar de solo contar con grabaciones. No obstante las limitaciones de tiempo y alcances no permitieron llevar a cabo observaciones en el sitio, limitándonos a solo observar por medio de video.

Más adentrados en el proyecto, al llevar a cabo la etapa de generación de conceptos, se hizo uso del método *Validation Scenario*[1] (*Cooper, Reimann, y Cronin, 2007*), el cual consistía en seleccionar el concepto que mejor abarcaba las especificaciones del proyecto para posteriormente ser desarrollado, sin embargo, este método de evaluación sólo contemplaba aspectos generales pasando por alto datos particulares y relevantes. El haber utilizado otro método que analizara más detalle las características de los conceptos, hubiese ahorrado tiempo para arreglar problemas de organización y distribución de elementos, simplificación de ideas y disminución en el número de pruebas realizadas con usuarios.

El concepto elegido fue probado por los profesores entrevistados anteriormente para poderlo mejorar por medio de una evaluación formativa, la cual daba solución a los errores encontrados durante la prueba para más adelante realizar una nueva evaluación. La manera de evaluar el concepto fue mediante una métrica de objetivos a cumplir considerando factores como el tiempo y número de errores cometidos. Durante esta etapa se generó un prototipo de papel con el que uno de nosotros interactuaba con el usuario mientras otro realizaba el llenado de las métricas. Esto a veces generaba que los valores se percibieran como subjetivos, sobre todo al momento de contar el número de errores generados por el usuario y el tiempo transcurrido, esto implicaba seguir corriendo el tiempo en tanto se tomaban en consideración los comentarios y dudas que el usuario transmitía. Así, el número de errores fue calculado en un aproximado, mientras que el tiempo registrado contemplaba comentarios y dudas. A pesar de esto el proceso iterativo mejoró el concepto, corrigiendo errores y cumpliendo con los aspectos de usabilidad.

Otra situación a tomar en consideración fue la propuesta final de diseño de los íconos, ya que estos estuvieron parcialmente definidos durante las evaluaciones con usuarios y fueron configurándose hasta la última iteración a consecuencia de limitaciones de tiempo. De haber realizado una prueba más, las propuesta de los íconos y elementos visuales en el diseño final pudieron ser mejoradas.
Se puede evidenciar que el proceso de diseño nunca sigue un camino lineal ya que existe más de una alternativa para dar solución a una problemática. Metodologías y técnicas de diseño, habilidad investigati-

[1] *Ver "Limit Down Ideas" (trabajo explicado en el capítulo 4 pag. 86 de este volumen).*

va e inventiva, brindan las herramientas para confrontar las dificultades presentes en un proyecto de una manera eficiente y con resultados satisfactorios. Así mismo, el planificar dará organización, coherencia, y jerarquización al trabajo y evitará que se pierdan de vista puntos clave. Por consiguiente cada elección ejecutada de manera premeditada y fundamentada en metodologías y técnicas de diseño acorde al plan de trabajo. Durante este proyecto las metodologías y técnicas tomadas en consideración fueron aquellas que estuvieran orientadas en el diseño de interfaces y con un enfoque en el usuario, con la finalidad de generar una empatía con ellos, saber quienes eran, entender sus aspiraciones e inquietudes que irían marcando las pautas que definirían la propuesta de diseño y así brindarles una experiencia enriquecedora.

Sin embargo, a lo largo del proyecto se manifestaron dificultades relacionadas con contratiempos que figuraban fuera del cuadro de planificación; consciente de esto, la dirección del programa fue planteada en un principio de una forma flexible la cual se adecuaba según las condiciones emergentes. De esta forma, vías alternas fueron investigadas y replanteadas en busca de nuevas soluciones. Esto nos da a entender que como diseñador es fundamental investigar y aplicar herramientas que eficienticen el proceso de diseño.

Como resultado final se generó un prototipo que presentaba las funciones del diseño. Para darle seguimiento al desarrollo de la interfaz esta debe continuar en la programación de la propuesta para mostrarse en las plataformas de tablet y computadora de escritorio, la cual requeriría el trabajo colaborativo por parte de programadores. En esta etapa una comunicación clara entre programadores y diseñadores sería esencial para generar acuerdos y tratar los problemas emergentes. Acto seguido se realizaría otra evaluación formativa para valorar los resultados finales, principalmente se ejecutaría una prueba con los usuarios directos para generar una retroalimentación que mejoraría la interfaz hasta lograr un resultado óptimo que cumpla con todas las especificaciones señaladas.

Al ser un proyecto en vías de desarrollo, la investigación que se gestó servirá como pauta para dar continuidad al proyecto y ser un punto de partida para futuras aportaciones.

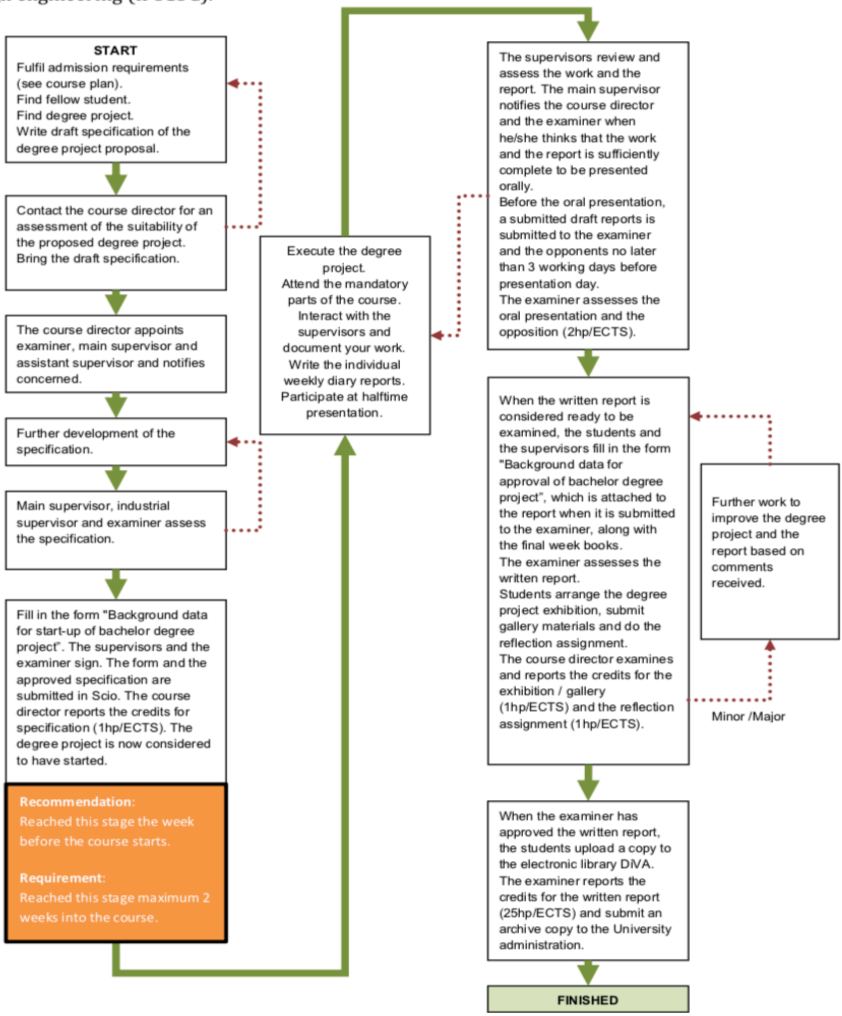
Comentarios

En un principio la Universidad de Skövde generó una serie de lineamientos para la realización del programa de tesis (figura 9) que consistía en hacer uso de una estructura predeterminada conformada por una portada, un resumen, tabla de contenidos, introducción, antecedentes, configuración organizacional, formulación de la problemática, el propósito y los objetivos del proyecto, así como la estrategia de ejecución para cubrir dichos objetivos. Los lineamientos mencionados solicitaban una investigación preliminar, el desarrollo de especificaciones, y el diseño final basado en generación y evaluación de conceptos, consideraciones para su desarrollo a futuro, una última evaluación del diseño considerando los resultados, discusiones y conclusiones. Y por último recomendaciones basadas en dichos resultados para la continuación del proyecto, y por último, presentar referencias y apéndice.

Al hacer una análisis del programa, este denota una configuración establecida de modo que cada resultado es consecuencia de una serie de decisiones que se fundamentan en el cumplimiento de este. No había lugar para conjeturas sin una argumentación previamente investigada que la respaldara. Los resultados obtenidos tenían su grado de importancia, sin embargo la fase de exploración e investigación para llegar a ese punto tenían más peso. De modo que el factor de investigación y aplicación metodológica siempre fueron los componentes esenciales del programa. Puedo concluir que el proceso brinda la ventaja de organizar paso a paso un proyecto anticipándose a la pérdida y descuido del enfoque de los objetivos principales y así prevenir contratiempos, divagaciones e ineficiencia.

En contraste, en mi experiencia como estudiante en el Centro de Investigaciones de Diseño Industrial, se fomentaba la investigación de una manera autogestiva sin una pauta rígida la cual seguir, propiciando un enfoque más práctico para la obtención de resultados. La investigación daba las pautas para abordar un proyecto y a la vez promovía el uso del razonamiento de una manera pragmática al alcanzar resultados de una manera flexible en donde la experiencia y sentido común se hacían presentes y tenían validez al mostrar resultados congruentes.

Flow chart of start and execution of degree project in integrated product development/product design engineering (IP515G).



[Fig. 9] Programa para la realización de tesis por la Universidad de Skövde. (Högberg, 2018).

Ambos caminos han aportado en mi formación como profesional. En ambos casos se demuestra que no hay un camino concreto al diseñar, ya que el ingenio tiene infinidad de herramientas a su disposición. Hay métodos que ofrecen mayor soltura en su desarrollo que otros, depende del proyecto es como este se analiza y se decide la manera para llevarlo a cabo. Asimismo por medio de la experiencia se brindará un mejor estudio de los proyectos para aplicar conocimientos adquiridos que propicien soluciones fructíferas, se reconocerán patrones para abordar una problemática y se eficientarán procesos. No dejo de lado la apertura de nuevos conocimientos adquiridos por medio de una constante investigación alimentada por la inquietud por saber más, ya que el diseño se renueva continuamente y las necesidades de los seres siempre estarán presentes. De modo que el diseñador y su labor que le compete en una sociedad es la de servir, facilitar la vida de la gente por medio de productos, brindarles satisfacción y así hacerles felices.

Puedo decir que el proyecto *IISEES* arrojó buenos resultados ya que se cumplieron con los requerimientos, hubo un proceso de desarrollo satisfactorio y se recabó suficiente información para darle seguimiento. Ahora, extrapolando la aplicación de este proyecto en un contexto como el de México, este podría adaptarse en las compañías de *Volvo Cars AB, Volvo Trucks AB* y *Scania CV AB* presentes en la nación y de ser posible en otras corporaciones similares, ya que México cuenta con diversas armadoras automotries. Sin embargo, esto tendría repercusiones en el ajuste de los estándares de evaluación ergonómicos debido a su enfoque en la población mexicana, y por consiguiente la identificación y solución de necesidades emergentes. La información y experiencia recabada en la problemática previa serviría como punto de partida para adaptar y generar una estrategia de planeación implementada en el nuevo contexto. De este modo el desarrollo del producto sería más eficiente y con un menor rango de errores sin dejar de lado los objetivos principales. El proyecto seguirá apostando por el cuidado de la salud de los trabajadores, para así mejorar la productividad y por ende, la reducción de costos para las compañías, teniendo siempre como prioridad al usuario para brindarle la mejor experiencia.

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Abstract

Abstract

During the spring semester of 2018 a product development project has been carried out at the University of Skövde by two Design Engineering Students, Pontus Rang-Roslund and Guillermo Munguía Velazquez, in cooperation with the project group for Smart Textiles for Sustainable Work Life at the University of Skövde as they are now focusing to develop a web-based software for ergonomists and work leaders/coaches. The aim of the project is to design the interface for the software. The project carried out literature review focused on basic principles of usability, cognition, user interaction, human-computer interaction, user experience and ergonomic evaluation methods. In order to uncover user needs, interviews and observations were performed, and inputs and outputs of the management information were analyzed. Based on the gathered information, concepts were generated and evaluated through formative evaluation. The final iteration brought a flexible and usable interface for ergonomic evaluations.

1. Introduction

1. Introduction

In manufacturing industries, the workers are exposed to risk factors produced by fatigue during the workday. When fatigue outruns the workers' body recovering system, the musculoskeletal disorder occurs (ergo-plus, 2018). According to ergo-plus (2018), the injuries of the musculoskeletal disorders often occur from repetitive movements, lifting, pushing, and pulling at such exhausting and strenuous work postures. The reason why an injury may appear is whether the worker has a bad posture while performing a task or the dimensions of the environment are not profitable to perform the tasks. Therefore, the musculoskeletal disorders may occur in many industries.

According to Påhlman, an ergonomist at Feelgood AB, to prevent injuries and to improve a workplace, ergonomists observe the workers while they are performing their tasks and use physical ergonomic assessment methods such as RULA, RAMP and KIM 1, 2 and 3, to identify what causes the injuries or how the risk is for an injury to occur, which includes postures that the workers retain. The assessments measure the various body parts, such as the degrees, distances, speeds, and forces from the workers.

According to Behrens, an ergonomist at Feelgood AB, ergonomists conduct an ergonomic assessment through observations of the activities that the workers perform which produces an imprecise evaluation because each ergonomist interprets each posture differently, from a range of acceptable to unacceptable postures. Conducting an assessment through observations is subjective, which causes each ergonomist obtain different results.
In addition, the data extracted requires being organized, classified, and

visually represented in charts and tables to allow a better understanding to manage the information.

By using the LPMS-B2 sensor (Ip-Research), the process of ergonomic analysis through smart textiles is highly improved and eased. The LPMS-B2 sensor is versatile, performs at an accurate, high speed orientation and provides relative displacement measurements. In the use of textiles, the LPMS-B2 sensors records the worker's activity and produce a great amount of data as numbers from each sensor in the textiles. This data generates precise information in real time of the activities. However, the process to make an ergonomic analysis through smart textiles is under development, and there is no way as of today to organize all the information extracted in the process. Therefore, the great amount of raw data produces difficulties to understand and analyze for the user.

Since the sensors collect much information that will be evaluated at the website, the problems that can occur for the ergonomists and coaches are to manage all the data and be able to differentiate from various types of data such as angles and movements measured from back and arms. To solve the problems that can occur for the ergonomists while using the website, the aim of this project is to develop an intuitive interface for ergonomic assessment which is flexible, considering the different methods of assessment each company implements. The solution developed must also be easy to use and be able to analyze both virtual and real cases while being usable for the user.

Background for the Project

The project Intuitive Interface Structure for Ergonomic Evaluation Software arose from another project, Smart Textiles for Sustainable Work Life which aims to develop a system to measure, assess and visualize physical loads and risks for musculoskeletal work injuries. The use of sensors and electronics in the Smart Textiles allows measuring parameters where the measurements are analyzed, and risks are estimated using the company's specific and scientific methods (Högskolan i Skövde, 2017).

With the extraction of the accurate information provided by the Smart Textiles leads ergonomists and coaches to make physical ergonomic assessments without ambiguous conclusions.

Smart Textiles for Sustainable Work Life is a collaboration between the University of Skövde and several other universities and companies, such as Kungliga Tekniska Högskolan (KTH), Karolinska institutet, Volvo, Feelgood AB and Vinnova.

Definition of the Problem

Although the smart textiles present aid to develop a physical ergonomic analysis, the accumulation of all the data is shown in a complex and intricate way. See table 1.

As the information needs to be analyzed by ergonomists and coaches, the information requires to be clear and understandable. Unclear information leads to mistakes and poor understanding between the variables and the results. Moreover, unnecessary time and effort would be used in trying to understand the complex and confusing data. An intuitive interface would solve both these problems.

Purpose

The aim for the project “Intuitive Interface Structure for Ergonomic Evaluation Software” is to design a software that integrates and organizes physical ergonomic data with inputs and outputs, allowing users to know the behavior of each variable along with the time to compare, analyze and classify the information regarding physical ergonomic assessments.

As the information requires to be presented in an understandable way to manage several ergonomic evaluation cases at the same time, the interface needs to be flexible and user-friendly. Studies in the Human-Computer Interaction benefit in terms of generating a clear communication between machine and person to solve issues regarding the interaction by giving guidance on actions to perform. In addition, the

User Experience area provides quality and enjoyment of the experience whereas an interface is a result. Therefore, those fields are the key to reach the goals presented in the project. The next objectives presented below are considered for the development of the project:

Focus on user experience and user interface literature, and their methodologies to fit user's needs.

- Development of a flexible and intuitive interface.
- The ergonomists shall know the behavior of each variable along time and be able to analyze both recorded and real cases.
- Research on physical ergonomic methods.
- Creation of flowcharts that explain the existing system
- Development of task and feature analysis to achieve the goals required by users.
- Validation of concept designs.
- Presentation of the design proposal aimed with HTML and CSS.

Initial Needs

The points below are the needs requested by the project group for Smart Textiles for Sustainable Work Life at the University of Skövde. These initial needs are explained further in detail in chapter 3.

- The interface should allow the user to analyze real cases and recorded cases by displaying the cases that are running and cases that have been recorded.
- The interface should show the behavior of each variable along time by displaying the variables in real-time.
- The interface should be flexible by offering a range of ergonomic evaluation methods. The interface should be usable by aiding the

user in ergonomic evaluations.

- The interface should be intuitive by enabling the user to progress throughout the interface with low or no mental load.

The Design Process

The general plan of action for a design project is described as sequences of particular activities that the designer is expected to perform, which is called a design strategy (Cross, 2008). To develop a final concept for an interface, the process of Goal- directed design offers the tools to reach the goals of the project. User Experience and User Interface methodologies are applied in the process in order to cover the gap existing in the digital product development process. Those methodologies embrace the user goals by enabling the understanding of the desires, needs, motivations, and contexts of users, resulting in a useful classification, choosing the most relevant activities for the design.

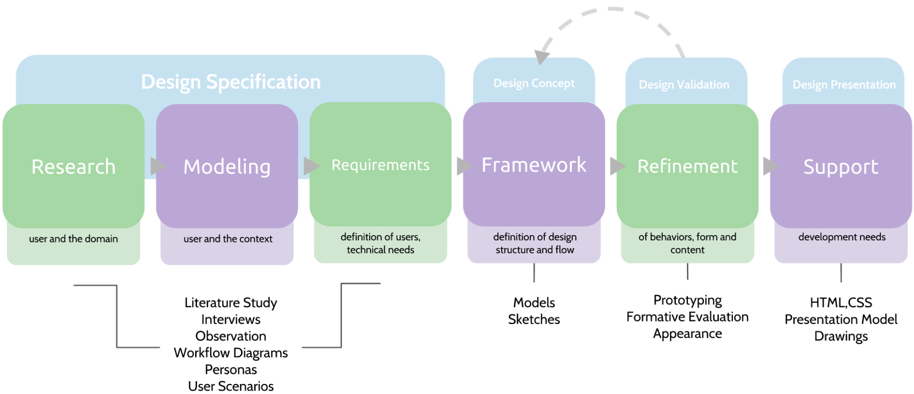
There are six phases that shape the process of Goal directed design: Research, Modeling, Requirements Definition, Framework Definition, Refinement, and Support (Cooper, Cronin and Reimann, 2007).

The research phase includes both interviews of customers and users and observations to provide qualitative data about users of the product. The outcomes of the research phase aim to identify behavior patterns that suggest goals and motivations. The behavior patterns are addressed to the creation of personas in the modeling phase with flowcharts diagrams to synthesize information from the research phase. Once the creation of personas occurs, the main characters are described as placed in a narrative called user-scenarios which belong to the Requirements Definition phase. During the Requirements Definition phase, the connections between the user and the framework of the design are presented as long as user-scenarios is being focused on meeting the goals and needs of specific user personas to be linked later in the Framework Definition to iteratively generate design concepts.

In the Framework Definition phase, the overall product concept is created through sketches with features and data elements that fulfill

the users' needs. By using a prototype, the concept is tested through a formative evaluation during the Refinement phase.
At the final stage, the design must be adjusted to be presented according to development challenge and technical question to reach the Development support stage.

The followed process is shown in the figure model 1, where the used method is presenting the development of the design proceeding from one stage to the next, but with feedback loops showing the iterative returns to earlier stages which are frequently necessary (Cross, 2008).



[Fig. 1] The project's design process.

2.Pre-study

To obtain a broader understanding of the project and to gain comprehension in the area of software development and its interface, literature and empirical studies were conducted. Information regarding Human-Computer Interaction (HCI), User-Interface (UI), Cognition, User-Experience (UX) and web development from scientific literature and articles was consulted.

In order to extract user needs that lead to the possible design solutions for the interface, empirical studies were made by interviewing ergonomists/physiotherapists and observations from a work session.
By conducting empirical studies, it is possible to collect qualitative data from users, the kind of methodologies applied by them and as a consequence the features needed in the interface to achieve user goals.
At this stage, the preliminary goals are turned into subgoals. How the subgoals are uncovered is through literature review, interviews, and observations. As result of the interviews and observation directed to users, qualitative data emerge with the purpose of discovering a set of demand specifications. All the demand specifications are translated into features for the interface which support the concept generation in next stage, with purpose of achieving goals and subgoals uncovered at this stage.

Initial Needs

The development of the interface according to the brief should be easy and usable. This project will cover the area of interaction design in which the central concern is to develop interactive products that are usable, as in easy to learn, usability and to provide an enjoyable user experience (Preece, Rogers and Sharp, 2002).

As the interaction design covers several areas, the project relies on the areas that are beneficial in developing the interface. According to Norman (2013), interaction design covers several principles of psychology, design, art, and emotions to ensure a positive and enjoyable experience. It has a focus on how people interact with technology.

Cognition

One area that is important in how the user is perceiving the information, for design interaction is psychology. “Good design starts with an understanding of psychology and technology” where psychology makes it possible to understand the mechanism of how people process information (Norman, 2013).

Thus, through cognitive processes, the brain is structured to act upon the world, and every action carries with it expectations (Norman, 2013). Sometimes, those expectations may drive an unexpected behavior from users if the communication is poor between the user and the proposed solution, where the designers must understand that people will make some errors and understand human error as any deviance from “appropriate” behavior (Norman, 2013). According to Cooper, Cronin and Reimann, (2007), the behavior could be designed, by an understanding of the user’s relationship with the product from before purchasing to end-of- life. Applying cognition knowledge will provide a good design solution that anticipates human behavior.

Cognitive Model

The classic cognitive model is also known as human information processing system (Rosli, 2015). The model explains how humans receive the information from sensory input and how they are transferred to the brain, the brain makes an interpretation and the human will perform an action upon it (Rosli, 2015).

According to Friedemberg and Silverman (2012), for a person to make an interpretation, firstly the information from sensory inputs such as visual and auditory is sent to the person's working memory. At this stage, if the information is activated by the user regularly, the information will be sent to the person's long-term memory but will evanesce if the information becomes passive. To help users to preserve the information on a system, designers should acknowledge ways to make use of the information stored in the long-term memory.

Interface design, as a negotiator between users and the system, plays an important role in the system (Rosli, 2015). The users will recognize the information from the interface and interpret it into relevant information. To make an astute decision in a system, the role of Situational Awareness (SA) is studied, which is often defined as the perception of elements in an environment, an interface system design where users need to understand available information that surrounds the users (Rosli, 2015).

To help users to understand the system, familiar, visible and consistent images and icons will improve the users' recognition of information that is useful (Shneiderman and Plaisant, 2010).

Perception

Perception is the process where humans gather information from the outside world via senses and interpreting the information (Friedenberg and Silverman (2012). Information that users recognize comes from clues in the environment. The information in the user's long-term memory helps the users to classify recognized information into relevant information (Endsley, 1995).

Comprehension

At the comprehension level, users will understand and organize the significance of perceived information on a particular situation. Users will be able to have a mental model about a situation stored in their long-term memory by using essential interpretation. At this level, Situational Awareness (SA) is defined as a situational model depicting the current state of the mental model. To aid the users to understand a system better, the information displayed on the interface system design needs to be semantically associated together (Endsley, 1995).

Pattern Recognition

The role of sensory memory is to encode the human perception of visual information so that the pattern recognition has the possibility to occur. Perceptual pattern recognition is, in many ways, a problem-solving process, although much of the mental work occurs subconsciously and rapidly (Ashcraft and Radvansky, 2010).

According to Ware (2011), an object may be separated from its background because the brain requires a generalized contour extraction mechanism in the pattern-processing stage of perception. Based on that, line drawings are effective in communicating different kinds of information.

Gestalt Laws

Soren Lauesen (2005) writes gestalt laws are what humans can perceive as a unit or an object without any training or conscious effort. The gestalt laws can, to an extent, be explained by the way the vision centers work in the brain. There are several gestalt laws on how a human perceives a unit or an object. Eight of the gestalt laws are explained next:

- Law of proximity:
  Pieces that are close together are perceived as belonging together.

- Law of closure:
  The area inside a closed line is perceived as a shape.

- Law of good continuation:
  Pieces on a smooth line are perceived as belonging together.

- Law of similarity:
  Things that look alike are perceived as belonging together.

- Law of prägnanz:
  Simplify complex shapes into simple shapes.

- Law of experience:
  Objects are perceived after earlier experience with similar objects.

- Law of common region:
  Elements that are grouped together within the same region of space tend to be grouped together (verywellmind, 2018).

- Law of element connectedness:
  Elements are connected to each other by the use of colors, lines, frames or other shapes that are perceived as a single unit (interaction-design, 2018).

Human-Computer Interaction

According to (Norman, 2013), a good design of an interface desires clear communication especially from machine to person, indicating what actions are possible, what is happening, and what is about to happen. The project is related to designing of an interface, which means it has a relation with the field of Human-Computer Interaction (HCI). Therefore, HCI aims to support a clear communication between the interface and the users.

Another fact to keep in mind is that HCI uses usability aspects to ensure it is effective, efficient, and satisfying for the user. This includes characteristics such as ease of use, productivity, efficiency, effectiveness, learnability, retainability, and user satisfaction (ISO 9241-11, 1997). Through the usability factors, the design triggers good experiences for the user.

Usability Factors

In the area of Human-Computer Interaction, there are several subareas of interest, which Soren Lausen describes in his book User Interface Design "A Software Engineering Perspective" as six usability factors:

- Ease of learning:
  How easy is the system for various groups of users to understand?

- Task efficiency:
  How efficient is it for the frequent user?

- Ease of remembering:
  How easily does the occasional user remember?

- Subjective satisfaction:
  How satisfied is the user with the system?

- Understandability:
  Is it understandable to know what the system does in an easy way?

Fundamental Principles of Interaction

Donald Norman writes in his book The Design of Everyday Things (2013) about the fundamental principles of interaction which are divided into five fundamental psychological concepts as affordances, signifiers, constraints, mappings, and feedback, where each concept is described next:

Affordance

An affordance is a relationship between a person and any interacting object's properties and how could be used, such as a door handle (figure 1 p49) that the person can use in order to pull or push (Norman, 2013).

The presence of an affordance is commonly determined by the qualities and abilities of the object that it is interacting with. The opposite of affordance is anti-affordance, which means the prevention of interaction. The affordances and anti-affordances must be perceivable to be effective by some means for signaling their presence through signifiers (Norman, 2013). By integrating affordances into an interface design, the user knows what to do by just looking at the design (McGrenere and Ho, 2000).

Signifiers

Signifiers communicate which actions are possible to conduct on an affordance, where figure 2 (p49) is an example of a signifier and an affordance where the arrow on the lid shows which way the lid should be rotated to open the packaging (Norman, 2013).

Signifiers are an important way of communicating to the user to understand to proper using a product's or service's action(s) (Norman, 2013).

Constraints

Constraints are about limiting the range of interaction possibilities for the user to simplify the interface and guide the user by clarifying what can be done. The visible affordances of the pieces are important in determining how the pieces fitting together. Four types of constraints exist (Norman, 2013):

- Physical constraints: apply to the limitations caused by features such as size and shape. Effective physical constraints are made by simplifying to visualize and interpret, followed by the set of restrictions before anything has been done. Otherwise, a physical constraint prevents a wrong action from succeeding only after it has been tried.
  An example of a physical constraint is the size of a coffee takeaway mug where the lid may be too small or too big to fit the mug.

- Cultural constraints: each culture has a set of actions that are allowed and not allowed to do in social situations where the constraints restrict a consequence of what is socially and culturally apply as acceptable behavior.
  An example of a cultural constraint is a person being hindered to perform an action due to breaching a norm or law.

- Semantic constraints: is the study of meaning where the constraints are limitations that rely upon the meaning of the situation to control the set of possible actions.
  An example of a semantic constraint is a traffic light where the color red means that the driver has to stop the vehicle and green color means the driver is available to drive.

- Logical constraints: are a type of constraint that comes to the attention due to the obviousness or due to logic was violated. There is a logical relationship between the spatial or functional layout of components and the things that either affect or are affected.

An example of a physical constraint is a door-block (figure 3 p49) that stops the door to move further when opened.

Mapping

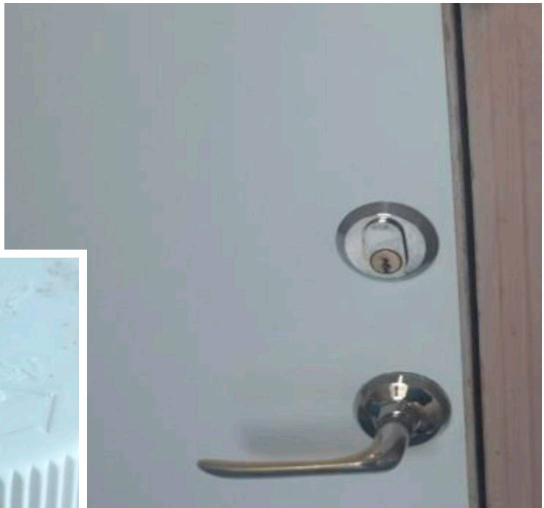
Is the relationship between elements of two sets of things. Mapping is an important concept in the design and layout of controls and displays. The relationship between control and its result is easier to learn if an understandable mapping between the controls, the actions, and the intended results exists. Natural mapping takes advantage of spatial analogies that leads to immediate understanding. To make a mapping,

[Fig. 1] Door handle, example of affordance.

[Fig. 2] Cover flask, example of signifiers.

[Fig. 3] Door bumping, Example of (physical) constraint.

[Fig. 4] The mapping of an oven.



the controls should be arranged in the same pattern as the product that shall be used (Norman, 2013).

An example of mapping (figure 4) are the icons immediately above the rotatable buttons that show which oven plate each button belongs to, where the buttons can be thought of as affordances and the icons as signifiers.

Feedback

Feedback is the result of a conducted action and must be immediate. Delay of seconds can be perceived as disconcerting for the user, and if the delay is too long, the user often gives up and goes off to conduct other activities. Poor feedback may be perceived as worse than no feedback at all if the user cannot interpret the feedback that has been returned (Norman, 2013).

An example of feedback is when rotating one of the buttons in figure 4, the user hears a clicking sound which is a type of feedback that the button has successfully been rotated, while another feedback is the rising temperature of an oven plate.

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User Interaction

A good user-interface guides user to know what to do through the interaction between them and the interface.
The context plays an important role in the field to ensure a good interaction: who the user is, what the user is doing, and what the motivations are (Cooper, Cronin and Reimann, 2007). Whereas inputs are uncovered, and outputs generate the configuration of solutions for the project based on what kinds of activities are needed to be supported (Hartson and Pyla, 2012).

Design Principles

Areas of interest within User Interaction are as follows:
According to Cooper, Reimann and Cronin (2007) interaction design principles are generally applicable guidelines that address issues of behavior, form, and content. Design principles inspire the design of a product's behaviors that aid the needs and goals of users and creates positive experiences with the product. The principles are, in effect, rules based on the values that the designer sets and achieves through experience to the values.

The design principles operate at several levels, ranging from general interaction design down to the specifics of interaction design. The design principles fall into following categories:

- Design values: describe imperatives for the effective practice of design. The principles inform and motivate lower-level principles.
- Conceptual principles: help to define what a product is and how the product fits into the broad context of the user required by its user.
- Behavioral principles: describe how a product should behave, in general, and in specific situations.
- Interface-level principles: describe strategies which are effective for the visual communication of behavior and information.

Interaction Design Patterns

Design patterns are means of capturing solutions of design and generalizing the designs to address similar problems. The effort to formalize design knowledge and record best practices can serve virtual purposes (Cooper, Reimann and Cronin, 2007):

- Reduce design time and effort on new projects.
- Improve the quality of design solutions.
- Facilitate communication between designers and programmers.

The patterns in a design are pedagogical and the efficiency is important. In the development of interaction design, patterns can represent optimal interactions between the user and the class of activity that the pattern addresses.

User Experience

User Experience design is the practice of designing products, processes, services, events, and environments with a focus placed on the quality and enjoyment of the total experience (Norman, 2013)
User experience ensures the quality of experience which is supported by usability factors, which includes effectiveness, efficiency, productivity, ease-of-use, learnability, retainability, and the pragmatic aspects of user satisfaction (Hartson and Pyla, 2012). Within the developing of the project, those usability factors need to be covered to generate good user experiences.

Moreover, user experience (UX) is the consequence felt by a user as a result of interaction with, and the usage context of a system, including the influence of usability, usefulness, and emotional impact during an interaction, plus saving of the memory after interaction (Hartson and Pyla, 2012). If the project aims for providing good experiences, it is requiring designing the behavior of an interactive system, which relies on the understanding of the factors involved and their interaction with the system. Since UX embraces the system, the project will include a lifecycle activity analysis to gather detailed descriptions of user work activities and underlying rationale.
This is achieved by the project's required contextual inquiry, based on information gathered through interviews of customers and users and observations of work practice occurring in its real-world context. Areas that are of interest in User Experience are as follows:

Mental Load

According to Cooper, Reimann, and Cronin (2007), one of the primary purposes principles is to optimize the experience of the user when he or she engages with the product. In case of productivity tools and other non-entertainment-oriented products can be optimized for a mental load by minimizing work, which includes:

- Cognitive work: comprehensions of product behaviors including text and organizational structures.

- Memory work: recall of product behaviors, command vectors, passwords, names and locations of data objects and controls, and other relations between objects.
- Visual work: determine where eye's starting point is on the screen, finding one object among many, decoding layouts and differentiating among visually coded interface elements.
- Physical work: keystrokes, mouse movements, gestures, switching between input modes, and the number of clicks required to navigate.

Ergonomic Evaluation Methods

There are many ergonomic evaluation methods that are used to make an ergonomic evaluation for various body parts such as RULA and REBA where the ergonomic evaluation methods are important for the project by being part of the initial need of flexibility. The interface should allow the user to choose and use a range of ergonomic evaluation methods based on the users' choice of the method since manufacturing companies use their own methods, such as SCANIA's SES and Volvo's BUMS (Behrens, 2018). A few ergonomic evaluation methods are described below.

OCRA

According to Colombini, Occhipinti and Casado (2013), OCRA (Occupational Repetitive Action) is a method which is suggested as a preferred method to measure the risk of biomechanical overload of the upper limbs in ISO and CEN biomechanical standards. The method provides criteria and assessment tools for risk evaluation at different levels of detail. OCRA method exists on three levels:

- OCRA Mini-Checklist: The OCRA Mini-Checklist enables faster assessment than the OCRA checklist, albeit with less precision. It is more suitable and most likely sufficient, for assessments in special sectors in which the work is not organized according to precisely defined rates, times and cycles as it is in the industry.

- OCRA Checklist: The OCRA Checklist is a tool used to draw up an initial map of the present risk of repetitive work. The map makes it possible to determine what proportion of the jobs or tasks can be classified as green (no risk), yellow (significant or borderline), red (medium risk) or purple (high risk). The OCRA Checklist can be applied quickly and does not include the specific analysis of each movement obtained.

- OCRA Index: The OCRA Index offer analytical risk assessment and should be used when designing or redesigning jobs and/or parameters related to work, organization, rotations, the relocation of diseased worker and strategic plans to increase productivity.

OWAS

The OWAS (Ovako Working posture Assessment System) is a method that focuses on postures during work using four digit-coding which is described as the whole-body posture. OWAS identifies postures that are the most common for the back, arms, and legs, and the weight of the load handled. OWAS can be used in many fields of manual work such as workers at steel industries, construction workers, healthcare workers (Karhu, Härkönen, and Vepsäläinen, 1981).

RULA

RULA (Rapid Upper Limb Assessment) is a method of observing postures of the upper limbs, neck, back, and legs, recording the values. After recording the values representing the observed posture in the first column of the score sheet is used to obtain a posture score for the A and B body groups. Values for each muscle are entered into their appropriate spaces on the score sheet. The scores C and D are then found by adding the separate scores. From these Grand, Score is found from table C of the figure. Enter scores C and D into the boundaries of the diagram and note the value where row and column intersect. Appropriate action requirements for the different scores are given at the bottom of the sheet (Wilson and Corlett, 1995).

STEM

STEM (Smart Textiles Evaluation Method) is based on several ergonomic evaluation methods such as RULA, EWAS, RAMP and SES. The STEM method was created for the software as the software's own ergonomic evaluation method (Högberg, 2018). Figure 5 and 6 show examples of what body parts the STEM method evaluates.

Upper arm elevation angle	Elevation angle, α ≥ 30°, t < 25% of selected time window and Elevation angle, α ≥ 60°, t < 5% of selected time window	**Green**	Arvidsson et al. (2017), modified by WP2 (percentage limits were added)
	Elevation angle, α ≥ 30°, 25% ≤ t < 50% of selected time window or Elevation angle, α ≥ 60°, 5% ≤ t < 10% of selected time window	**Yellow**	
	Elevation angle, α ≥ 30°, t ≥ 50% of selected time window or Elevation angle, α ≥ 60°, t ≥ 10% of selected time window	**Red**	

Upper arm angular velocity	Average generalized angular velocity, α/t < 60°/s, in selected time window	**Green**	Arvidsson et al. (2017)
	Average generalized angular velocity, α/t ≥ 60°/s, in selected time window	**Red**	

[Fig. 5] Upper arm angle/velocity (Högberg, 2018).

Wrist joint angle	Total time in Extension α ≥ 40° and Flexion α ≥ 30°, t < 12.5% of selected time window	**Green**	RAMP (2014) and Lind (2017)
	Total time in Extension α ≥ 40° and Flexion α ≥ 30°, 12.5% ≤ t < 25% of selected time window	**Yellow**	
	Total time in Extension α ≥ 40° and Flexion α ≥ 30°, t ≥ 25% of selected time window	**Red**	

Wrist joint angular velocity	Average angular velocity, α/t < 20°/s, in selected time window	**Green**	Arvidsson et al. (2017)
	Average angular velocity, α/t ≥ 20°/s, in selected time window	**Red**	

Thumb push force	F < 10 N neutral wrist, or F < 5 N bent wrist*	**Green**	SES (2015)	*Neutral wrist = Extension α < 40° and Flexion α < 30° *Bent wrist = Extension α ≥ 40° or Flexion α ≥ 30°
	F = 10-45 N neutral wrist, or F = 5-25 N bent wrist*	**Yellow**		
	F > 45 N neutral wrist, or F > 25 N bent wrist*	**Red**		

[Fig. 6] Wrist joint angle/velocity and thumb push force (Högberg, 2018).

Design Constrains for the Interface

The constraints presented in this section are the bases that rule the behavior in the development of the design of the interface.

Inputs & Outputs

The ergonomists work with spreadsheets in order to organize and analyze the information. They get used to working with spreadsheets in xlsx file because is the most commonly used. The information in an xlsx file usually has a text, numerical data and some functions for the automation of mathematical calculations and is placed into columns and rows. Thus, there is the presence of inputs and outputs of information extracted from the sensors which are placed in an xlsx file as is shown in table 1. The information provided allows to make an ergonomic evaluation where inputs are the variables to be analyzed and the outputs are the outgoing information of the smart textiles. As the execution of the ergonomic evaluation depends on the information extracted, it is required to understand the relation of the inputs and outputs to be placed in the design proposal.

Android_Ti	Work_Stat	Work_Cycl	Left_Arm_	Left_Arm_	Left_Arm_	Right_Arm	Right_Arm	Right_Arm	Trunk_Acti	Trunk_Ang	Glove_Ang	Wrist_Angl	Glove_Spe	Wrist_Spee	Glove_Pres	Thumb_Pre
hhmmss	STATUS	NUMBER	STATUS	degrees	degrees/s	STATUS	degrees	degrees/s	STATUS	degrees	STATUS	degrees	STATUS	degrees/s	STATUS	N
0	0	-1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
124518	0	-1	1	59.962128	0	2	60.369728	0	0	0.68281	0	0	0	0	0	0
124519	0	-1	2	61.980507	0	1	59.772114	0	0	0.593328	0	0	0	0	0	0
125033	0	0	0	6.403211	35.252037	0	5.31213	31.031321	0	8.233803	0	22	0	10.414034	0	0
125034	0	0	0	4.623013	35.175472	0	4.297882	30.962408	0	7.86195	0	22	0	10.380656	0	0
130815	1	1	0	26.756783	37.884644	0	1.473169	34.849312	0	4.080893	0	22	1	26.534313	0	0
130816	1	1	1	33.437546	37.730705	0	1.406997	34.632591	0	4.516898	0	21	1	26.395058	0	0
132457	1	2	0	16.080278	51.045738	0	8.213303	51.684608	0	13.684168	0	35.294117	1	68.414116	0	1.242757
132458	1	2	0	14.447268	51.522728	1	36.237118	51.878853	0	6.457722	0	33	1	69.219139	0	1.331525
132523	1	2	3	4.822302	73.590591	0	9.011998	48.735966	0	10.802482	0	1	1	61.472908	0	1.242757
132524	1	2	4	36.186069	72.926834	0	20.253954	48.171825	0	8.991767	-1	-73.529411	1	63.019093	0	1.153988

Time	Workcycle
Work Status	Body Part Analysis

[Fig. 7] Table 1: information extracted from smart textiles, (Högberg, 2018).

In the first column of the table 1 there is the time elapsed during a session. The second column belongs to the work status, which communicate whether a worker is working or resting during a session.
In the third column, the field of the work cycle is located, it provides information regarding the calibration of the sensors and the number of work cycles presented in a session.

The fourth column to the final column communicate information regarding the body parts activity, where values of angles, speeds and forces applied are presented. In addition, the columns present the status of the body parts. The status of each body part is scored with numbers according to the constraints of the ergonomic evaluation method. As the sensors are only able to capture the values of speed angles and force, those values are going to be represented in the interface.

Fonts

According to Weinschenk, (2011) the font selected is not critical if it doesn't produce difficulty to identify the letters. Nevertheless, some fonts look larger than others because different fonts have different heights although they have the same point size.

In addition, Weinschenk suggest the use of large enough font and create enough contrast between foreground and background in order to make the text easy to read. The best combination for readability is black text on a white background.

The fonts used in the interface need to be big enough for users to read the text without difficulties. During the evaluation of the concepts selected may present difficulties to be read if they are not appropriate for the users. In that case, fonts must be changed.

Colors

The colors used to assign a value to the ergonomic evaluation methods are red, yellow and green. The use of a red color means the presence of risk in a body part posture, a yellow one means possible risk and a green color refers to a good posture. Those colors have to be considered for the design of the interface. Colors can also be used for creating contrasts because they allow people to perceive elements quickly and easily (Cooper, Reimann and Cronin, 2007), for example, darker colors on a light background or lighter colors on a dark background can be used to indicate greater quantity (Ware, 2011).

A color blue represents calm and belongs to the “cool” colors and it is pleasant than warm colors (Modern Language Association, 2010) which represents a great alternative to be used in the interface. The presence of blue color in the interface provides a contrast against the red, the yellow and the green color used for the ergonomic evaluation methods.

Size of Elements

The size applied to the elements used in the interface gives the property of conveying information hierarchies. The larger the item is, the relative importance is bigger. The size applied to an element is a tool that provides distinction because it can draw the attention quickly (Cooper, Reimann and Cronin, 2007). By using the size property in the interface, it would serve as an ordered and quantitative variable.

Position of Elements

The interface requires organizing the elements to let know users the sequence of actions to be performed. After reading the order of a screen it is possible to find elements sequentially with the most relevant or first used in the top to the left. Position provides spatial relationships between objects (Cooper, Reimann and Cronin, 2007). Therefore, by using a grid the order of the elements will be uniform and consistent structure to layout the interface.

Results from Literature Review

In this chapter, the information collected during the literature review from books, papers, and scientific articles is summarized below to be applied forward for designing the interface. By using the information from the areas of cognition, HCI, UI, UX, the initial and collected needs (chapter 2.3.3.4) will be achieved to develop the interface. In addition, aspects of the framework, icons and colors constraints have to be covered according to the information collected during the literature review. According to Cooper, Reimann and Cronin (2007), the framework is the overall structure of the users' experience, from the arrangement of functions on the screen, interactive behaviors and to the visual and form language used to express data, concepts and functionality. Icons, from computer science point of view, is a representation of a function or command (Galaburda, 2018) and can be used to symbolize for example a worker by a hard helmet. Beneath is the collected information about cognition, HCI, UI and UX applied to the framework, icons and colors:

- Framework: Information regarding Human-Computer interaction, User-Experience, Cognition, User- Interaction and HTML & CSS needs to be considered when designing the framework by applying the information in the concept development phase.
  HCI, UX, UI and Cognition are the bases for designing the behavior in the interface. With HCI, the framework can provide a clear and flow communication with the users. The features applied in the framework should be understood without explanation.

- Icons: Information regarding Human-Computer interaction and Cognition has to be taken into account when designing the icons for the framework by considering icons that the users already have encountered in their daily life in the development phase.
  With HCI, the icons can be designed to make the interface usable for the users, such as efficiency and understandability of each page and also a button to press on. With cognition, the icons can be designed as similar icons that users already have encountered. An example is a worker with a tool which is similar to road warning signs for road work.

- Colors: Information regarding cognition about how colors are perceived by humans is necessary to inform the user if a posture is good, medium or bad with such as green, yellow and red in the development phase. Cognition has its role in the development of the interface on how the users perceive colors. In the western world, humans perceive colors differently, as an example the color red, which can be perceived in different ways, such as bad, rage or romance (bourncreative, 2011). Thus, the importance of cognition how the users perceive colors is necessary to show which posture is bad, medium or good.

- The software needs to allow the following ergonomic evaluation methods to be used:
  OWAS.
  OCRA.
  RULA.
  REBA. NIOSH. STEM.
  KIM 1, 2 and 3. RAMP.
  SES. QEC. LUBA. HARM. EAWS.

Empirical Studies

The main point of the empirical studies is to gather qualitative data about the product. By understanding the users because qualitative research helps to grasp the domain, context, and constraints of a product (Cooper, Cronin and Reimann, 2007). This chapter describes the information extracted from a CSV file (table 1), interviews with the main users and observation of an ongoing session at SCANIA and the results in each section

Interviews

The process to extract needs from user to target the most important features of the product is through user interviews and by observing users in their work (Goodman, Kuniavsky and Moed, 2012).

After identifying the stakeholders and questions of the survey were made according to the goals that the project claims, the interviews were performed with ergonomists at Feelgood AB in Gothenburg who conduct physical ergonomic analysis on an assembly line at Volvo company (one of the companies associated with the project). Two groups were interviewed, ergonomists at Feelgood AB and lecturers involved in the Smart Textiles for Sustainable Work Life project at the University of Skövde.

Since the software's main user are ergonomists, most focus was concentrated on finding ergonomists to interview. Contact email information of an ergonomist in Feelgood AB was received from an interview with a lecturer from the University of Skövde. An interview request through email was sent, explaining the bachelor's degree and the reason behind the interview. Two new email contacts of ergonomists at feelgood AB in Skövde were received as a reply. New same requests were submitted to those contacts, but no reply was received from the ergonomists. To compensate the lack of ergonomists to interview, requests for interviews were sent to lecturers involved with the Smart Textiles for Sustainable Work Life project. Those who participated were interviewed with the same questions as the ergonomists. In total two ergonomists at Feelgood AB in Gothenburg and four lecturers at the University of Skövde were interviewed. The foundation of the interviews lies upon ascertaining what kind features are wanted for conducting an ergonomic evaluation.

Interviews Sheet

According to Goodman, Kuniavsky, and Moed (2012), participants need to understand the questions that are going to be asked and freely agree to participate. Informing the participants and gain the participants' permission reassures both the interviewer and the interviewee to avoid the impression of being exploited, it is important to grant all the information that the participants' needs before the interview had started.

All interview participants were given a spreadsheet to fill out. The spreadsheet explains the purpose of the interview and, if the interviewee gives permission, to capture a video or audio recordings during the interview and quote any verbal statement. The spreadsheet allowed the interviewee to understand the reason behind the interview and if to permit to be recorded in video or voice, which made it easier to extract the needs from the interviews by being able to listen back at a later time. The interview sheet can be found in the appendix.

Questions

The questions formulated in the interview were regarding ergonomic constraints, ergonomic evaluation methods used during an evaluation, and features that may apply for the interface. As many companies use their own methods, work sessions and previous experience using software are aimed to perform ergonomic evaluations.

Ergonomic Questions	Interface Questions
• Which kind of physical ergonomic evaluation do you use? *• Which kind of physical ergonomic evaluation are more useful for you and why?* *• What are the features that reveal those methods?* *• Tell us about your experience using softwares to analyze physical ergonomic evaluations?* *• In which is way the information presented?* *• Which steps do you follow to analyze the information? (Sequential use)* *• What are the tasks to analyze the information gathered from the ergonomic assessments?* *• While you are analyzing the information, which kind of difficulties does it present?* *• What would you do to improve it?*	*• What kind of information is evaluated?* *• What kind of activities are evaluated?* *• Number of tasks to perform?* *• How many people are performing the tasks?* *• What do they do?* *• How do they do?* *• Where do they do?* *• The restrictions of usability for each user? - Who is going to have acess to the website's functions?* *• How do they access to the information (log in) steps?* *• In which way the info is presented (statistics, graphics, icons, percentages, icons for postures)?* *• What kind of Info is required from the users (ID, age, weight, height)?* *• What kind of format is required for the interface (computer, tablet)?*

Survey

A survey was created to reach more ergonomists and to extract more answers. The survey contains the same questions but was circumscribed to make the questions more understandable. For questions where multiple answers may occur, such as which evaluation methods are used, a range of alternatives to choose from was presented. The ergonomist could there use more than one method and answer and was also given the possibility to manually fill out a name of a method that was not listed. The survey was later posted on reddit.com in the subreddit ergonomics. The survey can be viewed under index B via a link.

Results from the Interview

The needs and wishes that were collected during the interviews are as follows:

Needs

- *Workcycles.*
- *See one to several exposures.*
- *Structure/organize levels of data.*
- *Feedback.*
- *Time of exposure (elapsed time).*
- *Overall view of data by be able to narrow down to specific data.*
- *Evaluate with numbers and colors.*
- *Comparison of data which includes speed, extension, angles, back, wrist, thumb force.*
- *Print report.*
- *Be able to navigate.*
- *Low steps.*
- *Menu system.*
- *Use of visual features (visualizations, graphs, numbers and statistics).*
- *Be able to handle different cases*

Whishes

- *Skip login.*
- *Be able in multiple languages.*
- *Easy visualizations.*
- *Weight, height, age and gender*

Zero results were derived from the survey since no responses were submitted.

Observing Users

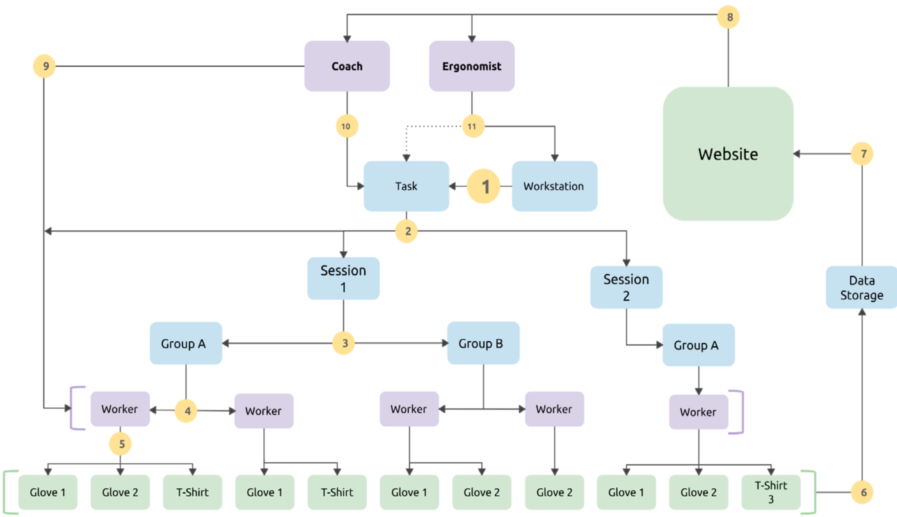
Another way to understand people's experiences is to observe the performed actions, which problems can occur and how and why the people do what they do (Goodman, Kuniavsky and Moed, 2012).

The observation was conducted in a workstation at SCANIA (one of the companies associated with the project), a recorded video from an ongoing session was analyzed by observing what the participants were doing, what tools were used, and how they were used. A better understanding of the system emerged as a result of the observation, whereas interactions between users, the tasks performed, and the roles of the users were uncovered.

The problem setting is often complex, confusing, and poorly understood. In the course of problem-solving, temporary formulations of the problem may be fixed, but these are unstable and can change as more information becomes available. Many constraints and criteria emerge as a result of evaluating solution proposals (Cross, 2008).

In order to clarify the information extracted during the observation, contextual inquiry framework (Goodman, Kuniavsky and Moed, 2012) is a method that provides a guide for the process. The method resides in the analysis of the system. Firstly, the method describes the tools that are used and how do the tools interact. Second, the sequence of actions presented. Third, how the information is organized and used. Fourth, the interactions between people, processes, information, and the inputs and outputs are introduced.

The results from the observations gave a hierarchical structure of the context. The structure of the system is represented into a flowchart in figure 8 with the sequence of interactions numbered. The flowchart is linked with the contextual inquiry (figure 9) framework where the context is explained in detail.



[Fig. 8] Flowchart of the context.

Contextual Inquiry Framework

Tools	In the framework, the tools are colored in green. There are gloves and T-shirts, which are the smart textiles used by workers and do motion captures of their movements. All the information of the captured motions is placed on a website and presented to ergonomists and coaches.
Sequence of Actions	There is a loop of the actions that starts in the workstation where the activities take place for workers and coaches (number 1), followed by tasks to be performed by workers (number 2). In order to perform the tasks required, first, a session shaped with several groups has to start. Each session has a determined time to finish. After a session finishes, a new has to start (number 3). For each group where the workers are, they start their duty wearing the smart textiles (number 5). Thus, the smart textiles extract information from workers to share it into a cloud (number 6). The information is presented through a website to coaches simultaneously as the workers perform their tasks (number 8). After a quick analysis, the coaches can judge according to the information presented on the website whether or not a worker needs help to improve his or her work. At this point, a coach can give feedback to workers and avoid the risk of injuries (number 9). In addition, a coach can modify a task based on the results shown on the website (number 10). After the tasks are finished, the ergonomist analyzes the information from the website, and evaluates the overall and specific information. Once the ergonomist has analyzed the information, he or she can make suggestions of how to improve the environment where the tasks are taking place (number 11).
Organization	The information from the activity that is registered by the smart textiles is organized and presented on the website. Angles, velocity, and forces of each body parts of workers are presented. The information of the activities is shown along the time the task is performed and is continuously registering amounts of the status of each body part. Thus, the information gives an instantaneous status of the workers to let the coaches know whether or not a task is performed properly. However, ergonomists want to know the reasons for tasks that performed badly. Therefore, an ergonomist needs to analyze the data in detail, by observing and comparing each variable.
Interactions	In the flowchart the interactions are represented with arrows. The people who are involved in system are represented in purple. The important roles in the system are for the coaches and ergonomist. The coaches are at the workstation, collaborating with workers and supervise that the tasks performed at the workstation are good. The coaches go into assessments based on the information checked from the website. After that, the coaches give feedback to workers if needed. The interaction of ergonomists is more like an external interaction. They interact with the information presented on the website to improve the workstation with suggestions. Workers have to perform the tasks required at the workstation. Each worker is organized into groups to perform the tasks, whereas there is a time limit to each session in order to achieve those tasks. In addition, workers have to wear the smart textiles to extract information about the tasks they perform and later on, share it in the data storage for presenting it on the website.

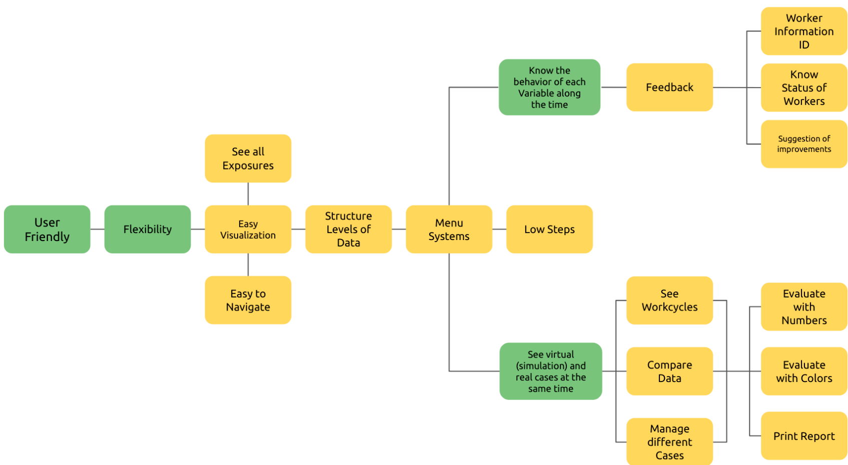
[Fig. 9] Context inquiry Framework.

Design Specification

According to Cooper, Reimann and Cronin (2007), the design specification aims to set up all the requirements by redesigning the goals to uncover what the users want within the interface. With the creation of personas, the aim is to get an understanding of the behavior and motivations of the users and to put the personas into context when using the interface by later extracting the needs (Cooper, Reimann and Cronin (2007).

Redesign Goals

Once the interviews and observation had been performed and analyzed, a set of goals and issues arose. The next step was to prioritize those goals to uncover what the users want and how they are doing it. A useful tool to do it is to go through all the notes, highlight patterns in the data and create a binder of notes where they are all visible simultaneously (Cooper, Reimann & Cronin, 2007). The flowchart in Figure 10 is the result of goals and issues found in the observations and interviews. All the goals and issues are classified and constrained in a hierarchical way.



[Fig. 10] Structure of the goals uncovered.

Creation of Personas

From the previous step, it is now possible to base the context inquiry and the user's goals in a specific context that triggers an understanding of the behavior and motivations of users, this now provides the creation of personas, a critical tool for using user research to inform and justify the designs (Cooper, Reimann & Cronin, 2007). The personas can be viewed in figure 11, 12 and 13. way.

Applying personas to the process provides an understanding of the users involved and visualize their relationships with each other and with the social and physical environment (Cooper, Reimann and Cronin, 2007). Personas are based on wishes and demands extracted from interviews that were made with lecturers in the area of ergonomics at the University of Skövde and ergonomists Feelgood AB and from the

[Fig. 11] Gustav Svensson persona.

EMELIE GRAN

DAILY TASK/RESPONSIBILITIES:
Plan/structure work and coach, motivate the workers.

LIKES ABOUT THE JOB:
Helping the workers in the team.

NEEDS:
Wants to know which posture is good and bad during an ergonomic assessment.

DATA HABIT

IT and Internet

Computer program experience

Software

AGE: 33.

WORKS AS: Physiotherapist.

LOCATION: Kinnarp.

TIME AT KINNARPS AB: 4 years.

"I want to create a better workplace for the employees."

BIO

Emelie began working at Kinnarps AB after her education in team leading 4 years ago. Emelie wants to reduce the sick leaves caused by musculoskeletal disorders. She wants to use the software to give direct feedback to the workers. To better understand each posture in the software she wants visualizations and colors representing each unacceptable and acceptable posture to work in.

[Fig. 12] Emelie Gran persona.

ESA KOIVISTO

DAILY TASK/RESPONSIBILITIES:
Saw out pieces of wood and build furniture.

LIKES ABOUT THE JOB:
Good salary and colleagues.

NEEDS:
A better ergonomic work environment for reducing his back pain.

DATA HABIT

IT and Internet

Computer program experience

Software

AGE: 55.

WORKS AS: Building furniture.

LOCATION: Kinnarp.

TIME AT KINNARPS AB: 20 years.

"I want my workplace to have an ergonomic improvement."

BIO

Born in 1963 Kuopio, Finland. Immigrated to Sweden from Finland in 1977 with his parents. Esa partly grew up outside Stockholm and has spent his working life in industries. Esa moved with his family to Kinnarp in early 1998 where he began working as building furniture. Esa has been on sick leaves several times during the past 7 years due to musculoskeletal disorders and is hoping for the team leader Emelie can make his workplace ergonomic better.

[Fig. 13] Esa Koivisto persona.

observations of a video at the workstation. Thus, two profiles resulted from the creation of personas: an ergonomist and a coach. The persona for the physiotherapist/ergonomist is based on an ergonomist of Feelgood AB who conducted ergonomic evaluations by observing the workers while performing their work tasks. What was considered when creating the persona was the data of user's profile, the users' role, and the way the user was performing the work.

The profile of the coach is based on observations from videos testing the software on a tablet. The tablet gives direct feedback of the ergonomic evaluation through visualizations and colors, and the status of the arms, legs, and trunk. But, why is a website needed if the coach is using the tablet? The reason is that as the project proceeds, the coach's interaction with the received data might change, because the project Smart Textiles for Sustainable Work Life still remains under development. In the observations, the coach follows the worker around with the tablet to evaluate him showing how the visualizations change in color depending on which postures the worker holds. The coach has an interest in how the values of the postures will change when the worker is conducting a work task at a specific workstation. Thus, the coach can give feedback to the worker in order to improve his task to avoid the risk of injuries. Therefore, the role of workers is to be analyzed and assessed by coaches through the interface. The worker has an indirect connection with the interface because he does not use the interface but is affected by the results of it. The personas were created to get a broader insight from each potential user (except the worker).

Creation of Scenarios

According to Cooper, Reimann and Cronin (2007), personas allow to fit users' needs into a scenario that is based on a story describing an ideal experience from the persona's perspective, focusing on people, and how they think and behave. At this stage, the goals are used to filter tasks and for guidance in structuring the display of information and controls during the iterative process. Thus, the use of scenarios for the project will extract the structure and behavior of interactive functions of the design proposal where personas-based scenarios are a summary of describing of one or more personas when using a product to achieve the goals that the personas have.

Personas allow the designer to describe an ideal experience based on the person's point of view on how they behave and think when they are using the product. With the scenarios, the designers are able to conduct a nonverbal dialogue between the user and the product over time, and also for the behavior of how the user interacts with the functions (Buxton, 1990).

The purpose of using scenarios is to focus on the point of view and which activities, perceptions and desires the user has. The development of this kind of scenario allows the designer to find the best fit to create an ideal user experience for the product's interface (Cooper, Reimann and Cronin, 2007).

The scenario that was created is a context scenario in which, according to Verplank et. al (1993) the content and context are derived from the data gathered in the research phase and that is later analyzed in the modeling phase. When creating the context scenario, the designers role-play the personas as characters in the scenarios, which leads to a present time of synthesis of structure and behaviors. The characters in the scenarios are used by the designers to test the design ideas and assumptions during the process. Then there are the creations of scenarios based on personas description.

Scenario 1 - A workday with Gustav Svensson

Gustav Svensson, 47, opens the main door to his workplace at Feelgood AB at 7 am in the morning, where he works as a physiotherapist/ergonomist. He goes through the doorway and continues up the stairs two levels. Gustav proceeds through the next door that leads him to where his office is located. Gustav continues forward and goes through yet another door to his office. Gustav takes off his jacket and begins his work day as he usually does by grabbing a cup of coffee.
Gustav returns to his office and turn on his computer and takes a sip off his coffee. The first thing Gustav does is to check any newly received emails. One of the emails is marked prioritized from his executive, which he immediately checks out. In the email is the following text:

"Hello, Gustav. Yesterday, we received an order of an ergonomic assessment from the manufacturing department at Kinnarps AB. Several of the employees at the manufacturing department at Kinnarps AB experience musculoskeletal disorders while working. The team leader at the department, Emelie, has been able to provide a video recorded at the workstation and the data of the analysis is available on the website
add excel-file with data from tests during manufacturing furniture. This data comes from the smart textiles that the workers was wearing during their work hours. Emelie wants to know the source of the musculoskeletal problems and your suggestions to enhance the worker's conditions. Regards, Carl-Jan."
When Gustav has read through the mail and thinks "To evaluate these postures, I need to compare the data to each other and evaluate it."
First Gustav goes to the website that has the data extracted from the tasks performed the last day.

In order to locate the problem, he goes to the main screen, which has a graphic with an overall view of the exposures performed within the current month. The graphic measures the status of the activities with colors (green, yellow, and red) according to levels of risk against the elapsed time.
But Gustav wants to know the data regarding the last day. Thus, he clicks on the calendar boxes located below the graphic, where Gustav is able to select the desired day. The graph now zooms in on the selected day and shows the status of the day transcurred.
While Gustav realizes that there is a specific period of time in the day where there is a high exposure of the risk levels, he goes deeper into the graph by scrolling the mouse to zoom in. Gustav goes into the "visualization box" which unfold a cascade of boxes that organize the visualization of the graph by groups, workers, and body parts.
Gustav clicks on the group option and the graph shows each group status represented by lines. He wants to find which one of the groups that is experiencing the problems.
Under the graph, a table pops up showing the data expressed in the graph but organized in a

framework. It contains the time transcurred and the groups with their status scored with numbers.

Gustav is tracking the red numbers that have high-risk level scored. By doing that, Gustav finds that the group "X" shows a poor performance. He clicks on the group to see the workers who present problems.
Thus, the graphics screen chance the variables into the status of each worker that belong to the group selected, and the information on the table changes as well, now showing information according to the new graphics presented. It shows status scored with numbers and colors of each worker as well.
Gustav picks the workers that are at risk. Each time Gustav picks one of the workers, a new window with graphs and a table appears with the information unfolded showing each body part analyzed. By comparing the data between workers, Gustav realizes that the arm-activity in all the cases is at risk due to the degrees and the time of exposure in that position generates a risk of injury. Gustav then goes to the video that was recorded at the workstation, where he observes that the workers have to keep their arms raised for long periods of time.
Now that Gustav has found the reasons for the problematics, he needs to direct his observations from the specific information presented in the analysis. Thus, Gustav wants to share his analysis. Therefore, he pushes the button to create a pdf, and a new window appears that allows Gustav to choose between the elements that he has unfolded from the analysis to create the pdf file. He selects the elements for the file and fills out a text box with comments that explain the problem and suggestions of how to solve it. Afterward, the file is saved to Gustav´s computer and ready share through email.
Gustav accesses his email account again and sends a reply to his executive Carl-Jan with the following text:

"Hello, Carl-Jan. I have evaluated the data of yesterday. I now have the report as a pdf, which includes comments and suggestions on the problematics. I attach the report to this email. Regards, Gustav."

Scenario 2 - A workday with Emelie Gran

Emelie Gran, 33, begins her workday at her office at the manufacturing department at Kinnarps AB, where she works as a team leader/coach at the department. At her desk lies a complaint from Esa Koivisto, 55, saying that his workplace is causing him back pain. Emelie knows that the workers do not want to be disturbed during work hours and do not want to work during their breaks.

Emelie has a solution to this problem, she is going to use garments with built-in sensors that register data such as movements and angles.

The next day she tells Esa to wear the garments with the built-in sensors during his work hours and take them off on his lunch break. Esa put on the garments and proceeds to his workplace. Emelie follows Esa with a tablet and a computer to monitor him. Emelie starts the app on the tablet and activates the sensors by clicking on the start button on the sensors.

On the website, the data that the sensors registers can be followed while Esa is performing his work.

Emelie notices how user-friendly the website and its structure are. When entering the website, Emelie sees a menu bar. She proceeds to move the mouse pointer and reveals several available functions and notices the ease of navigation. Emelie wants to see how the data change as Esa is performing his work and proceeds by clicking on a function that makes Emelie able to see how the values from the sensors change. The function takes Emelie to several graphs that corresponds to each sensor. The graphs give feedback in form of colors such as green, yellow and red. Above the graphs is the worker's ID in form of a number, in this case number 1.

When Esa conducts his work, the colors of the graphs changes. As the color changes, Emelie can suggest to Esa to try a different posture while she observes the color. The procedure is repeated until the posture signals the color green. When the color turns green, Emelie tells Esa to work with that postures and proceeds to discuss with Esa if he feels any difference when he is working in a certain posture. Emelie wants to be assured that Esa is feeling better. At lunch, Emelie walks back to her office and sends an order to Feelgood AB together with the data that was recorded to evaluate the postures.

Results of Pre-study

In this chapter, information is collected from the literature review that stood out during the pre- study and also answered the initial needs of the project.
How can an interface be formed in the best way possible to meet the initial and collected needs?

- The interface should be constructed from the usability factors.
- The interface should be constructed from the fundamental principles of interaction.
- The interface should be constructed from the design principles.
- The interface should be constructed from the gestalt laws.

What kind of data should the users interact with?
- Left and right arm degrees and speed.
- Trunk angle.
- Glove angle, speed and force.
- Wrist angle and speed.
- Thumb force.
- The status of each body part.
- Time (hh/mm/ss).
- Work status.
- Work cycle.

3.Specification

According to Shneiderman (1998), after the completion of the personas, the personas were analyzed to extract the needs, which can be viewed as consisting of objects, actions, and contexts. The needs based on the personas and the information gathered from interviews were added into a specification table (Table 2 and 3). According to Cooper, Reimann and Cronin (2007), the needs extracted from the personas can be separated and divided into sections as follows:

Data requirements: The data needs to be extracted from the personas are the objects and information that must be represented in the system. Data requirements can be thought of as objects and adjectives related to those objects.

Functional requirements: The action of the needs to be performed on the objects of the system, which are typically translated into interface controls. These can be the actions of the product.

Other requirements: It is important to get a firm idea of the realistic requirements of the business and technology that it is designed for. Other requirements contain several subsections such as:

- Business requirements: which includes the timeline of the product's development, regulations, structures and business models.
- Brand and experience requirements, which reflects the attributes of the experience, so that the users and customers could associate the product with the company.
- Technical requirements, which includes weight, size, form factor and software platform for the interface.
- Customer and partner requirements, which includes ease of installation, maintenance, configuration and licensing agreements.

Validation Scenario

The specification has also the basis from Quality Function Deployment (QFD) which is a method to match customer needs with product functions. The QFD method works as a development tool to compare two existing products with each other. The basis of QFD is the analysis of connections between needs and metrics. The needs correspond to what, and then how the need shall be achieved, where each need is defined to one or more metrics, where the metrics need to be measurable characteristics (Österlin, 2011). Parts of the QFD matrix have been left out such as valuation, which compares the product with competing products since there is no competing ergonomic evaluation software to be found on the web.

The specification has been divided into two tables because the needs in table 2 cannot be measured physically. Therefore, how the needs in table 3 are achieved is through ideas generated.

For the specification, brand & experience and customer & partner requirements were disregarded. Brand & Experience was disregarded because the software is not a project for a product of a commercial company. The University of Skövde's logo was disregarded as an add-on to the software because such a logo might make the user perceive the software to be a tool for learning instead of a tool to conduct ergonomic evaluations.

Customer and partner requirements were disregarded to be included in the specification considering that the software is web-based and cannot be installed as a program on a computer or as an application on a tablet. The maintenance was chosen to be discarded because the software's interface maintenance is not currently actual since the Smart Textiles project is still in development, which means that the interface is not yet commercial. Maintenance, configuration and licensing agreements were discarded for the same reason.

Besides the needs extracted from the personas and gathered from the interviews, the interface has to fulfill the goals mentioned in the initial needs considering the constraints for the interface and the properties of the ergonomic evaluation methods. All the requirements and the ill-defined needs presented in the initial needs were clarified to be placed all together in the list of specifications.

One of the aspects clarified was the flexibility, it plays an important role to arrange the information presented as the ergonomists need to know the behavior of each variable along time considering the differences as height and weight among the subjects of the study, the different parts of the body and the different types of evaluations. Regarding the methods used, SES (SCANIA Ergonomistandard) method has to be available for the ergonomists because it provides better compatibility with the Smart Textiles system.

Another aspect to consider is that the user-friendliness for enabling users analyzing data regarding the ergonomic evaluations. The interface has to be intuitive to make the ergonomists understand most of the information through visualizations to deal with it without complications of reasoning processes.

Soren Lauesen writes in his book User Interface Design: A Software Engineering Perspective (2005) about the usability factors which consist of six factors:

- Fit for use: The system is available to support the user to perform tasks that the user has in real life.
- Ease of learning: How easy is the system for a various group of users to understand?
- Task efficiency: How efficient is it for the frequent user?
- Ease of remembering: How easy does the occasional user to remember?
- Subjective satisfaction: How satisfied is the user with the system?
- Understandability: Is it understandable to know what the system does in a easy way?

Those factors can be applied to the need of visualizations. By resembling the functions which the visualizations are connected to, the interface becomes easy to learn, intuitive and easy to understand. Task efficiency, ease of remembering, subjective satisfaction and understandability also applies to visualizations. The frequent or occasional users can thereby effectively conduct the task(s) by understanding the visualization (factor of understandability) and remember until next time when the interface is used (factor of ease of remembering), and, depending on the user, be satisfied (factor of subjective satisfaction) with the interaction the user had with the interface.

		1	2	3	4	5	6	7	8	9	10	11	12	13
	Ideal	∞	∞	1	100	<10	<300	Y	∞	100	100	20	<10	8th of may
	Marginal	1	1	5	50	<15	<600	Y	1	100	100	40	<15	15th of may
	Unit	Sec	Sec	Nr	%	Sec	Sec	Y/N	Day(s)	%	%	Nr	Sec	Day(s)
	Metrics	Amount of seconds passed from a started session	The number of seconds of a continuing changing value	Average number of misunderstandings	The ratio of useful work performed by the user to complete task	Amount of time to change from lab to live session	Amount of time spent on each subpage	Subjective	Number of passed weeks	Completion of task	Ratio of success of conducted task	Number of mouse clicks to perform task	Time to select function	The amount of weeks
	Data requirements													
1	Elapsed time	x	x											
2	Behavior of each variable along time	x	x											
3	Low steps			x	x							x		
4	Intuitive			x			x				x	x		
5	Usability - The usability of the interface includes factor as: -Fit for use - The interface shall be able to perform ergonomic assessment -Easy of learning - The interface shall be easy to learn -Task efficiency - The interface shall have low task failure -Subjective satisfaction - The interface shall be satisfying to the user -Understandability - The interface shall be easy to understand				x					x	x		x	
6	Flexible -The interface shall be able to manage different ergonomic evaluation methods and functions				x									
7	Structure levels of data -The interface shall be structured which enables the user to perform the task in a intuitive way					x	x							x
8	Easy to navigate						x					x		
	Functional requirements													
9	Date							x	x					
10	Visualization box -The use of buttons							x				x	x	
11	Menu bar											x	x	
	Buisness requirements													
12	Time of bachelor degree													x

Table 1: the list of specifications with metrics.

		1	2	3	4	5	6	7	8
	Ideal	16	3	Y	<600	∞	Y	Y	Y
	Marginal	20	5	Y	<1200	1	Y	N	Y
	Unit	Nr	Nr	Y/N	Sec	Nr	Y/N	Y/N	Y/N
	Ideas	Number of figures, icons, graphs and tables that the user interacts with	The use of colors to visualize musculoskeletal risks (green, yellow)	Output of information based on input of data	Low thinking process	Numbers visualizations, colors and time	Function to export of information to PDF	Be able to support platforms as computer and tablet	Input of information
	Data requirements								
1	Visualizations -The use of appearance that allow visualizations as icons, figures, graphs and tables	x	x			x			
2	See exposures of musculoskeletal risks -The interface shall visualize low, medium or high risks by color (green, yellow and red)		x	x		x			
3	Behavior of each variable along time -The interface shall be able to visualize the change of each variable's value along time					x			
4	**Feedback**	x	x	x		x	x		
5	Intuitive -The interface shall be able the user to perform task(s) with low or no reasoning process	x	x		x				
6	Worker ID -The interface shall entitle the workers as numbers	x				x			
	Functional requirements								
7	Compare data	x	x	x		x			
8	Export to PDF						x		
9	Analyze both virtual and real cases -The interface shall be able to analyze ergonomic simulations and ongoing assessments	x	x			x			
10	Evaluate data with colors and numbers		x			x			
11	Menu bar	x							
12	Visualization box	x	x						
	Technical requirements								
13	Be able for multiple software platforms							x	
14	Search and text boxes								x

Table 2: the list of specifications with ideas.

4. Concept Generation

At this stage, all the needs and the specifications serve as the constraints for the generation of concepts.

By designing solutions and subfunctions it is possible to embrace all the stated problems. During the iterative process, the concepts generated are guided by a formative evaluation, where a concept is selected, tested and fixed several times through the extraction of feedback from users. After each concept evaluation, the design problems are encountered to narrow down the solutions until getting a final concept that fulfills all the requirements.

Idea Generation and Evaluation

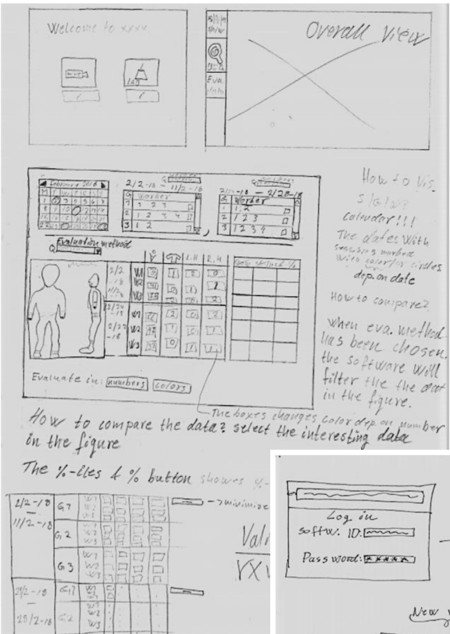
Idea generation and evaluation
The idea generation begins with a brainstorming session for the interface's framework, which includes the needs and demands, and the structure.

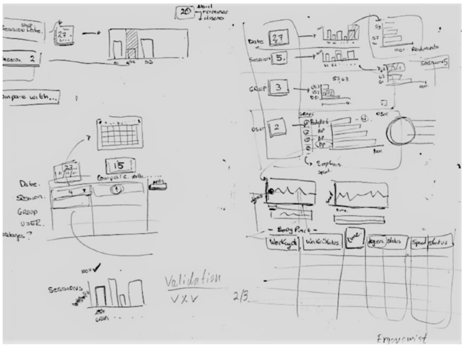
The solutions for the interface's framework are based on the inputs from context scenario (presented in the pre-study) that generate a set of features through sketches as a result of a brainstorming session. According to Österlin (2011), brainstorming is described as a method where all participants have a discussion where the ideas are shared and built on. The open discussion should stimulate the participants creative potential. Thus, rules that apply for brainstorming are avoiding critique and judgement of other participants, combining and complete developed ideas. Brainstorming was conducted to get several solutions for the interface's framework and the structure where the ideas were sketched on a paper.

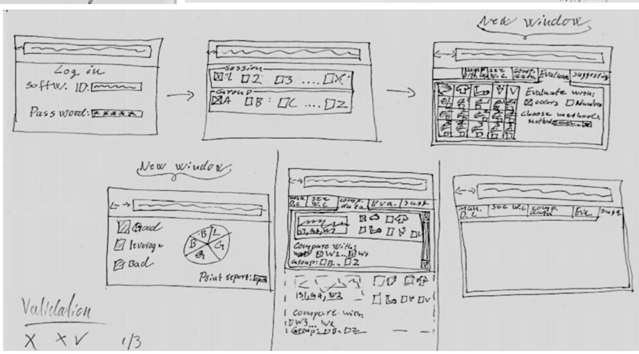
The completion of the brainstorming sessions resulted in several concepts of solutions for the interface's framework. Solutions from the concepts were discussed and applied to each other where the solution would best fit to improve the concept. The final result of this stage is to create the design framework. Cooper, Cronin, and Reimann (2007) describe the design framework to define the overall structure of the users' experience, from the structure of functional elements on the screen to interactive behaviors and underlying organizing principles, to the visual and form language used to express data, concepts, functionality.

Results of Idea Genaration

All the requirements were translated into functional elements and data elements after the brainstorming session. Cooper, Cronin, and Reimann (2007) mentioned the data elements correspond to images, pie charts, graphs, tables that are referred to, responded to, and acted upon by the people using the product and the functional elements are the operations that can be performed with the data elements and their representations in the interface. The elements were classified and organized into groups that shape the concept, and each concept solution have a purpose that can be traced back to the context scenario (presented in the pre-study). This produces the interaction with users and the concept, which belongs to the key path scenario. According to Cooper, Cronin, and Reimann (2007), key path scenarios are more focused on task details described and suggested in the context scenario which describe the user's interaction with the functional and data elements. Three of the most relevant concepts generated are presented in figure 1, 2, and 3 resulting from the brainstorming session.







[Fig. 1] Concept 2.

[Fig. 2] Concept 3.

[Fig. 3] Concept 4.

Limit Down Ideas

After generating several ideas in the brainstorming session, the next step was to select the concept that better filled all the requirements. The concepts were conducted through an evaluation with a validation scenario in order to select the better one. According to Cooper, Reimann, and Cronin (2007), validation scenarios aims to find holes in the design and fill these holes or exclude for future development. The concepts were classified into three categories:

- Key path variant scenarios: Interactions used as an alternate point that split off from key path scenario.

- Necessary use scenarios: Interactions that have actions that must be performed, but only infrequently.

- Edge case use scenarios: Abnormal situations interactions must nevertheless be able to handle, even if the situation is infrequent.

The concepts were compared according to the three points above and were scored 0 - 3, one score for each fulfilled point. One of the concepts was given the score 0 since the concept was made early in the project, due to several needs that were missing. The rest of the concepts scored 1 and 2 for not accomplishing the second point. After the concept was chosen to continue developing it, the concept had to be guided into a formative evaluation because it allows getting feedback on the next possible solutions once the concept is tested.

Evaluations of Concepts

In order to test the concept selected, a prototype was created made out of paper. The paper prototype lies as a base for performing formative evaluations, which Cooper, Reimann, and Cronin (2007) describe as tests that are quick and qualitative which are conducted during the design process, generally during the refinement phase. Formative evaluation accesses a window to the user's mind and allows the designers to see how the targeted audience responds. The method looks for information and tools provided by the interface to aid the user to accomplish a task. During the process, a concept is tested by users for detecting issues regarding User Experiences. Thus, it is possible to directly or indirectly observe the effects of the design flaws on the users (Hartson and Pyla, 2012).

After one evaluation is completed, all the issues based on observations or user's suggestions are adjusted to improve the concept. By applying the formative evaluation in the design process is possible to identify defects in the interaction design to be fixed later on. The ideal users to test the interface are the physiotherapists/ergonomists who are the interface's main users. Nevertheless, because of the long reply time from Feelgood AB in Skövde, the physiotherapists/ergonomists were discarded due to time constraints. Therefore, the user test was focused on lecturers with ergonomic knowledge at the University of Skövde.

Think-Aloud Protocol

According to Hartson and Pyla (2012), the general observation data are important during an evaluation session with a participant performing a given task. The think-aloud (TAP) protocol is simple to use, for both analyst and participant. The usefulness of the method is when the participant goes through the prototype or helps with an UX inspection. During the evaluation, the analyst has the possibility to observe which parts of the task the participant is having trouble with such as if the participant is showing hesitation or having troubles to understand parts at the interface. UX problems are still hidden and placed within the participant's mind. Therefore, asking the participant to "think aloud" is a way to uncover the hidden UX problems.

The usage of the TAP will take place during the evaluation sessions by asking the participants if any parts within the interface were hard to understand and if they had any confusion. By asking these questions, it is possible to uncover UX flaws that need to be corrected until the next evaluation session. During the tests, a series of tasks to accomplish was given to the users and each one of them was measured according to the metrics extracted from table 1 chapter 3 (list of specifications with metrics).

In table 1shows the measures to accomplish each task. The metrics were measured during tests with users by observing each step the user made while proceeding throughout the interface. The data collected from the tests was written down below "Measure" for the metrics. The reason for measuring while testing the interface was to notice if some measured values cross the values in the specification, and if so, to change the interface, so the next measured values do not cross the specification.

Need	Metric	Unit	Measure
1	Amount of seconds passed from a started session	Seconds	
3	Average number of misunderstandings	Number	
4	The ratio of useful work performed by the user to complete task	%	
5	Amount of time to change from LAB to LIVE session	Seconds	
6	Amount of time spent on each sub-page	Seconds	
9	Completion of task	%	
10	Ratio of success of conducted task	%	
11	Number of mouse clicks to perform task	Number	
12	Time to select function	Seconds	

Table 1 Table for measurement.

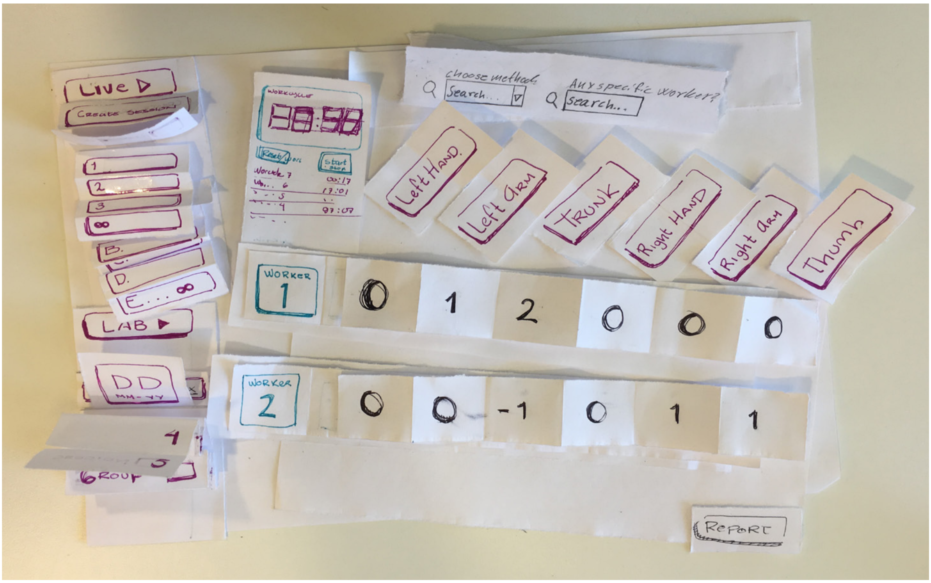
First Evaluation

All the elements of the interface's framework concept were drawn, cut out on second paper (figure 4). The first concept tested shows the interface which is dedicated to the user who will conduct an ergonomic evaluation.

The concept is divided into two sections, the Live section and the Lab section.

The Live section is used by coaches in the work environment in order to assess workers during a workday. At the top left corner of the interface there is the Live section button, whose function is to allow the coaches to create sessions and choose already existing sessions, where a session is a work cycle after a defined amount of time that can range from one day to weeks. After a session has been created or selected, the user can create a group or select an existing group that allows the user to add one or multiple workers. At this point, all the participant workers added are ready to be assessed by wearing the smart textiles.

At the top of the interface, there is a toolbar, where the coach can select or search for an ergonomic evaluation method, and, if wanted, for a specific worker to be evaluated. When the method has been selected, the coach can start or reset a work cycle to generate the elapsed time



[Fig. 4] The concept as paper prototype.

during the session. Thus, the data for left and right hand, left and right arm, trunk, and thumb shows up at the right side of the work cycles. When the user has started the work cycle, the number of workers is shown as worker 1 and worker 2. The numbers next to the worker's numbers represent the ergonomic values of the body parts which are extracted from the sensors.

The LAB section is where the ergonomist analyzes in detail the data generated in the Live session, but is still not defined in this first concept. The step that was followed by the completion of the paper prototype is to test the prototype in a formative way, a form of evaluation that is beneficial to the interface by pinpointing issues with the user experience. The paper prototype was demonstrated to the assistant supervisor who returned feedback on what within the interface needs to be changed such as the work cycle and new functions wanted by the parties involved in the Smart Texiles project, such as percentages that have to be added to the interface.

The specific data of the elements analyzed, the percentages give precision and also can be represented with pie charts and bar charts to enhance the visual representation of data. Thus, the feature of percentages is applied in the next concept. Considering ergonomists required to analyze the data and also requires comparing it. For the next concept, the feature added made the ergonomist able to compare a session with other sessions, a group with other groups, and workers with other workers.

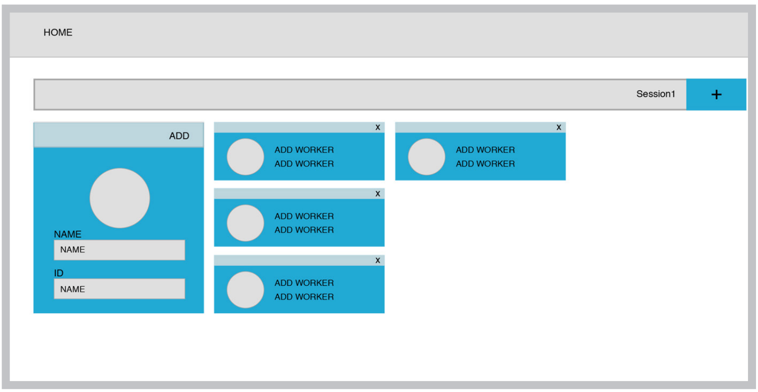
In addition, a new visualization had to be added. To better visualize if the posture for the registered body parts has a low, medium or high risk of musculoskeletal disorder, colors as green, yellow and red shall visualize these risks depending on which number each body part has. Thus, the colors would provide better recognition of the data evaluated. From the first evaluation, no measurement was able to be conducted, table 1 was not yet completed. Instead, the changes depended on oral feedback from the participant were the feedback consists of the participant's thoughts about using the interface and what hesitations occurred while using the interface.

When the formative evaluation had been conducted with the assistant supervisor, the interface was changed accordingly to the features that had to be removed or added.

In the second concept, the interface started on the home page (figure 5), which was divided into three main parts: Creating Session, Live Session and LAB Session.

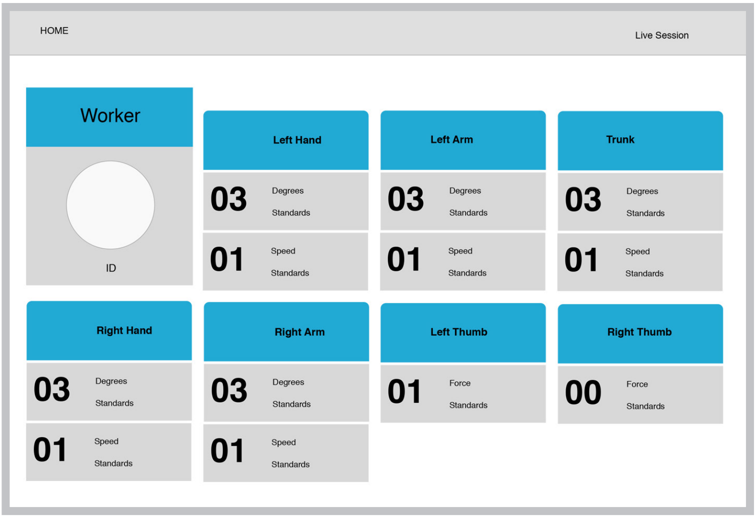
[Fig. 5] HomePage.

The section of Creating Session is presented in figure 6, where participants are added to be analyzed in the Live Session.

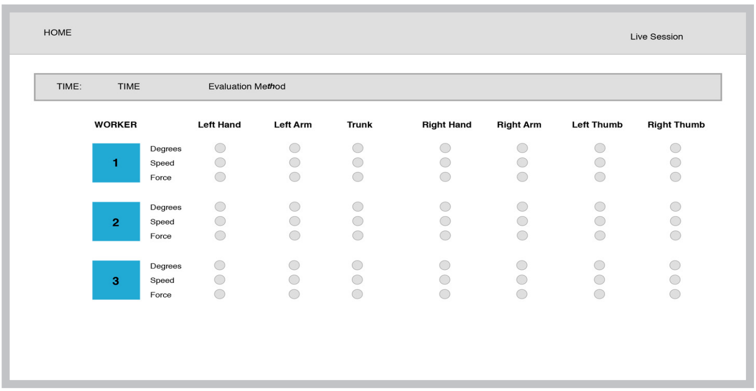


[Fig. 6] Create Session Page.

The Live Session, as is shown in figure 7, is where the exposure of the body parts of each worker is presented. The information shows values of speed, degrees, and force, depending on the body part. Each value is rated with colors according to the ergonomic method selected. It is possible to click on each worker to visualize each body part exposure in detail like in figure 8. The section provides a number scored according to the evaluation, this section was added because of the previous test.



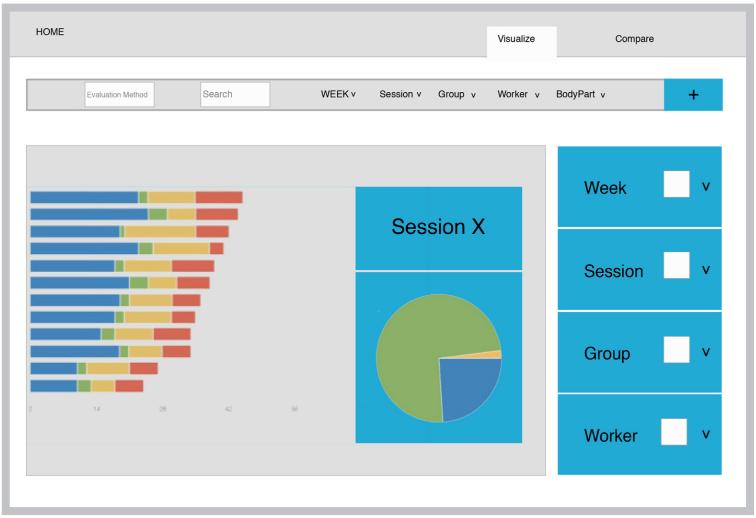
[Fig. 7]: Live Session, general view.



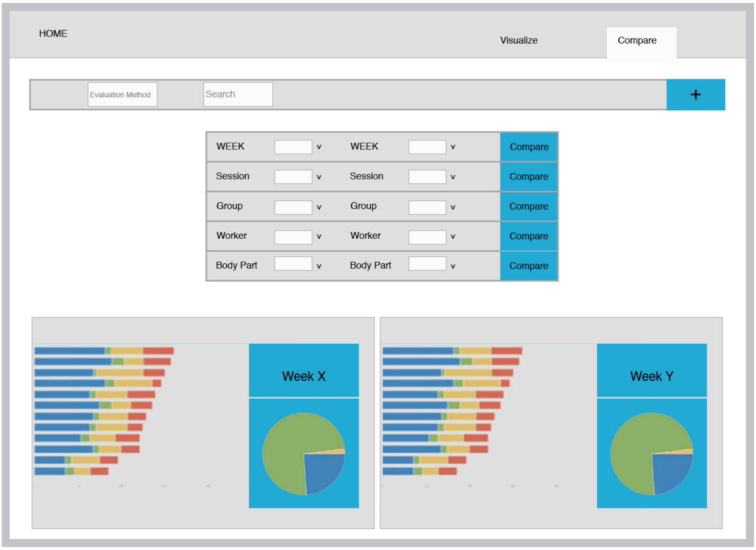
[Fig. 8] Live Session, information in detail of a worker.

In the LAB Session, all the information from the Live Session is gathered to be analyzed in detail. The ergonomists can choose between the visualization section or the comparison section that appear at the top of the screen.

The visualization section presented in figure 9 provides the analysis of a session performed previously on a workstation. After selecting a date in the second toolbar from the top, a session can be tracked and analyzed with its corresponding groups, workers and body parts. Each value is visually represented by a graph and a pie chart that show the percentages of the ergonomic posture analysis. In addition, one specific value can be traced by looking into the search bar tool. In the comparative section, the features for comparing sessions, groups, workers, and body parts were added to this concept as is shown in figure 10. There is a table presented in the comparative section, in the first column the ergonomist adds the data corresponding to the first variable to compare and the second column belongs to the second variable to compare.

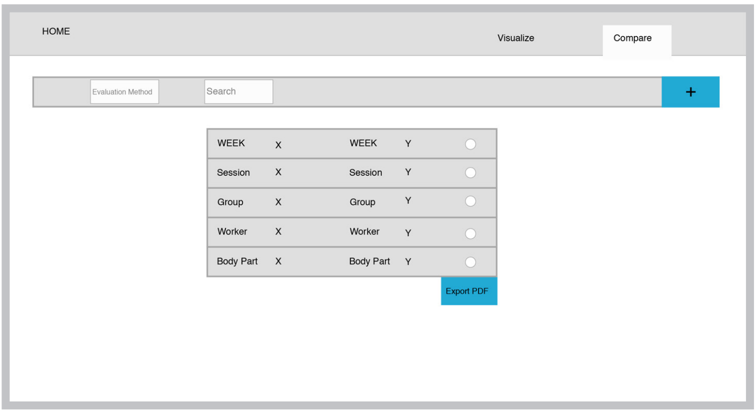


[Fig. 9] LAB Session, Visualization Section.



[Fig. 10] LAB Session, Comparative Section.

At the end of the report, in the comparison section, a table appears, where the ergonomist can select the values to be exported for print (see figure 11).



[Fig. 11] LAB 3 Session, export values.

From the second evaluation, the data in table 2 under "Measure" was fulfilled during the test. With the next formative evaluation, in comparison with the specification, the aim is to decrease the values for the length of seconds passed from a started session, the average number of misunderstanding, and the length of time spent in each sub-page. Those values overlap the standards in the specification. The remaining measurements meet the respective marginal and ideal standards in the specification. The needs that met the marginal values will be measured again to keep the ideal score.

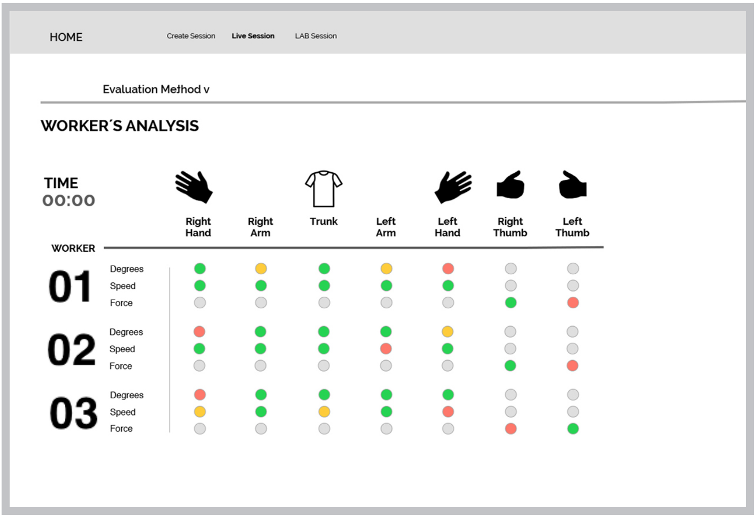
Need	Metric	Unit	Measure
1	Amount of seconds passed from a started session	Seconds	4028
3	Average number of misunderstandings	Number	12
4	The ratio of useful work performed by the user to complete task	%	70
5	Amount of time to change from LAB to LIVE session	Seconds	~3
6	Amount of time spent on each sub-page	Seconds	120/80/540/300/1320/180/180/90/600/180/255
9	Completion of task	%	100
10	Ratio of success of conducted task	%	70
11	Number of mouse clicks to perform task	Number	20
12	Time to select function	Seconds	~3

Table 2: Data from measurement of the second evaluation.

Third Evaluation

The feedback extracted from the second evaluation led to modify some features. In the third concept, at the top of the interface, a toolbar is placed for presenting the sections of Creating Session, Live Session and LAB Session because it allows a fluid navigation between sections.
In this concept, preliminary icons and graphs were added to be tested as visual representations. Those elements were applied in the concept and detailed later on the design process.

The icons in the Live Session represent each body part to give users a better recognition of the elements (see figure 12). Those icons are arranged in a row where the first elements placed in the row are those that are measured by the values of degrees and speed and, correspond to the right-side body parts because they are commonly the most used. Therefore, the values of force corresponding to the thumb body parts are located at the end of the row.



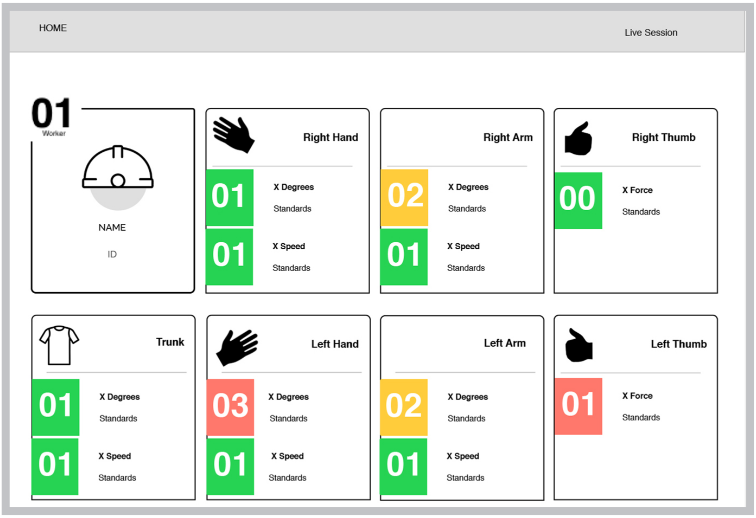
[Fig. 12] Live Session, Visualization Section.

In addition, a timer was added for the coach to follow the elapsed time in the work cycle of the session performed.

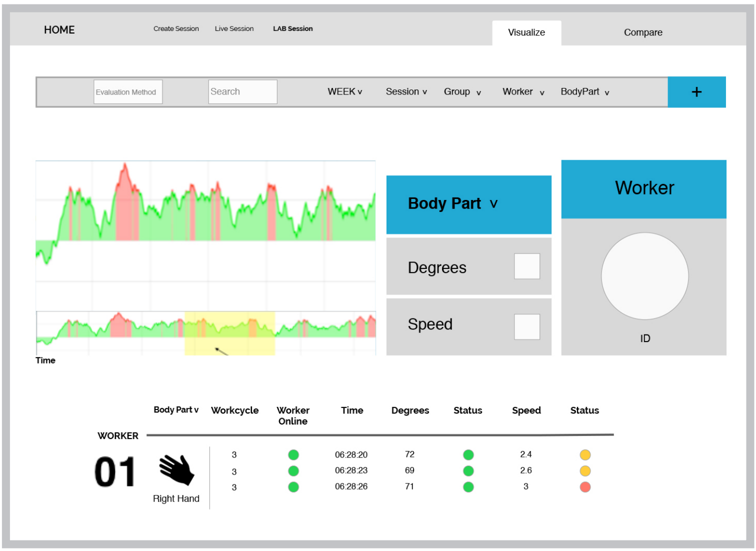
The values of the exposure after a click on a worker were changed (see figure 13). All the body parts analyzed are organized in two rows, where the right-side body parts are placed in the first row because those parts are commonly the most used. The second row corresponds to the left side body parts and the trunk. Regarding the colors and numbers, they represent the value scored of each variable. The box of a body part may contain the overall values of degrees, speed and force applied during the session transcurred.

Nevertheless, after testing the concept, the user was not able to identify where to click to visualize the exposure of each worker. Another problem was that after seeing the exposure of the values for each worker, the user found difficulties to understand the relation between numbers and colors.

Features of visualization were modified in the LAB Session as well; the most relevant characteristic is that the ergonomist can visualize through a graph a body part exposure (see figure 14). Then, the ergonomist is able to zoom in a specific section of the session recorded

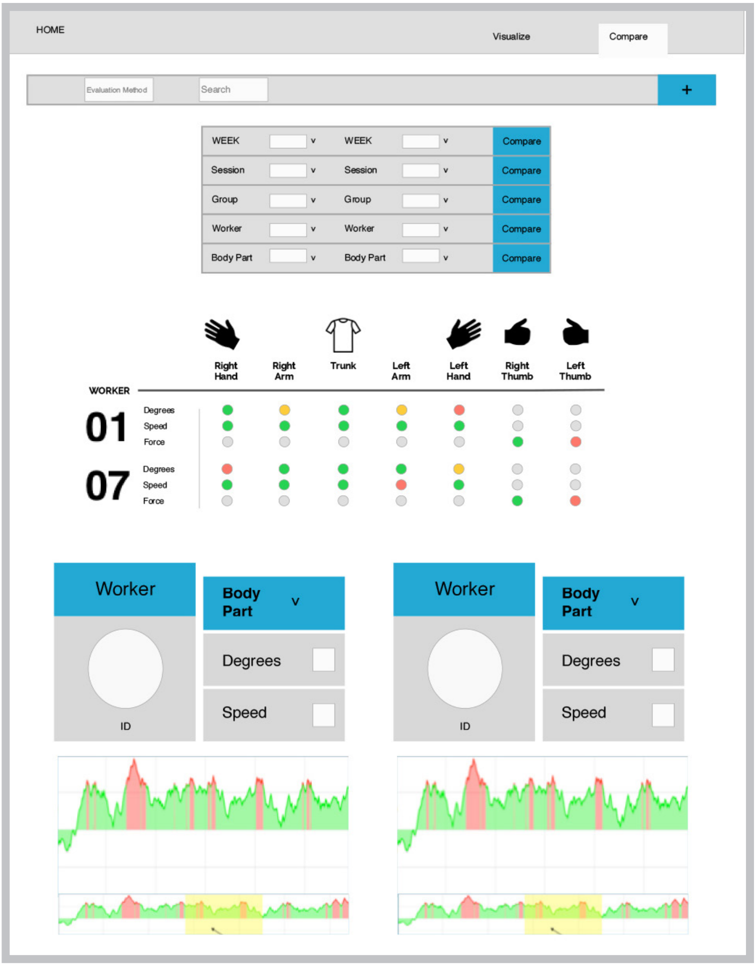


[Fig. 13] Exposure of the values of a worker.



[Fig. 14] Exposure of the values of a worker.

in order to obtain information in detail of the ergonomic exposures. Right below the graph, a table is presented with information of the body part, the time recorded, and the values of degrees and speed of the section zoomed in. But the organization of the data was not clear enough for the user to understand where to start to click to analyze the exposures. Visualization on the comparative section changed by adding the tables and graphs exposures of the body parts analyzed (see figure 15).



[Fig. 15] Comparative section of body parts.

From the third formative evaluation, the following data (table 3) were able to be recorded from the participant. Certain need values decreased and other increased by comparing results between table 1 and 2. The missing measurement of need 6 depends on difficulties to measure the time the participant spent on each sub-page due to blocked sight when the participant was using the interface but is estimated to be similar to the measurement in table 2.

The length of seconds passed from a started session now meets the marginal value by being below 2700 seconds and will be attempted to be decreased in the fourth evaluation. The average number of misunderstandings has a rate of 7, which does not meet the marginal value that depends on the participant having trouble to understand the interface. The remaining measured values meet the respective marginal and ideal values in the specification. The needs that reached the marginal values will be measured again to keep the ideal values.

Need	Metric	Unit	Measure
1	Amount of seconds passed from a started session	Seconds	2400
3	Average number of misunderstandings	Number	7
4	The ratio of useful work performed by the user to complete task	%	90
5	Amount of time to change from LAB to LIVE session	Seconds	3
6	Amount of time spent on each sub-page	Seconds	
9	Completion of task	%	100
10	Ratio of success of conducted task	%	90
11	Number of mouse clicks to perform task	Number	19
12	Time to select function	Seconds	4

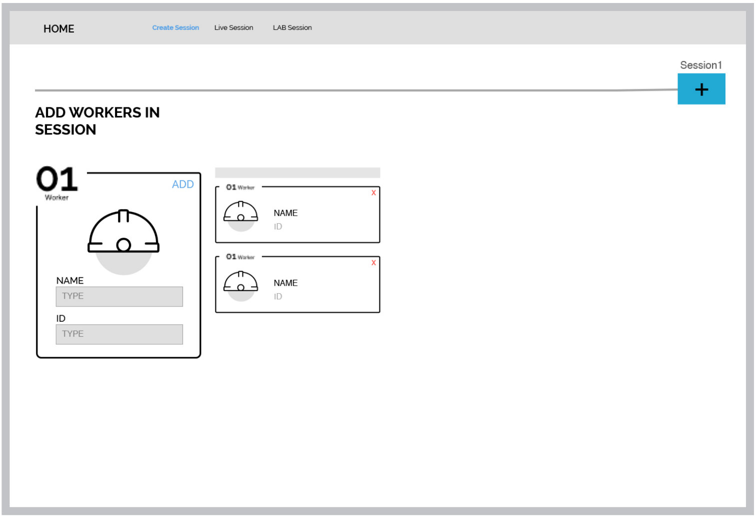
Table 3: Measurement from the third evaluation.

Fourth Evaluation

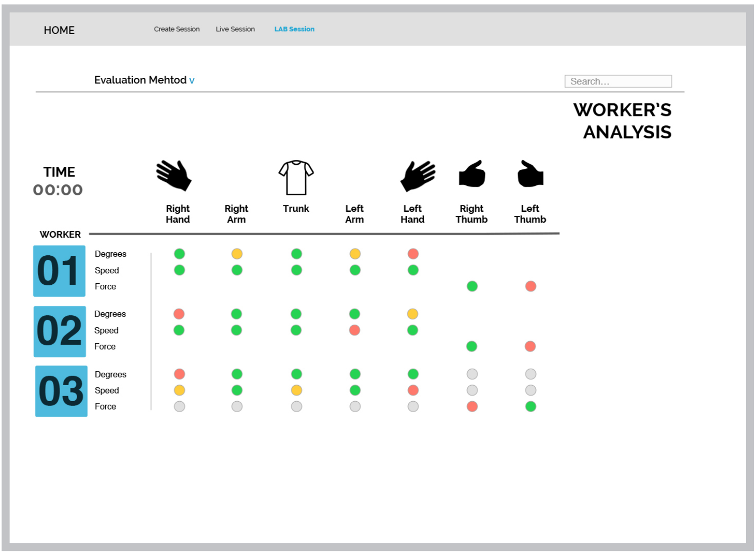
In the generation of the fourth concept, new subfunctions arose due to the previous evaluation. In the section of Create Session preliminary icons were added as is shown in figure 16.

The blue buttons now presented in the Live Session (see figure 17) allow the user to understand where to click in order to get further information about each worker.

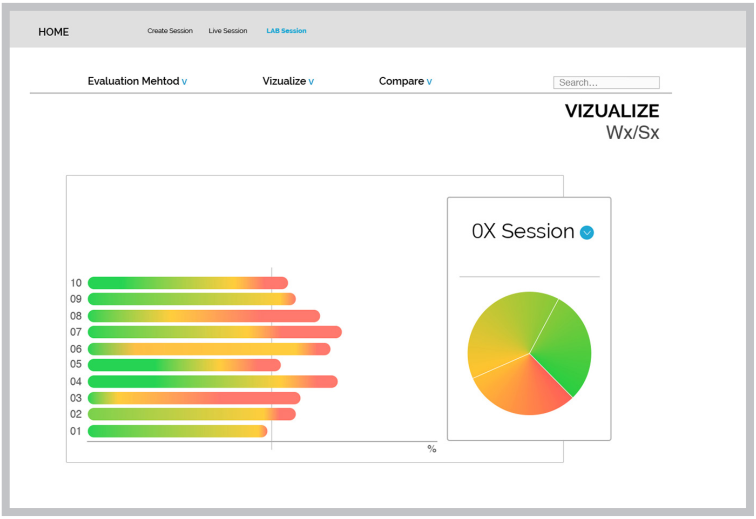
Further development in the visualizations of the graph and pie chart in the LAB Session was created in the concept (see figure 31). Also, a blue



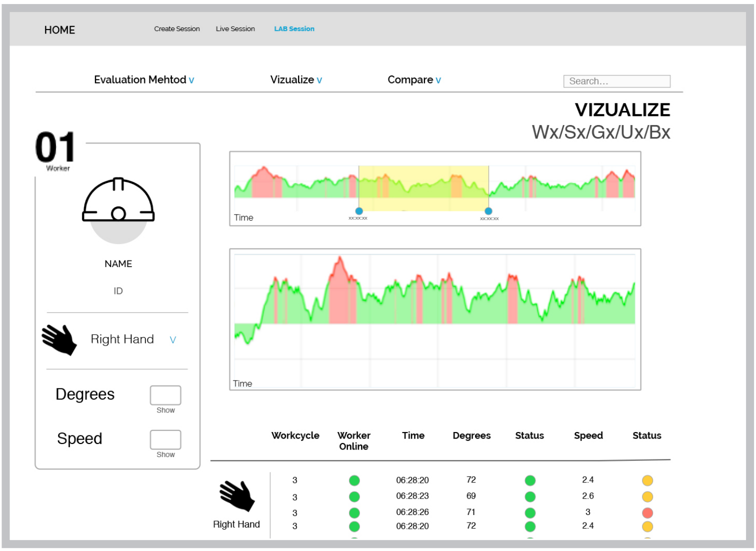
[Fig. 16] Preliminary icons in Create Session.



[Fig. 17] Addition of blue buttons.



[Fig. 18] Development in data elements.



[Fig. 19] Development in the arrangement of values.

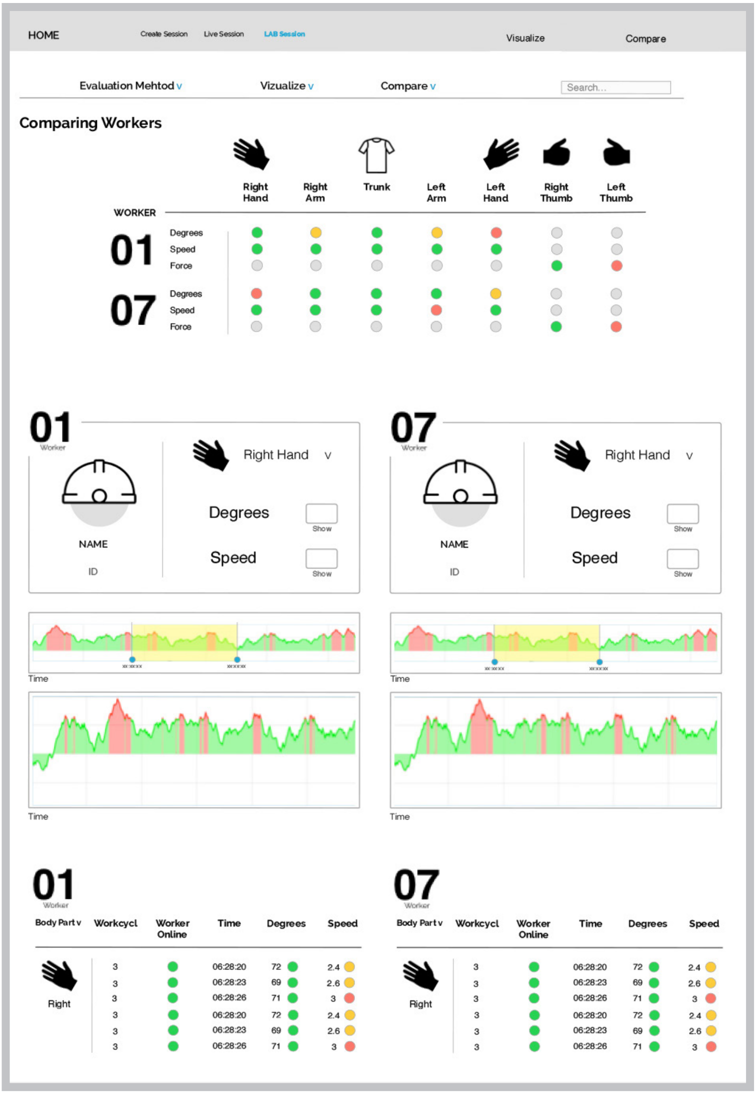
button above the pie chart represents an affordance to explore the variables of sessions, groups, workers and body parts.
In figure 19 a better arrangement of the body part exposures is shown. The use of the graph represents the behavior over time of either degree, force or speed of the body part selected. But, as the values are independent values the user had problems to understand what value was presented in the graph.

The organization of the body part information in the comparative section was affected due to the modification of the features in the previous sections (see figure 20). This new arrangement gave the user a better understanding of the information that was presented.

From the fourth formative evaluation the following values were able to be measured (table 4). By comparing table 4 and 3 the results in certain needs have been decreased and in other increased. The missing measurement of the length of time to change from LAB to Live Session depends on blocked sight but is estimated to be between 3 and 4 seconds. The ratio of success of conducted tasks did not meet the marginal or ideal value compared with the value in the specification, which may depend on the number of misunderstandings the participant had when testing the interface. Otherwise, the rest of the measurements reached the marginal or the ideal values set in the specification.

Need	Metric	Unit	Measure
1	Amount of seconds passed from a started session	Seconds	1433
3	Average number of misunderstandings	Number	3
4	The ratio of useful work performed by the user to complete task	%	95
5	Amount of time to change from LAB to LIVE session	Seconds	
6	Amount of time spent on each sub-page	Seconds	6/20/10/121/180/300/240/480/150/20
9	Completion of task	%	100
10	Ratio of success of conducted task	%	95
11	Number of mouse clicks to perform task	Number	19
12	Time to select function	Seconds	~5

Table 4: Measurement from the fourth evaluation.

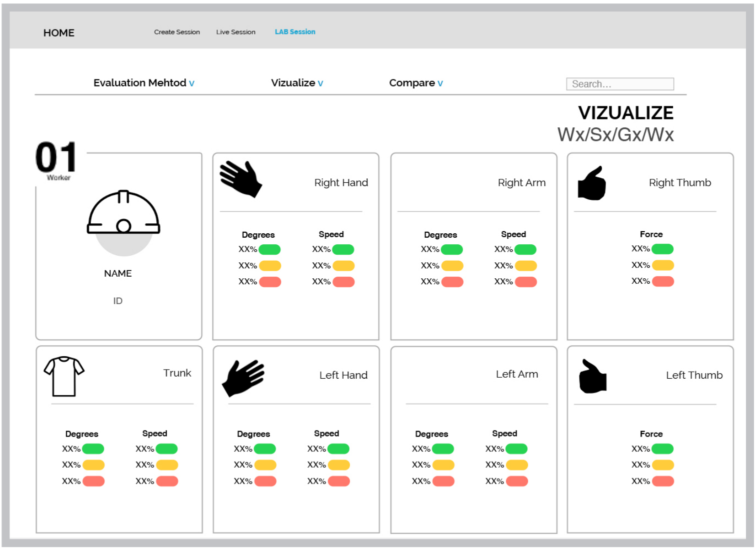


[Fig. 20] Development in arrangement of the data.

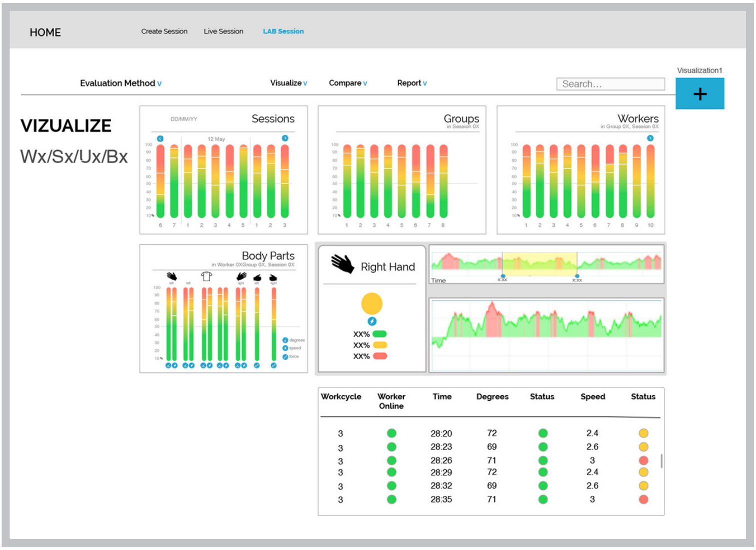
Design Refinement

The ideas that the fifth concept generated were mostly regarding the cases for re-arranging information and fixing some features.
The new proposal for the body parts exposure (see figure 21) presents the percentages and colors of the score for each body part according to the ergonomic evaluation method selected. Nevertheless, the accumulation of numbers creates confusion in users.

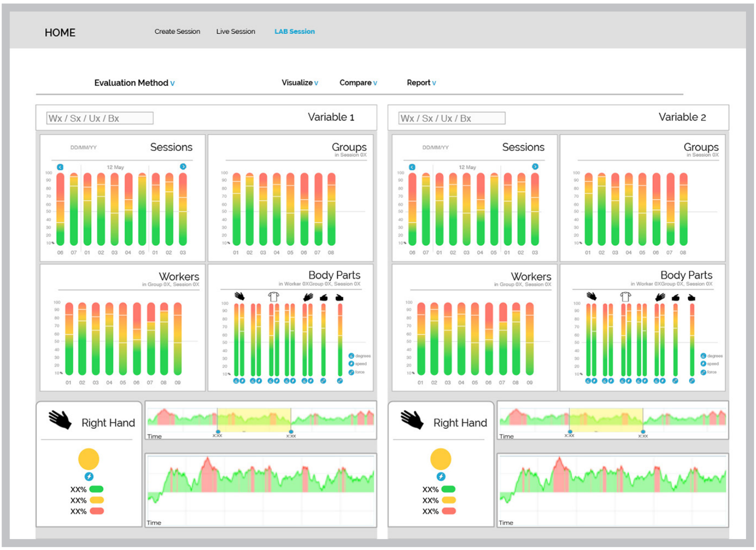
The results achieved for the LAB session in figure 22 present an arrangement in the values of the case analyzed, this solution allows the ergonomist to visualize the variables of a session, group, worker, and body part with its exposure. Nevertheless, the table at the bottom of the screen may have been suppressed because according to the last meeting with the supervisor, the ergonomist users prefer to handle that information in an xlsx file.



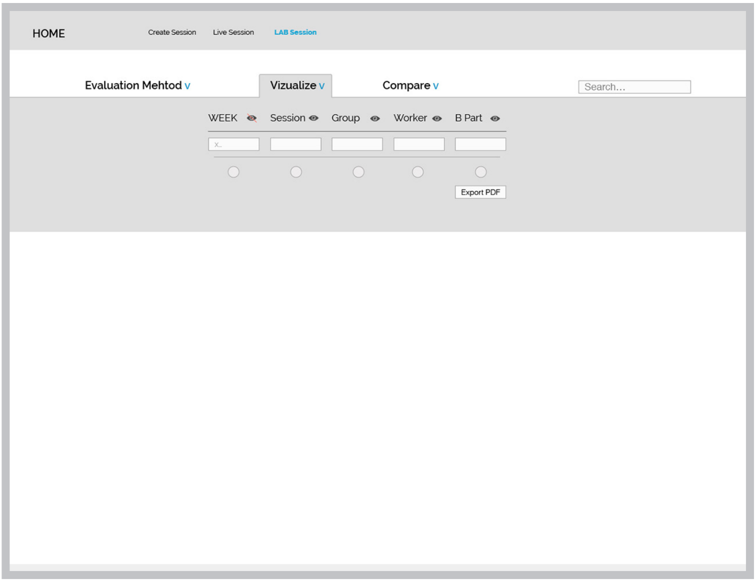
[Fig. 21] Percentages in Body parts exposure.



[Fig. 22] LAB Session arrangement.



[Fig. 23] Comparing variables.



[Fig. 24] Export files feature.

In the solution for comparing variables such as sessions with sessions, groups with groups, workers with workers and body parts with body parts the screen had been divided into two columns (see figure 23). At the top of each column, a toolbar is presented, which is filled with information to look for a specific value such as the date, the session, the group, the worker and the body part. The information filled is written with a specific terminology, DD-MM-YY is for the date, Sx is the session with its number, Gx is for the group with its number, Wx is for the worker with its number and, for the body parts, the terminology depends on the part. For example, right- hand speed value is only written with the capital letters RHS and the left thumb force is written like LTF.

The solution for exporting the files to PDF for printing had to be fixed as well. The feature presented in figure 24 proposes to fill a bar with the information of the values to be printed. The problem with that solution is that users can't understand where to click in order to export the file. The solution for the next concept was to use an independent feature for exporting the files.

5. Final Result

As a result of all the formative evaluation, each iteration added detail that improved the overall coherence and flow of the interface. The final concept is the result after five iterations.

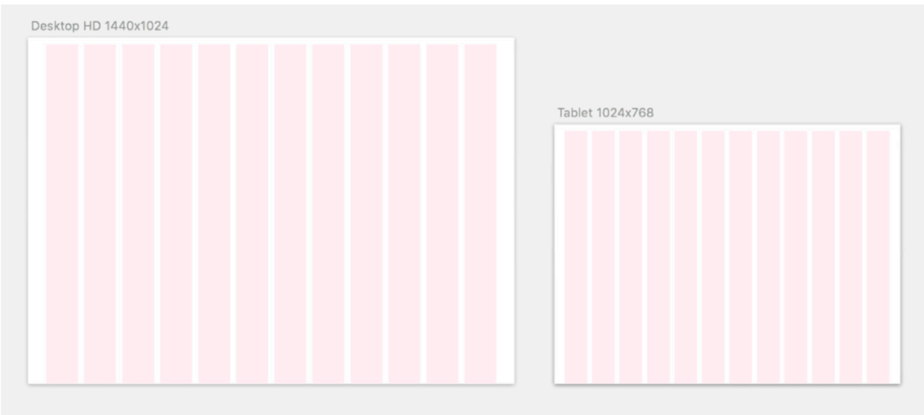
The Platform and its Layout

The platform for the interface has to support the needs of users. Therefore, as the duty of the coach is performed in a workstation, the coach uses a tablet because the size of a table allows the coach to move around the workstation. In contrast, the ergonomists work at the office and they use laptops or a desktop.

Because the section of Live Session in the interface is used by coaches, the elements for the live session section were placed on a tablet platform and the elements corresponding to the LAB session section were placed on a desktop platform.

The elements are used in groups, which are then grouped together into panes, which then may, in turn, be grouped into screens, views, or pages. The use of a layout in a platform provides a visual structure and flow at each level of organization (Cooper, Cronin and Reimann, 2007).

The creation of the layout for the arrangement of the elements was the result of the Design Constraints for the interface in section 2 regarding the position constraints.



[Fig. 1] Layout for the desktop and tablet platform.

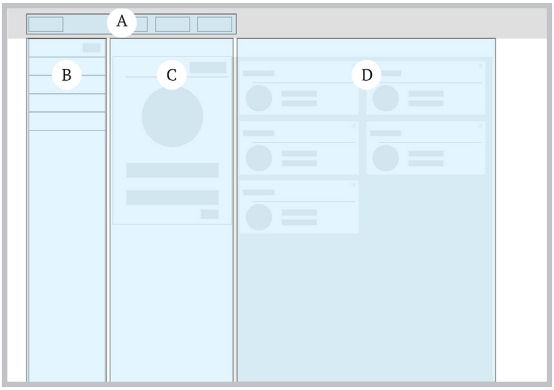
In figure 1 there are sizes of the platforms used with twelve columns to arrange the elements. The principles for the position for creating the layout were mentioned in the Design Constraints for the interface in section 2.

Design Pattern

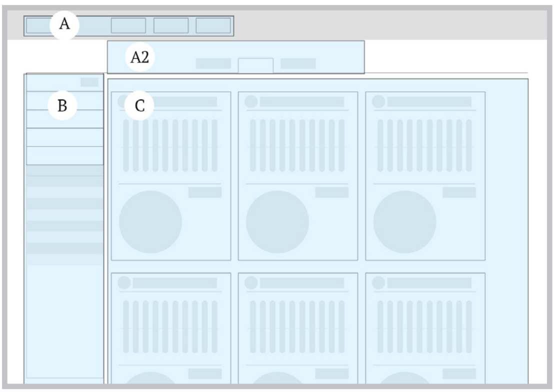
The design of the pattern is based on the principles of logical constraints presented in chapter 2 Human-Computer Interaction section and the principles of user interaction mentioned in the second section.

The final concept uses a structural pattern, which allows arranging information and functional elements on the screen (Cooper, Cronin and Reimann, 2007). As long as the interface presenting several data to organize in the sections of Create Session and LAB Session, the design of a structural pattern allows access to different kind of objects, manipulation of those objects in groups, and display of detailed content or attributes of individual objects.

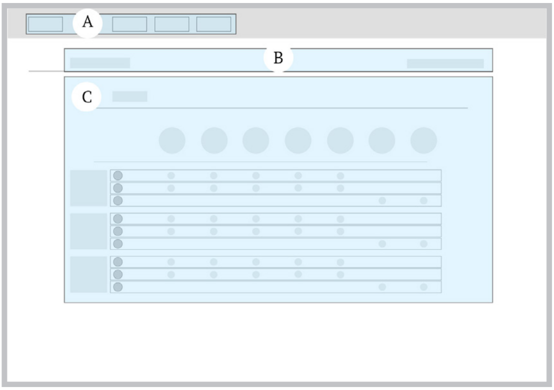
At the top of each screen in figures 2 and 3 there is the section A presenting a navigation menu. The section A2 in figure 3 is used for navigating between panels, where the user can choose the pane suitable for his current tasks. The B section serves as an index of objects. In the C section,



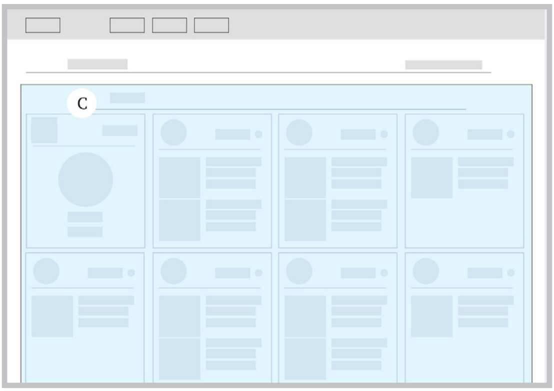
[Fig. 2] Pattern for Create Session.



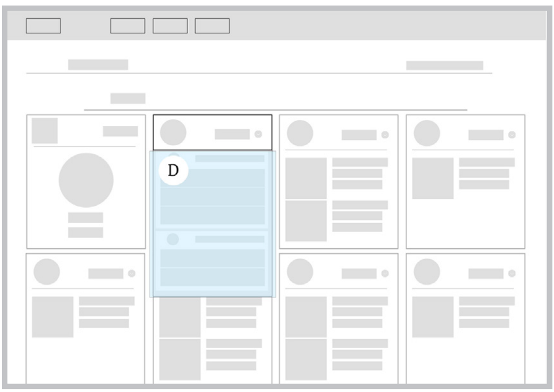
[Fig. 3] Pattern for LAB Session.



[Fig. 4] Pattern for Live Session.



[Fig. 5] Second Pattern for Live Session.



[Fig. 6] Information hidden in pattern.

the manipulation of objects take place and in the D section presented in figure 6 the content of the objects is displayed in detail

The pattern in figure 4 corresponds to the Live Session. It also presents a Menu Navigation at the top of the screen in section A. Continuing in the Live Session there is a section B for specific features and section C corresponds to the manipulation of objects.

The visualization of the screen in figure 5 changes in section C after clicking for information in detail of the objects. Further information is unfolded from each object as is shown in section D in figure 6.

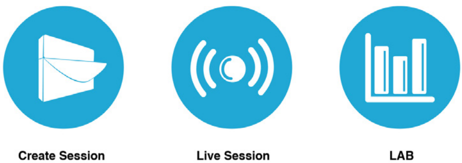
.

The design of the icons is based on Cognition Principles and the Design Constraints for the Interface described in chapter 2 and of course according to the needs requirements. The icons are represented as simple shapes that respond to the law of prägnanz, they are used as a visual representation of the inputs discussed in the Design Constraints for the Interface.

All the icons are used next to text items to be identified faster and to provide a distinction to other controls that do the same task (Cooper, Cronin and Reimann, 2007).

Nevertheless, a further test is required to know how users interact with the final design proposals and how acceptable is.

The first icons presented in the interface are those belonging to the Menu. Those icons represent each section of the interface. The first icon shown in figure 7 is for the Create Session section, the second belongs to the Live Session section and the third icon belongs to the LAB Session section

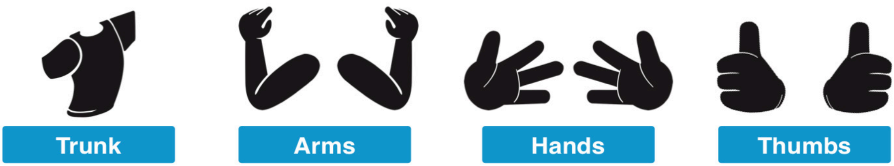


[Fig. 7] Menu section with icons.

The icons of figure 8 correspond to the elements that classify the data into sessions, groups, workers and body parts.

[Fig. 8] Icons of Sessions, Groups, Workers and Body Parts presented in that order.

The next generation of icons represent the elements and the values analyzed in an evaluation method. In figure 9 shows the icons designed for the elements of body parts. Some icons are flipped to identify whether a body part corresponds to a left side or a right side.



[Fig. 9] Icons of body parts.

The values of the angles, the speed, and the force are shown in figure 10. The presence of contrast is presented in the design in order to create a difference between the body part icons.

[Fig. 10] Icons for values of angles, speeds and forces.

Font Selection

Along all the tests, the fonts that are used for testing the prototypes are a Raleway font with 20 and 18 points for headlines and a Helvetica font with 12 and 10 points for secondary information as is shown below:

Raleway 20 - 18 pts

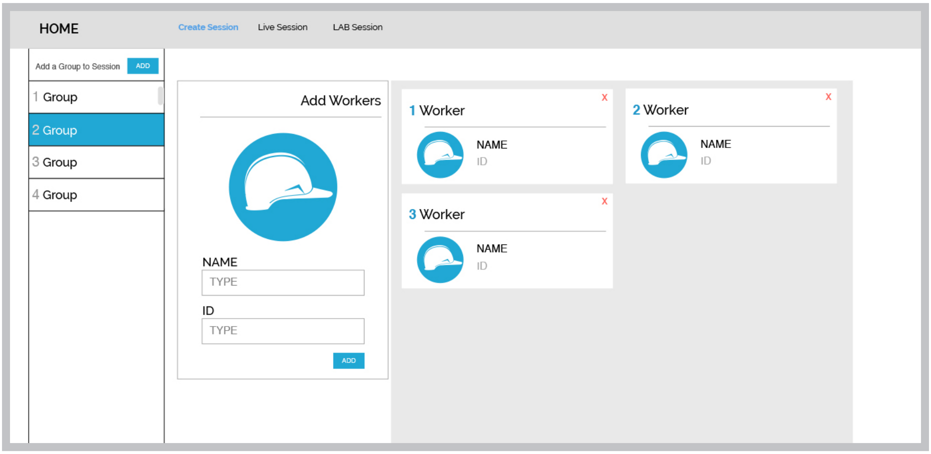
Helvetica 12 - 10 pts

The size and the characteristics of each font generate a contrast and a nesting to organize and classify the information presented in the interface.

Because the people in the tests never presented difficulties in reading the text in the interface, the fonts proposed remained until the final concept.

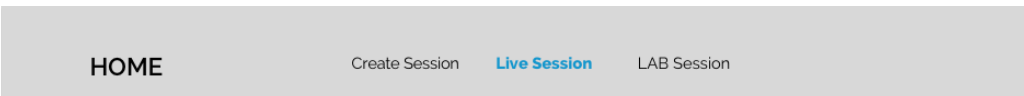
The Section of Creation Session

The final design of the Creation Session section is presented in figure 11.



[Fig. 11] Overview of the section of Creation Session.

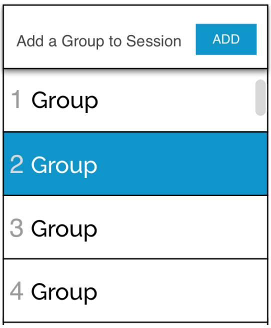
At the top of each section, a menu navigation bar is presented as can be seen in figure 12. The letters differ in to indicate which section they belong to.



[Fig. 12] Menu navigation bar.

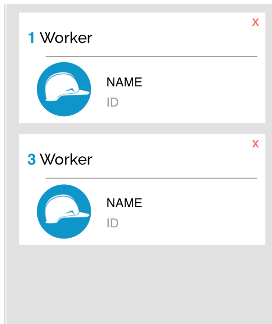
The first element the user finds is a column in which the user can add as many groups as he wants into the session (see figure 13). Each time the user clicks on the ADD button a new group is generated right below in form of a cascade. The presence of a scrolling bar allows the user to visualize all the elements presented in the cascade.

There is a contrast with blue and white colors indicating to the user the group in which he is working. The arrangement of the elements is the consequence of the Gestalt laws discussed in cognition in the section 2.



[Fig. 13] Adding groups function.

[Fig. 14] Adding workers function.



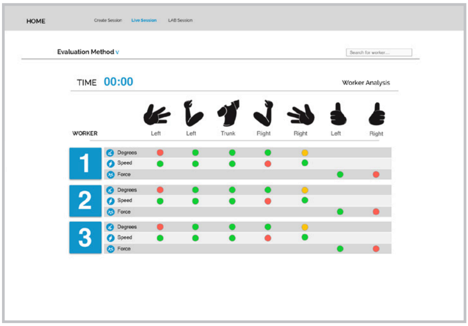
[Fig. 15] Workers added.

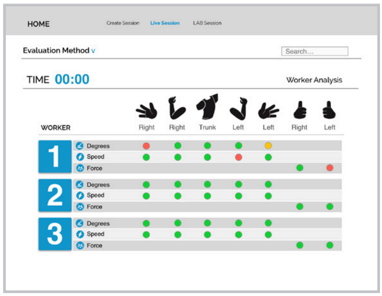
After adding the groups in the session, the user requires adding workers corresponding to the group selected. This function is presented in figure 14. By typing the name of the worker and his ID, a worker appears in a panel as is shown in figure 15. Each worker is numbered and presented with his name and ID number where there is also a red X in order to delete a worker.

The section of LIVE Session

The final design concept for the Live Session Section is presented in figure 16 for a desktop and a tablet platform.

The section of the Live Session had to be rearranged into a tablet format because the coaches work with that platform. At the top of the screen, right below the Menu navigation bar, there are two features. The feature on the left side is for selecting an evaluation method and on the right side, there is a search bar tool for finding a specific worker.

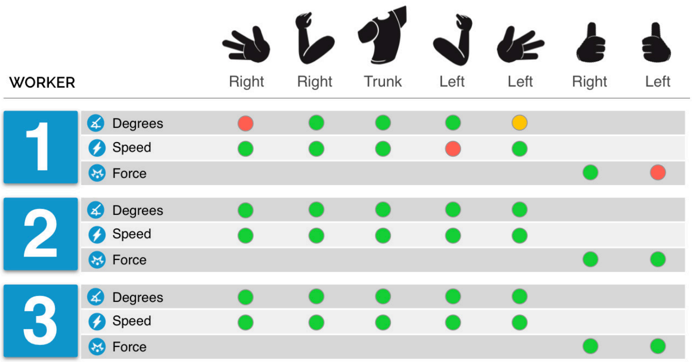




[Fig. 16] Arrangement on desktop platform and tablet platform.

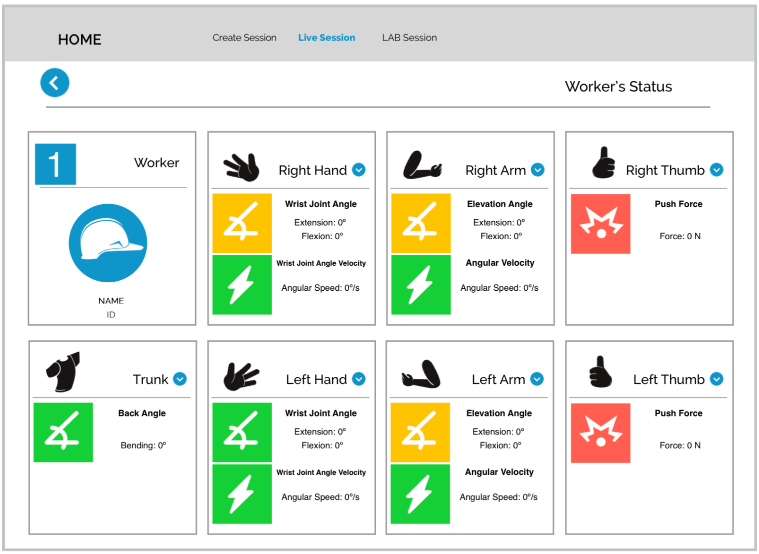
The next section below presents the elapsed time during the Live Session and in the last section the information regarding the worker's analysis is presented in a table like in figure 17. At the top of the table, the elements of the body parts are presented. Each body part is evaluated with colors according to the evaluation method selected, and when the information of a body part is not available it has no color.

The organization of the body parts has changed in order to provide better mapping of the elements. The parts of the trunk, the arms, and the hands are placed from the first column until the fifth column to be measured by degrees and speed values, while the thumb body parts are measured by force values, which are placed in the last two columns. Also, each left body parts is situated on the left side and the right body parts are situated on the right side.

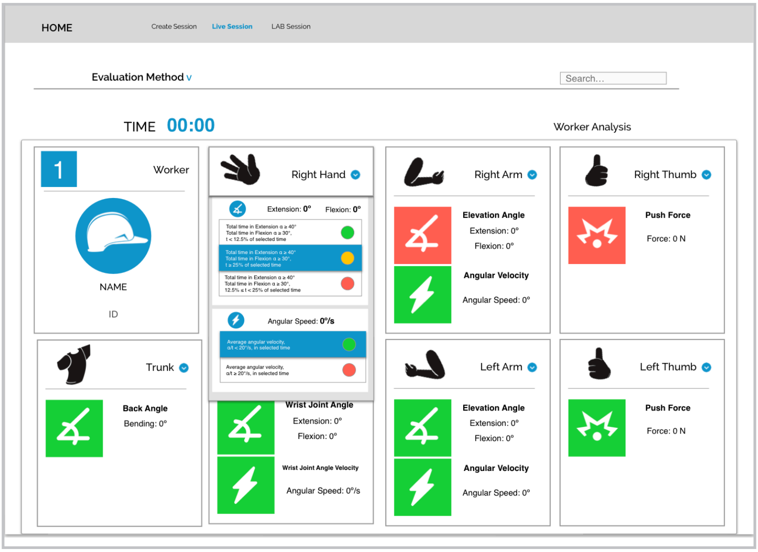


[Fig. 17] Worker's analysis table.

All the workers are placed in the first column of the table and each one is represented by a number shaped into a blue button. Further information regarding the worker is presented on a screen after a click on the blue button like in figure 18. The new screen presents each body part with its respective ergonomic value. The values are represented by icons and they are colored according to the constraints of the ergonomic evaluation methods.

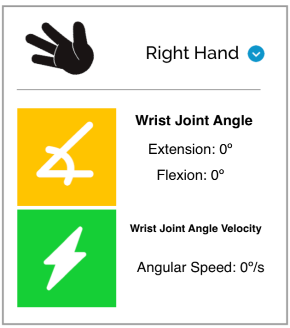


[Fig. 18] Worker's information.

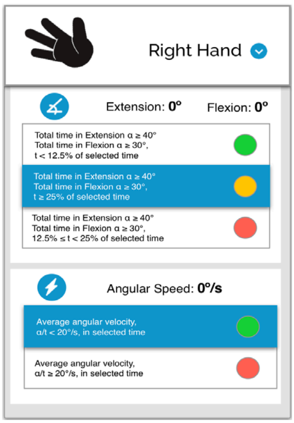


[Fig. 19] Further information unfolded.

The information next to the colored icons represents the average of the values analyzed. If the user requires more information about it, the blue button next to the headline unfolds further information about the constraints of the ergonomic evaluation method (see figure 19).



[Fig. 20] Body Part evaluation.

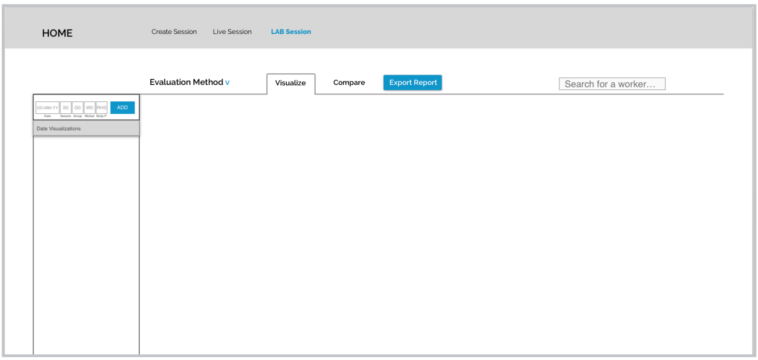


[Fig. 21] Constraints of the evaluation.

A visualization detailed regarding the blue button feature is shown in figure 20 and 21.
The user can return to the first screen after clicking on outside the window.

The section of LAB Session

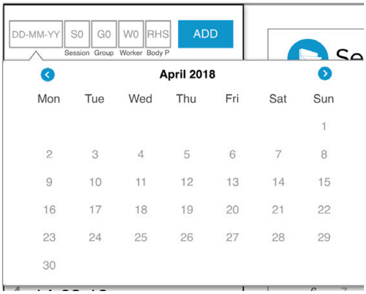
The section of LAB Session is used by ergonomist because in this section the information of the Live Session section is analyzed more in detail.
In figure 22 right below the menu navigation bar, there are the features of evaluation method and the search bar tool, and in addition, there is another feature for navigating between the panes of visualizing and comparing, and a button for exporting the report into a pdf file.



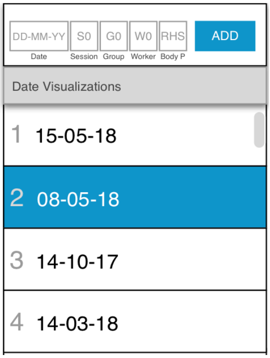
[Fig. 22] Visualization part in LAB Session.

The use of panes provides the user with the option to choose suitably for his current tasks (Cooper, Cronin and Reimann, 2007). In the left side of the "visualize" pane, there is the column which has to be filled with the information for visualizing an element.

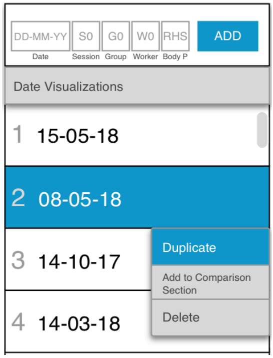
Because people being able to memorize three to four things, the information to fill the column is sectioned into chunks which are also used to classify the information required.



[Fig. 23] Calendar feature.



[Fig. 24] Visualization groups

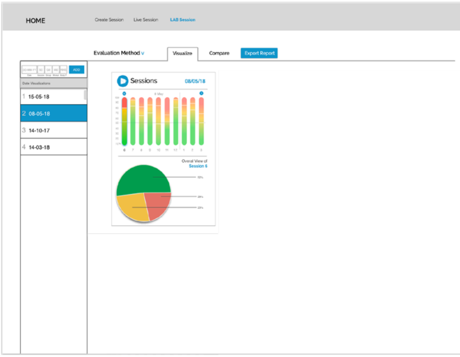


[Fig. 25] Visualization options.

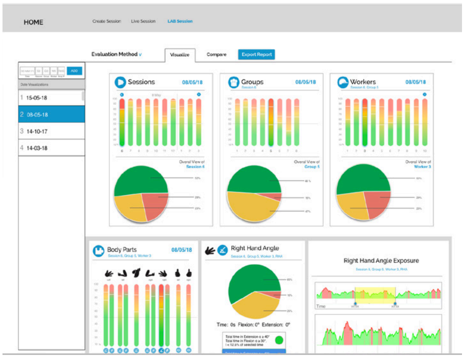
The first chunk corresponds to the date which is filled with the use of a calendar as is shown in figure 23. The next groups of chunks are for looking a session, a group, a worker and his corresponding body part. Once the user is placed into a chunk box, the chunk box suggests filling information into each section. After the chunks are filled the ergonomist presses the add button to visualize the information. Each visualization is grouped and numbered right below like in figure 24. In addition, each visualization can be duplicated, added to the comparison section or deleted (see figure 25).

The number of fields filled in the column correspond to the number of elements presented in the display section. For example, in figure 26 only the fields of date and session were filled whereas in figure 27 all the sections were filled.

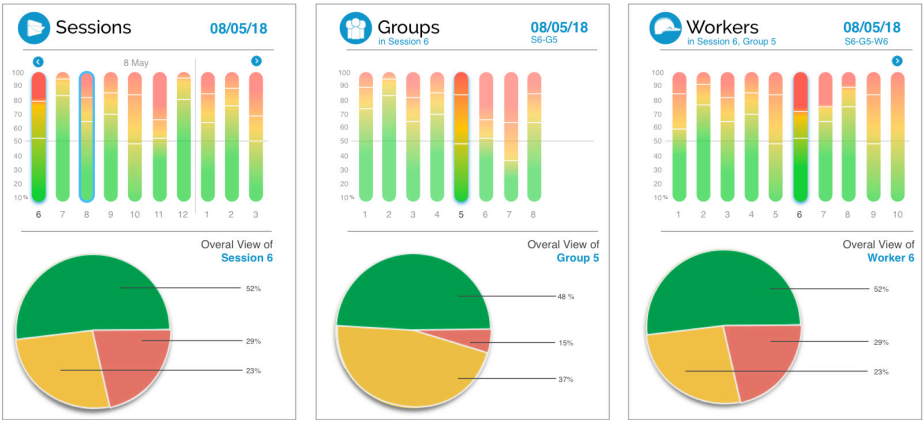
The information regarding the section of sessions, groups and workers are presented in figure 28. At the top of each frame, the elements are labeled according to section belonged with the corresponsive code. Below the headline, the elements of each section are represented with bars which are valued with percentages according to the ergonomic evaluation method. If there are a large number of bars, the blue button above the bars allows to the user uncover the other hidden elements.



[Fig. 26] Visualization groups



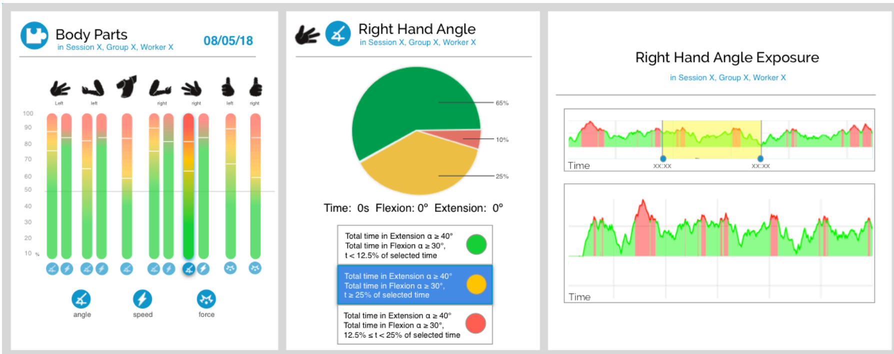
[Fig. 27] All elements presented in the visualization section.



[Fig. 28] Sections of sessions, groups, and workers.

The information presented in the body part section is quite different than the previous sections. In figure 29 the information is divided into 3 sections. The first section shows all the body parts of the worker analyzed. Each body part is evaluated with percentages based on the ergonomic evaluation method selected. The second section presents a pie chart with information of a specific body part extracted from the first section. In addition, below the pie chart, there are the average values of the body part analyzed with ergonomic constraints. Next, to the pie chart, there is the third section where users can visualize an overview of the body part exposure. The small graph on the top provides a big picture view and context for the zoomed-in view on the bottom. The ergonomist can visualize the critical section by moving the yellow area.

The blue buttons represent the hours and minutes of the section analyzed and they can be dragged to adjust the area of visualization.



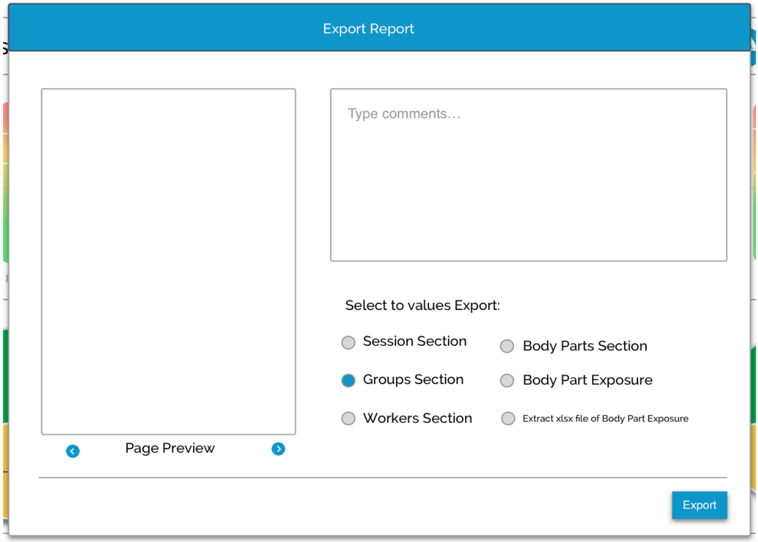
[Fig. 29] Body Part section.

The variables analyzed in the graph are the values of speed, angles, and force against the time. Each value is analyzed according to the constraints of the ergonomic evaluation methods. The contour of the elements is turned blue each time the cursor crosses them. The affordance suggests to the ergonomist that an element may be clicked. Therefore, the user is able to change between values by click on another element to being analyzed. After that, in order to visualize the next section, the user has to click on the pie chart. Nevertheless, the next section will appear with the first element selected by default, but the user is able to select another element if he wishes.

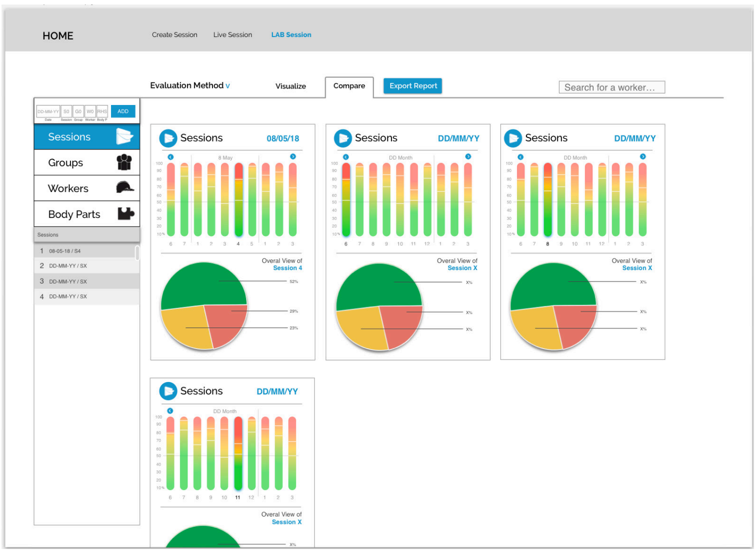
After visualizing all the information, the user can go to the "export report" button in order generate a pdf file for printing.

A window like in figure 30 is presented for exporting the report. The window presents a previsualization of the pages that integrate the report, a box for adding comments, and a section to select the elements to be exported. In addition, the section allows extracting an xlsx file which contains all the data regarding the body part exposure.

The comparative section presented in figure 31 is where the user can visualize and compare values each other.



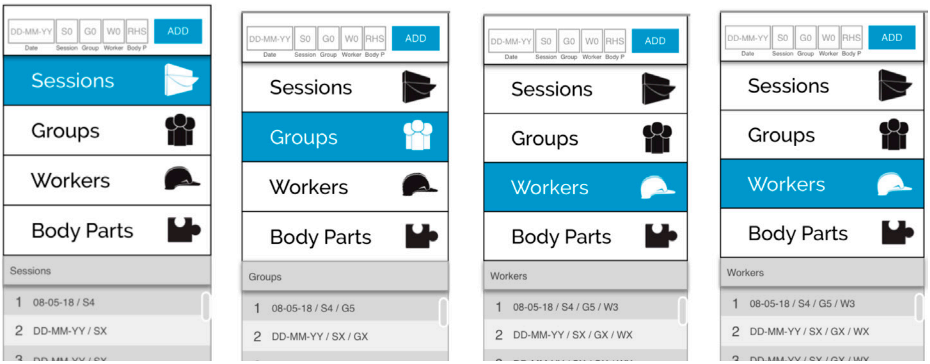
[Fig. 30] Export report window.



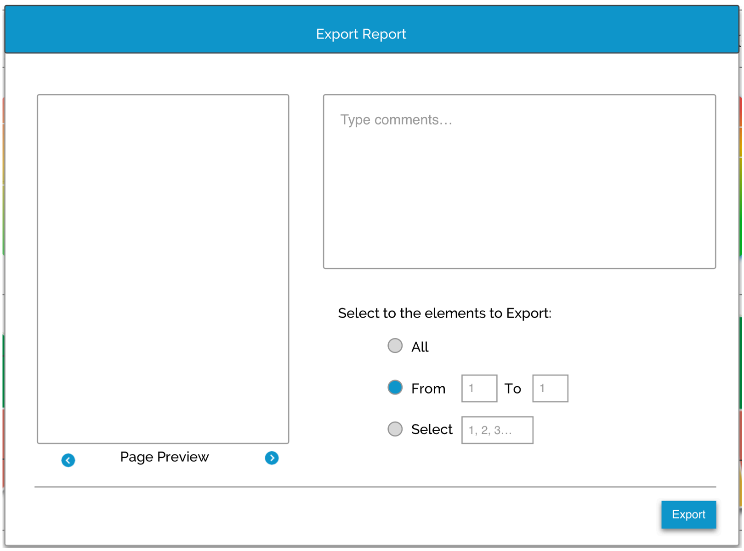
[Fig. 31] Comparative section.

The elements to be compared can be added from the visualization section or by filling the left column like the way it was filled in the visualization section.

The difference between the comparing section and the visualization section is that the arrangement of the sections in the comparing section allows comparing elements each other.



[Fig. 32] Arrangement of elements in column.



[Fig. 33] Export report for printing.

The left column in Figure 32 allows the user add elements to compare and navigate between sections. Right below the sections, there is a cascade with the elements compared in each section. The elements can be duplicated and deleted as in the visualization section.

After clicking on the export report button, a window like in figure 33 will appear, the elements to be exported correspond to the section in which the user is located. That means, if the user clicks on the export report button while he was on the section of the groups, the elements regarding that section would be exported. So, the window allows to export all the elements or to select the specific elements to be exported.

6. Discussion

The sensors collect much of information that will be evaluated at the website, the problems that can occur for the ergonomists and coaches are to handle all the data and tell the difference from various types of data such as angles and movements measured from back and arm. To solve the problems that can occur for the ergonomists while using the website, the aim of this project is to develop an intuitive interface for ergonomic assessment which is flexible, as each company uses their own assessment methods. Be easy to use and be able to analyze both virtual and real cases while being usable for the user, which has been reached, but improvements can still be made (further explanation chapter 7).

From the early stages of the project, the results of the empirical studies could be improved. In the interviews, some of the questions during the interviews could be more specific or rewritten, for example, “What are the features that reveal those methods?” can be rewritten to “What kind of data, from the worker, do you base your choice of evaluation method?” and “How the information could be presented?” can be rewritten as “How does the evaluation method of choice present the results? Does it present it as colors or as numbers, etc?”. Because the questions were not enough specified, most of the participants had difficulties to understand some of the questions. Some of the answers obtained from users may be not relevant to the project and miss out on important information. By specifying and/or rewriting the questions, more relevant information for developing the project would be generated.

In addition, the interviewees behaved a bit distant. Starting with small talk and easy questions might feel the interviewee relaxed, which would lead to information more relevant for the project. Also, the interviewing environment could be improved. The interviewees behaved a bit numb; the reason might be a lack of “good contact” with the interviewee.

The survey received no answers after posted on Reddit. The reason is that the subreddit for ergonomics does not have many visitors and the users were varied. By asking ergonomists at Feelgood AB to send the survey to other ergonomists, it might lead to extract more answers, about ergonomic evaluation methods or experience from another ergonomic evaluation software which could be inspiring when developing the interface.

When recruiting interview participants, the main problem was to get in contact with actual ergonomists at companies such as Feelgood AB. To get more answers from ergonomists, the survey could be sent to ergonomist through the ergonomists who were interviewed in Gothenburg. The way the observations were conducted was through a recorded video. Some insights get lost or misunderstanding some of the procedures of the system as a result of observing a recorded film. Performing the observation by visiting companies rather than watch it through a video could generate clever information for understanding the system.

The level of specificity of the design specification tables could have been increased in some areas (see table 1 and 2 in chapter 3). During the creation of the specification, the data elements, functional elements, and the framework was not defined yet, because the data elements; functional elements and the framework was forgotten to be defined. Once the forgotten elements and framework came into knowledge, the specification was forced to be put temporarily on ice until the elements and the framework was defined and by putting the specification on ice, the specification as the time to specify the metrics and ideas were not completed until early in the evaluation process.

The method of choice to decide which concept to continuing developing could be different. All the encountered concept evaluation methods are brand new and none of the methods were heard of before earlier in the project. The validation scenario works as an evaluation method, but only analyses the concept in a general way as if the concept splits off from the key path scenario where some aspects may have been overlooked. Another method that could have used instead of validation scenario is what Hanington and Martin (2012) describes as Weighted Matrix. According to Hanington and Martin (2012), a weighted matrix is able to help and identify concepts that is most promising to continuing developing by ranking potential design ideas against key success criteria where the criteria represents the primary measures of product success rated on a scale defined by the developer(s). By using Weighted Matrix, it would be possible to choose a concept that could better fit to continuing developing.

The method of choice by evaluating the concept selected could also be different since the method was not discovered early in the project. In this project, the formative evaluation method together with a paper prototype was chosen by testing the interface to users to detect issues that the interface had to be fixed. Using paper prototypes with formative evaluation gave an insight of issues that the interface holds. Another method that could been used instead is what Hanington and Martin (2012) describe as Wizard of Oz. According to Hanington and Martin (2012), the Wizard of Oz is a technique in which the participants are led to believe they are interacting with a working prototype of a system, while a researcher (the "wizard") is operating the system by acting as a proxy for the system behind the scenes. By operating the system without the participants' knowledge, it would give a greater insight of what kinds of issues the interface holds, for example, observing the amount of "wrong" clicks the participant does, which will require an on-screen prototype instead of a paper prototype.

The way of measuring the metric values during the formative evaluations could be a lot better. During the evaluations, all the measurable metrics were recorded by observing the participant using the interface, where one in the project group was recording the measurements while another one was speaking with the participant. Another problem with the measurement was that some of the values were subjective, like the metric for amount of misunderstandings. When trying to count the amount of misunderstandings, this gave an approximate value, where in reality, the value may be more or less. Yet, another problem that arose during the measuring for example was when to stop measuring the time when the participant gave their thought about the interface. In the first evaluation, the amount of time spent on the interface from start was measured to one hour and seven minutes including when the participant gave his or her toughts. The measured values are not accurate but only approximately. Another, more accurate, way to measure the values of the metrics is to divide the metrics that are going to be measured within the group, by doing this, the values could become more accurate.

The icons may present issues for being interpreted because they were proposed after the last formative evaluation. If the icons were developed during the formative evaluations, the icons could have further improvements in the next evaluations. Nevertheless, the time constraints disabled the opportunity for presenting proper icons for the evaluations.

7. Further Development

Continuing work with the interface which can be conducted is to continue with the formative evaluation, especially with ergonomists and coaches since they are going to use the interface, Trough more formative evaluations, it will create fewer issues to fix after each iteration.

Another task to continue with is to code the interface into a website using HTML with collaboration with programmers. Since the developed interface is dedicated to a software on the internet, the coding requires more than HTML to be a fully functional website which can be used for ergonomic evaluating. A collaboration with programmers is needed to code the PHP and JavaScript. According to w3schools (2018), PHP can be used to generate dynamic page content, collect forms of data and encrypt data, and according to w3schools (2018), JavaScript controls the behavior of the website. With HTML together with PHP and JavaScript the interface can be coded into a fully functionally website.

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Images

Prefacio

[Fig. 1] Diagrama de interacción del contexto. Fuente: elaboración por autor.

[Fig. 2] Representación del contexto del proyecto en el que se contempla el área de trabajo donde laboran trabajadores haciendo uso de sensores que brindan información a ergonomistas y entrenadores para realizar análisis ergonómicos. Fuente: elaboración por autor.

*[Fig. 3] Representación de las secciones de la interfaz.*Fuente: elaboración por autor.

*[Fig. 4] Visualización general de la sección "Live Sesion".*Fuente: elaboración por autor.

[Fig. 5] Visualización del estado de un trabajador en la sección "Live Sesion". Fuente: elaboración por autor.

[Fig. 6] Ingreso de datos para su análisis en la sección "Lab Sesion". Fuente: elaboración por autor.

[Fig. 7] Visualización de datos en la sección "Lab Sesion". Fuente: elaboración por autor.

[Fig. 8] Comparación de datos en la sección "Lab Sesion". Fuente: elaboración por autor.

[Fig. 9] Programa para la realización de tesis por la Universidad de Skövde. Fuente: Guidelines and support for the course Bachelor Degree Project in Product Design, Dan Högberg, School of Engineering Science, University of Skövde, Ver. 2017-10-05.

1. Introduction

[Fig. 1] The project's design process. Source: creation by autor.

2. Pre-study

4. Concept Generation

5. Final Result

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Interview sheet and survey

This is an interview study of The University of Skövde, which has the project of a website devoted to analyze ergonomic evaluation. The purpose of this interview is to collect information about the experiences of the users that analyze ergonomic assessment data, thus it would be possible to have more widespread knowledge about the necessities of users, their demands and wishes, and the problematics. We will ask you to answer specific questions and tell us what you think.

We would like to video and/or voice record this interview and share the results with the people involved in the project for the purpose of designing the website. We will not share your name or any other identifying information with anyone else.

Please check the box if

[ ] You give us permission to record **video** and share it with the people involved.

[ ] You give us permission to record **voice** and share it with the people involved.

[ ] You give us permission to quote any verbal statements you make during the test in our reports.

You are free to leave at any time. If you end participation, we will delete any video we have captured and notes that we have taken.

Please let us know as soon as possible if you have any questions or concerns.

I understand and agree.

Name ________________ *Signature* ______________ *Date*________________

A link to the survey:

https://docs.google.com/forms/d/1VPrrEh45NZRdovMuPom5bIzIYOTI7MrLr5H_WKac Pq0/edit