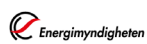A practical guide on how to use wearable eye tracking to document, analyze and learn from tacit knowledge in work procedures for better learning material and faster onboarding.

BUFAB Lann

IF METALL

SKTC SKÄRTEKNIKCENTRUM SVERIGE

INDUSTRI ARBETSGIVARNA

INDUSTRIVALIDERING

Teknikföretagen

tobii

UDDEHOLM

METALLISKA MATERIAL

GJUTERI FÖRENINGEN Sweden's Foundry Association

Jernkontoret

Svenskt Aluminium

Innehåll

01. Introduction

Starting point in the company

- There is no overall picture of the influence that different individuals with their individual conditions and behaviors have on a work process.

- It is often not entirely clear why one employee works more efficiently than another. Results are measured and differences are visible, but there is no opportunity to capture, above all, tacit knowledge. Good training requires the employee's own initiative and interest in learning.

- Ad-hoc training often takes place.

- It is common for companies to trust that employees ask questions or tell themselves about the need for training, which can be difficult for the individual depending on personality and / or language skills = a risk on the way to efficient production.

- In addition, experienced people often find it difficult to put their learned behavior or tacit knowledge into words.

Without the use of wearable eye tracking

- Observations by shadowing usually lack a real first-person view and insights into a person's way of thinking

- Documentation is based heavily on subjective verbal expressions

- Observations and interviews are based on the interviewer's memory

- Tacit knowledge cannot effectively be extracted

The advantage of the method around behavioral examinations with eye tracking glasses is;
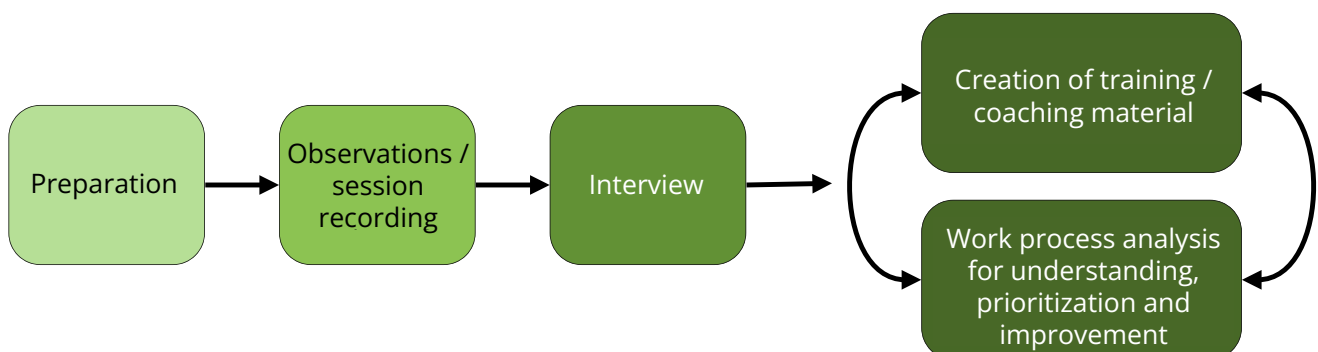
- To be able to document and visualize subconscious and intuitive behavior and knowledge with film, sound recording and particularly with eye movement visualizations,

- Triangulate implicit and explicit behavior,

- Visualizations of behavior are a key to observational learning,

- Easy to get started with observations and analysis of behavior

Guide

02. Preparations

a) What is known already / where to start?

Depending on what is known about work processes already, the starting point will also differ. For example, in cases where there is no written standard operation procedure and rather flexible checklists are used as the only guidance, it could be a good idea to start with the general documentation of how different workers perform their work tasks. Comparing different approaches will quickly give a good overview of which workers have established an efficient way of working. Those ways of working could then be used as a template for a more standardized process or training.

In case there is already a standardized process, it could be used as a reference. Learning efficient ways of working directly from workers can be a great contribution to process innovations.

b) Minimizing bias

Bias is a prejudice in favor of or against one thing, person, or group compared with another usually in a way that's considered to be unfair. Biases may be held by an individual, group, or institution and can have negative or positive consequences.

The most important bias to be prepared for:

- **Selection bias**, where the selection of a certain task, environment, test person, and/or sampling can imply bias. Be super-vigilant. Don't try to decide what is and is not important while you are capturing. Take it all in.

- **Hawthorn effect**, when a respondent behaves unnaturally as he or she feels observed. A good practice to reduce the Hawthorn effect is to focus on the technical components and descriptions about the setup and purpose of the study (introduction, consent form, etc.) first and as early as possible. Followed by distracting small talk about other things, the respondent can be distracted from equipment and study purpose. Unfortunately, there is no fixed amount of time a respondent needs to relax. The observer needs to be aware of the respondent's stress level and eventual concerns and perhaps prolong the introduction and/or address concerns. A respondent should never be forced to participate in the study.

- **Objectivity of the observer, such as Confirmation bias**, the observer can take steps to ensure systematic and rigorous approaches to sampling, field notes, and data collection to increase transparency. Objectivity is mandated. Do not begin observing a situation with preconceived notions.

c) Validity

The fact that observational data is situation-specific and not easy to replicate, together with the possibility of observer bias, are potential threats to the validity of an unstructured observation.

Therefore:

- Be aware of potential bias when performing the observation! See section b) Minimizing bias.

- Check the observations and interpretations of them, together with respondents, as a form of validations.

- Choose a larger sample size (number of test persons). This can be challenging though, as in reality the number is often dependent on actual availability of suitable test persons in the

company. More details about recruitment in section e) Recruiting respondents.

- The observer should be circumspect to be able to abstract from the data general principles that can throw light on other similar situations.

d) Location and timing of observations

Make sure normal conditions apply in the test environment both in time and location. Ideally, nobody should unnecessarily disturb the observation (unless this counts as normal).

- The location should be well lit (standard office brightness for optimal results), but no direct sunlight.

- The observation itself takes no longer than the actual task, plus time for introduction and setup of equipment (about 5-10 minutes). A follow-up interview after the observation to understand the respondent's behavior better, typically adds 15-20 minutes. In total, 20-30 minutes longer than the task.

e) Recruiting respondents

With the purpose to learn tacit knowledge and competencies as well as to create better learning material to onboard new employees more efficiently, the goal should be to:

- Recruit respondents with the requested knowledge / skillset,

- Recruit respondents on different experience levels, to be able to identify differences in behavior while performing similar tasks. A good indication of experience level of respondents in the company could come from performance data, such as variations in processing durations, error frequency, etc.,

- Look for respondents with different personalities that could affect the way of communication and willingness to learn and share, such as intro-/extrovert, proactive/reserved, etc.

Also, some eye tracking specific criteria need to be considered:

- For respondents that require prescription glasses (and cannot use contact lenses instead) the Glasses optical lens kit should be used (as from Tobii). Remind the respondent before the session to look up the strength needed, to avoid long searching and try out before the session can start.

- Respondents must not have visual limitations (such as cross eyed or droopy eyelids for example) or neurological conditions.

- Respondents must not have had eye laser treatments or other surgeries.

Typically, not more than 12 respondents need to be recruited to identify the most relevant behavioral patterns.

f) Privacy and data handling

Privacy and data handling is a highly important and potentially sensitive topic when working with personal (employee) data. Here, local legal regulations should be followed and if available a representative of the union be involved.

Typically, respondents must consent to the use of the eye tracker, storing, processing and maybe publishing personal data. In Appendix B, you can find an example of such a consent form.

- Consent form signed?   Yes ☐   No ☐

g) Permissions

- Are any permissions required for filming in the area?   Yes ☐   No ☐

- Will confidential material potentially be visible in the footage?   Yes ☐   No ☐

h) Handling potential concerns

Remember that you are an observer and not a spy! Generally, show respect for a person's integrity and concerns. Answering respondent questions clearly and objectively has shown to gain trust. The local union representative should be informed and can provide support as well.

Those are typical concerns to be prepared for:

Will participation affect a person's employment?

Be clear that it will not under any circumstances. It is advisable to discuss the approach with the local representative of the union (if available) before as well and to mention this to gain additional trust.

What is the purpose of the study?

Explain that you want to learn from how similar work tasks are performed by this and other workers to create better training material for new colleagues.

How will the data be used later?

Data will be used in accordance with the consent given and no other reason than that. It will only be used to learn about work procedures. It is all about documentation of and learning from employee's behavior.

With whom will the material be shared / how published?

This depends on the type of training material that is planned. Be honest.

i) Task(s) and goal

A good task should set the respondent's mindset for the upcoming exercise as well as being clear about the expected outcome. Ideally, the given task reflects the standard work procedure, to capture regular behavior. Except wearing eye tracking glasses, there are no further limitations for the respondent performing its normal work.

Example:

"Imagine you work at machine X in procedure Y. Please proceed and adjust the machine according to the SOP. You will perform this task on your own, as you normally do. I [the observer] will not be around, please let me know when you are done by coming to my desk."

Recommendation:

Have a good sense of the kind of data you want to collect. It is easy to capture sessions that are longer than needed. That's why a good foundation of secondary research is very helpful in this process. Try to frame the task as good as possible for less work in post-sessions data handling.

Below some guiding questions for inspiration:

- Are there written processes that operators are supposed to follow and can be used as a reference for observations and measurements?

- What training material is being used now and how is it perceived by the target group?

- Where do people from the target group see challenges during observational learning?

j) Who will be the observer?

Eye tracking sessions are most suitably performed by company staff with deeper knowledge about the work task to be documented/learned from. During the eye tracking observations and follow-up interviews, it will be easier for the observer to understand certain behavior when there is some previous knowledge about the process available.

k) How to operate the eye tracker?

a. Eye tracker overview

The Tobii Pro Glasses wearable eye tracker was used. The equipment on the respondent consists of a glasses head unit, to be worn as normal glasses, and a small wearable hand-sized computer, to be worn on the trousers belt. The head unit has a camera pointing forward and providing a first-person view, a microphone, as well as eye tracking sensors pointing towards the respondent's eyes. Eye tracking sensors emit low energy infrared that is not harmful to the eye. Both units are connected by a thin and flexible cable. The eye tracker unit on the respondent connects wirelessly with a computer for live video and data streaming to the eye tracker application. All recorded data is stored exclusively on a SD card inside the eye tracker. The eye tracker is battery powered and can run 90 minutes on one charge. During the eye tracking session, the observer can live view the data and video stream on the computer. After a session is finished the eye tracking video recording can be replayed in the Tobii eye tracker application.

b. Preparation of equipment

- At least four hours before use, batteries are recommended to be put on charge until fully charged both for the eye tracker and the computer.

- Clean the glasses head unit with the provided microfiber cleaning cloth so no fingerprints are visible on the sensors or camera. Connect the head and recording unit by cable, insert a fully

charged battery and a SD card. Power the unit on and allow it to start up (typically one to two minutes).

- From your computer, connect to the eye tracker's wireless network and open the eye tracker application.

- Keep all other batteries in the battery charger so you always have a fully charged battery to hand.

c. Eye calibration

At the beginning of each eye tracking session an eye calibration will be performed. This normally takes about 30 seconds. Aim to be accurate during calibration as it affects data quality of all data that is collected afterwards.

Following, best practice to perform an eye calibration*:

- Let the respondent wear the glasses and mount the recording unit on the person's belt. Ensure the head unit is comfortable to wear and no cable limits head or arm movements,

- Initialize a new session and you will be automatically prompted to start the calibration,

- Ensure good lighting conditions (standard office brightness), no direct sunlight,

- Tell the respondent to stand still, to look forward and keep eyes open,

- Present the calibration target to the respondent at about arm length distance*,

- Ask the respondent to look concentrated at the calibration target. Ensure the respondent is concentrated and for example not moving eyes nor head in that situation. Both pupils need to be fully visible,

- Start the calibration in the eye tracker application and wait until it is finished. Once finished, do not comment for the respondent yet – check if the red gaze circle matches the calibration target. In case of a major offset, re-calibrate immediately. Once you are happy with the calibration, let the respondent know that he/she did this very well,

- After a successful calibration, you can start recording the eye tracking session.

d. Session replay

* general instructions. Note any device specific instructions.
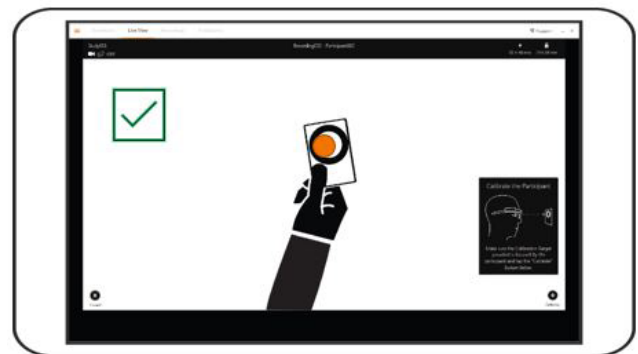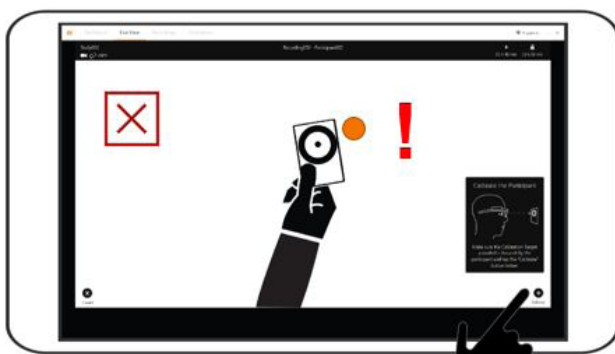
After the eye tracking session is finished the observer has the option to replay the eye tracking session video and discuss interesting behavior and situations together with the respondent.

03. Observations / session recording

To onboard new employees faster, a company needs to understand what skills and knowledge are required to perform a work task efficiently. In many cases highly experienced workers have found efficient approaches towards certain work tasks. It makes sense to learn from this experience. However, learned (tacit) knowledge and competences can be difficult to express by the person him or herself. An observer tries to identify what makes an experienced person more efficient in performing a work task than others, by comparing individual knowledge and skills/behavior. Findings can then be used to coach new employees.

Observation and documentation of different peoples' behavior and understanding the reasoning behind, will be performed by controlled nonparticipant observation and in-depth interviews. The environment for task fulfilment is controlled by a given task, a pre-designed workplace, and an operation procedure to follow.

Via the eye tracker application, the observer can capture and observe (gaze) behavior live from a distance, connected wirelessly to a computer. On the computer screen the observer can see the live video stream from the glasses' front camera (providing a first-person view) and the person's projected gaze point, indicating lines of reasoning. This is powerful as the respondent doesn't need to express its behavior with its own words.

The observer can simply follow the gaze and identify behavioral patterns and differences compared to other respondents.

Instructions:

- Take notes about interesting observations during the session. Those can be used in the interview to discuss. Do not rely on your memory.

- Log interesting moments during the live session in the eye tracker application. This will help you later to find the moments on the session replay timeline quickly.

- Depending on the task you could look for the certain gaze behavior, such as:

- **Visual orientation** (where the eye typically makes longer "jumps" with short gaze fixations in single spots to roughly perceive the environment, where highly salient spots initially gain more attention than others).

- **Mental focus patterns** (gaze fixation duration with increasing size of the gaze point while fixated in one location, and/or fixation cluster when the gaze point stays in a limited area),

- **Comparison patterns** (gaze wanders from one element with mental focus pattern to another and back)

- **Reading patterns** (gaze fixations follow a text in an ordered way),

Visual examples for above gaze behavior can be found in appendix A.

04. Interview

Perform an interview to understand the reasoning behind (gaze) behavioral patterns after the task and eye tracking session is finished.

The observer interviews the respondent about its behavior. The goal is to understand (gaze) behavioral patterns, how and why it differs compared to others. For a respondent it can be challenging to describe one's own complex and trained/intuitive behavior verbally. The big advantage of having the eye tracking session video is that the complete behavior is recorded - the video can be replayed as many times as needed to analyze.

Instructions:

- Together, talk through observations and behavior in general,

- Take notes and/or audio record the interview,

- Show situations from the eye tracking session video to the respondent to let the respondent describe the behavior in as much detail as possible. First, when the respondent cannot find any description for their own behavior, the moderator can help to find the right words. Replaying the eye tracking session video helps visualizing the respondent's own behavior and supports the person's memory recall strongly.

- Inspiration for a conversation guide:

  - Please, describe what you did here. [show video sequence]

  - What did you think when you were doing this...? [show video sequence]

  - Why did you perform this step? [show video sequence]

05. Work process analysis for understanding and improvement

With focus on data driven process analysis, behavioral data from the eye tracking glasses can be analyzed further to receive objective behavioral metrics and visualizations. Such an analysis can be conducted to gain a broader picture of operational procedures in general and individual persons in the process in detail.

The following aspects were found to be most valuable for process improvements:

- Dwell time mapping per work step in an operational procedure and per person,

- Identification of work steps with biggest variance in processing time among all participants. This allows prioritization of improvement measures on tasks with biggest potential improvement effect,

- Analysis of the order of steps taken per person, to perform a given work task,

- Visual attention distribution mapping to investigate (visual) ergonomics of a work environment.

Despite the high usefulness of such analyses, access to necessary internal resources and knowledge to carry them out efficiently often is limited. The use of external eye tracking and behavioral data analysis services could be considered.

Instructions (simplified):

- Import session data from the eye tracker's SD card into Tobii analysis software, installed on a computer,

- Set the correct data filter settings (see the software documentation for detailed explanations),

- Use the method of behavioral coding as a basis for behavioral metrics such as start/end and dwell time per work step and number of work steps (with standard operational procedure (SOP) as reference).

- To measure visual attention distribution on certain objects, use the Tobii analysis software for a mark-up using areas of interest (AOIs).

- Extract metrics from behavioral coding (dwell time, work step orders) and AOI metrics (fixation duration and count, visit count).

- Optionally, extract data visualizations such as a heatmap or gaze plot (requires data mapping that is performed to extract AOI metrics).

- Creation of (timeline based) data visualizations in e.g., Microsoft Excel (see examples in appendix B).

06. Creation of training / coaching material

This step can be performed in a later stage and does not need to be in direct connection to the interview. Insights and learnings from the observations and interviews could be used to coach individuals or a team, alternatively to create educational material for new employees, such as a training video from eye tracking video sequences visualizing best practice from different respondents.

It is recommended to start with a storyboard, then identifying and exporting relevant eye tracking session video sequences in the eye tracking analysis software from Tobii before further video editing in a third-party software.

The first-person view and moving gaze point from the eye tracking video data makes observational learning easy by following someone else's behavior and line of reasoning (indicated by the gaze behavior). A speaker is recommended to explain key situations for easier learning. For the training material to be less dependent on local language skills, easy to translate and exchange subtitles could be used.

The training method is based on the method of observational learning. Observational learning is described to happen in four main steps. A good practical training method should consider following best practice in those steps:

- **General requirements for a good practical training method:**

    - Is standardized and success does not depend on a person's personality (extrovert asks around easily, but an introvert would have a harder time with it).

    - Gives the person permission and space to take in the information and try in several rounds.

    - Conceived as an approach where theory and practice alternate.

    - Focuses on clear communication of the purpose and use of recorded material. It is important to emphasize that it is not a matter of assessing individual performance, but to improve the work process/work environment.

    - Is based on the learner's general curiosity and willingness to learn. Could be designed as a company-internal "campaign" to produce new learning material to help the company with a positive change and confirmation to individuals. Typical comments that were received from such campaigns: "... felt that I can contribute to a positive change in the company" and "... I felt important for the company when my knowledge is requested".

- **Four main steps of observational learning**

    - **Attention –** the learner needs to be aware of the knowledge to be learned.

    - **Effective learning material should:**

    - Focus on key moments only, to stay short,

    - Information to be taught must be highlighted

    - Show a work method that has been proven and accepted,

    - Be easily accessible and understandable / meet the people at the level they are at,

    - Be person-neutral,

    - A film should be commented with both sound and text

    - Text in the film should be interchangeable to be able to adapt to other languages easily, and

    - Give experienced and well-established employees the opportunity to teach their knowledge

    - **Retention** – the learner uses mental modeling to keep the information for later use. The learning itself, i.e., the mental modeling, does not require practice initially. **Learning success** can be measured by the learner's ability to re-tell learned knowledge at first stage. **Operant conditioning** (the strength of a behavior is modified by reinforcement or punishment) during the learning phase has in previous studies shown to be potentially counterproductive. More important than operant conditioning is general curiosity of the learner.

    - **Motor reproduction** – the learner practices modeled knowledge

    - **Adoption** – the learner adopts learned knowledge to similar situations

07. Next steps

What other actions can an eye tracking observation lead to, in addition to faster learning/onboarding and increased productivity?

Eye tracking-supported observations can be very powerful and flexible in use. Observations are not limited to creating learning materials but can be conducted in any area in the company to learn from the companies' staff's tacit knowledge and competences. It can be a huge step towards (process) innovation!

Following some concrete examples of actions that both management and employees can easily take on board:

- Changed/improved process orders, based on the most efficient approaches found,

- Split or merge of work processes into more/fewer partial moments at a certain workstation,

- Changed quality/inspection routines,

- Improved technical aids,

- Modified work environment layouts,

- Better ergonomics.

08. Appendices

Appendix A – Visual gaze examples
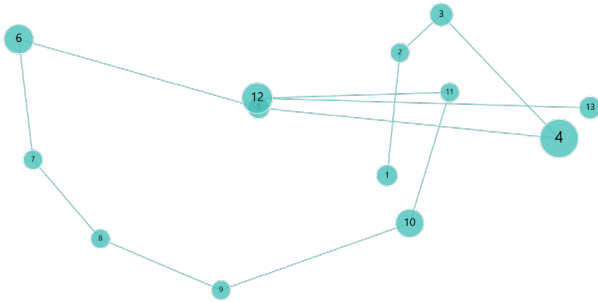
Visual orientation

Typically, the eye makes longer "jumps" with short gaze fixations in single spots to roughly perceive the environment, where highly salient spots initially gain more attention than others.
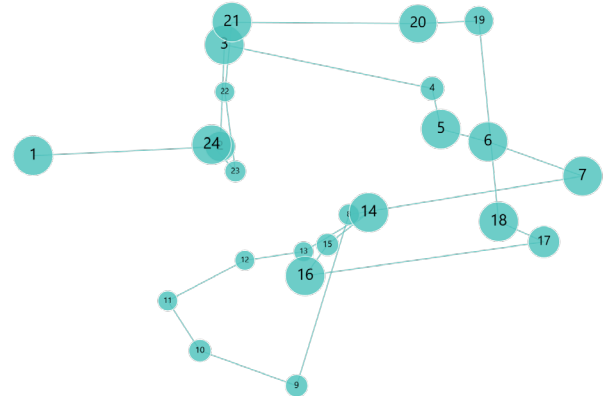
Mental focus

Longer fixations (larger dots) on single elements of relevance for the person. The longer fixation duration (larger dots), the longer mental information processing.
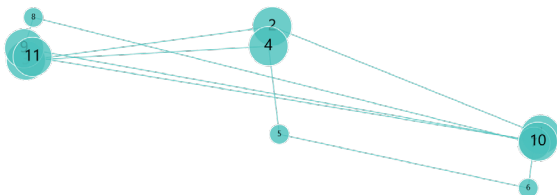
Comparison behavior

The eye "jumps" between and fixates on different objects (here A, B, C) for comparison of visual information.

Reading

Gaze follows the text pattern (row by row) with fixations on text elements. Differentiate between reading and just scanning behavior, such as diagonal gaze paths with fixations on keywords, headlines, or images only.
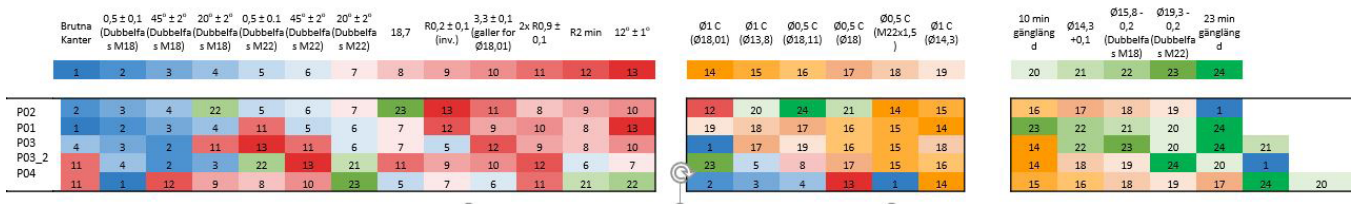
Process analysis - Processing time per work task and participant

Time by Task (Mätbord)

P01   P02   P03   P03_2   P04

SPS	M18 Medeldiam Gängmikro-meter	M22 Medeldiam Gängmikro-meter	Gängringar	Höjd 18	Höjd 12	Höjd 13	Pinntolkar	Längdmätning med skjutmått	Yttermått med skjutmått	M18 Ytterdiam mikrometer	M22 Ytterdiam mikrometer	Okulär kontroll
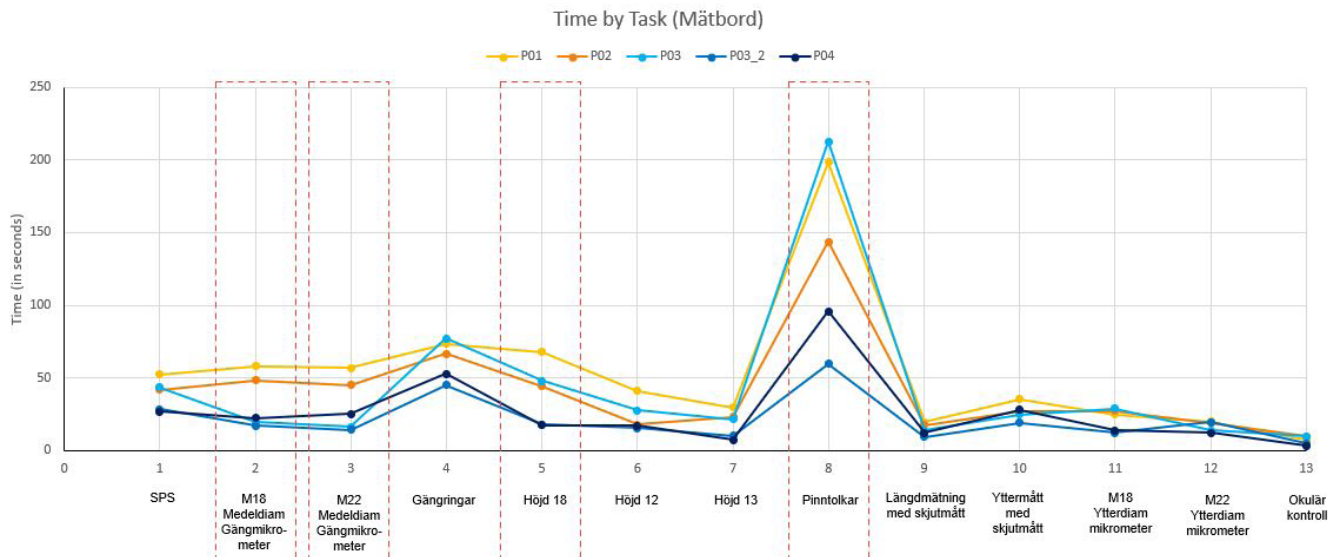
Actual work task order vs. written process / guide

Real work task processing order. In general, many tasks were done in different order than on the form. Certain tasks were skipped. For process innovation, most efficient approaches can be learned from experienced employees. It also becomes clear, what new employees do different which allows for targeted training assignments.

	Brutna Kanter	0,5±0,1 (Dubbelfas M18)	45°±2° (Dubbelfas M18)	20°±2° (Dubbelfas M18)	0,5±0.1 (Dubbelfas M22)	45°±2° (Dubbelfas M22)	20°±2° (Dubbelfas M22)	18,7	R0,2±0,1 (inv.)	3,3±0,1 (galler for Ø18,01)	2x R0,9± 0,1	R2 min	12°±1°
	1	2	3	4	5	6	7	8	9	10	11	12	13
P02	2	3	4	22	5	6	7	23	13	11	8	9	10
P01	1	2	3	4	11	5	6	7	12	9	10	8	13
P03	4	3	2	11	13	11	6	7	5	12	9	8	10
P03_2	11	4	2	3	22	13	21	11	9	10	12	6	7
P04	11	1	12	9	8	10	23	5	7	6	11	21	22

	Ø1 C (Ø18,01)	Ø1 C (Ø13,8)	Ø0,5 C (Ø18,11)	Ø0,5 C (Ø18)	Ø0,5 C (M22x1,5)	Ø1 C (Ø14,3)
	14	15	16	17	18	19
P02	12	20	24	21	14	15
P01	19	18	17	16	15	14
P03	1	17	19	16	15	18
P03_2	23	5	8	17	15	16
P04	2	3	4	13	1	14

|	10 min gängläng d	Ø14,3 +0,1	Ø15,8 - 0,2 (Dubbelfas M18)	Ø19,3 - 0,2 (Dubbelfas M22)	23 min gängläng d		
	20	21	22	23	24		
P02	16	17	18	19	1		
P01	23	22	21	20	24		
P03	14	22	23	20	24	21	
P03_2	14	18	19	24	20	1	
P04	15	16	18	19	17	24	20

Form to fill with measurement values. Measurements are ordered and inherit a certain work order.

Process improvements
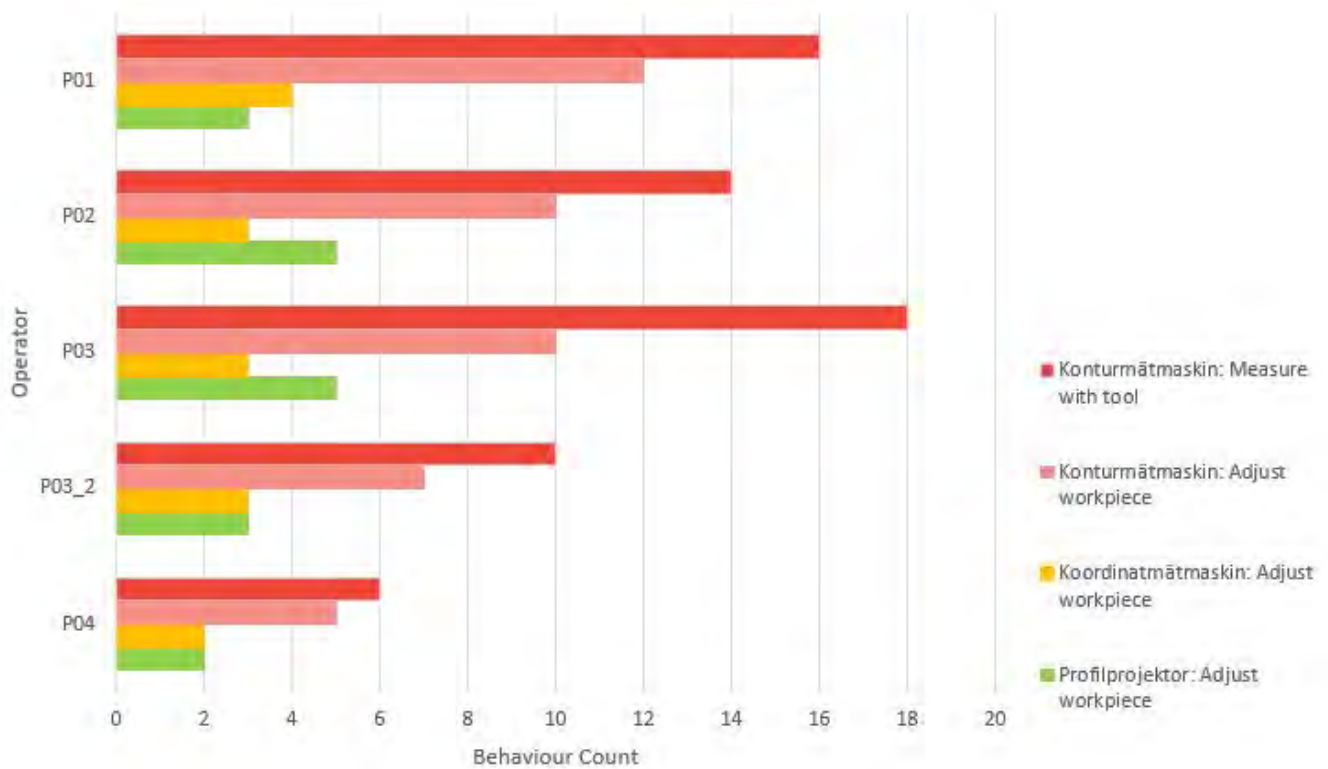
Logging behavior and time objectively to understand human behavior in work processes better.
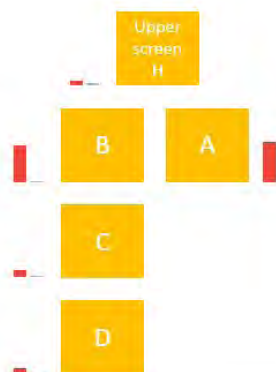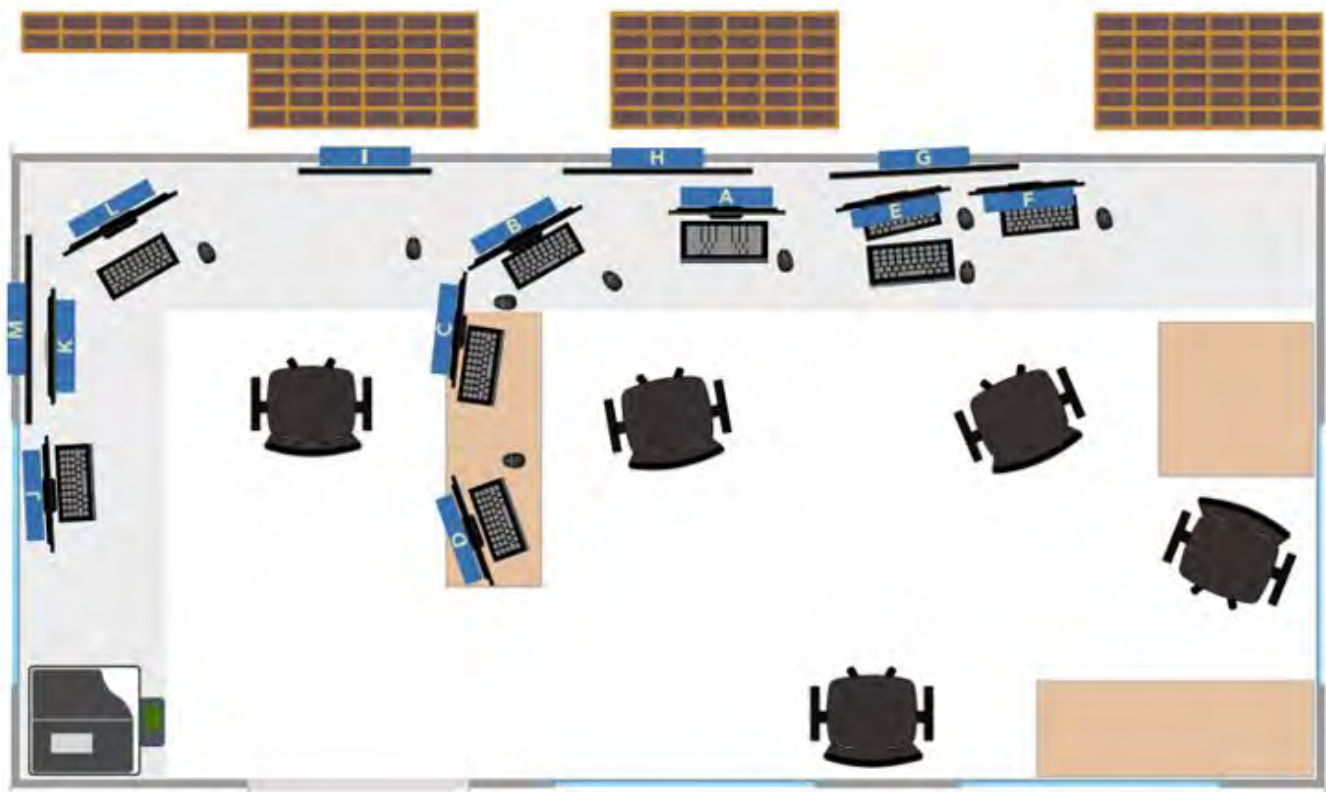
Visit Count					
Screen	A	B	C	D	H
User Group 1 (Lag 1 + 2)	156	146	30	22	20
User Group 2 (Lag 5)	0	6	2	1	9

| Visit Count			
Screen	E	F	G
User Group 1 (Lag 1 + 2)	15	0	26
User Group 2 (Lag 5)	19	64	18

Work environment visual ergonomics

Gaze visit count to measure objectively and visualize what screens were used most frequently (together) during a work task. Results can indicate which screens should be group and/or placed in most ergonomic position.

Visual Attention (Time) Distribution by Object
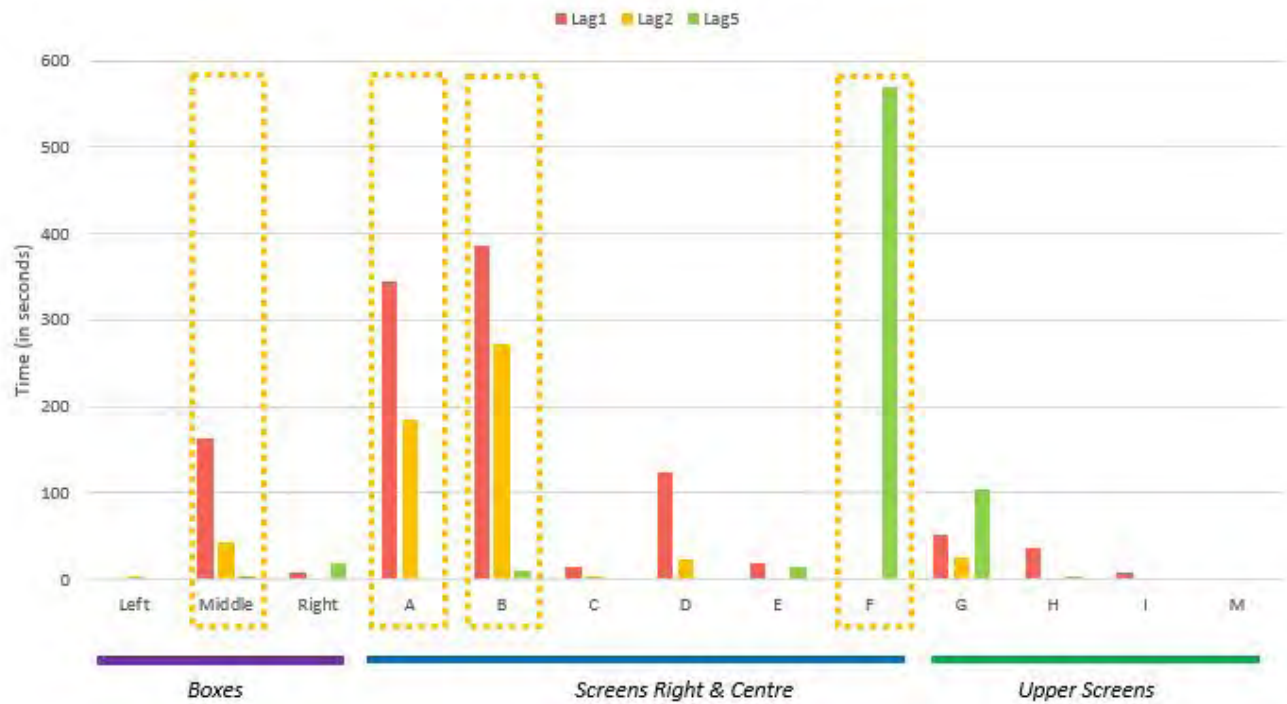
% of Attention Time Spent on Screens/Boxes by Participant
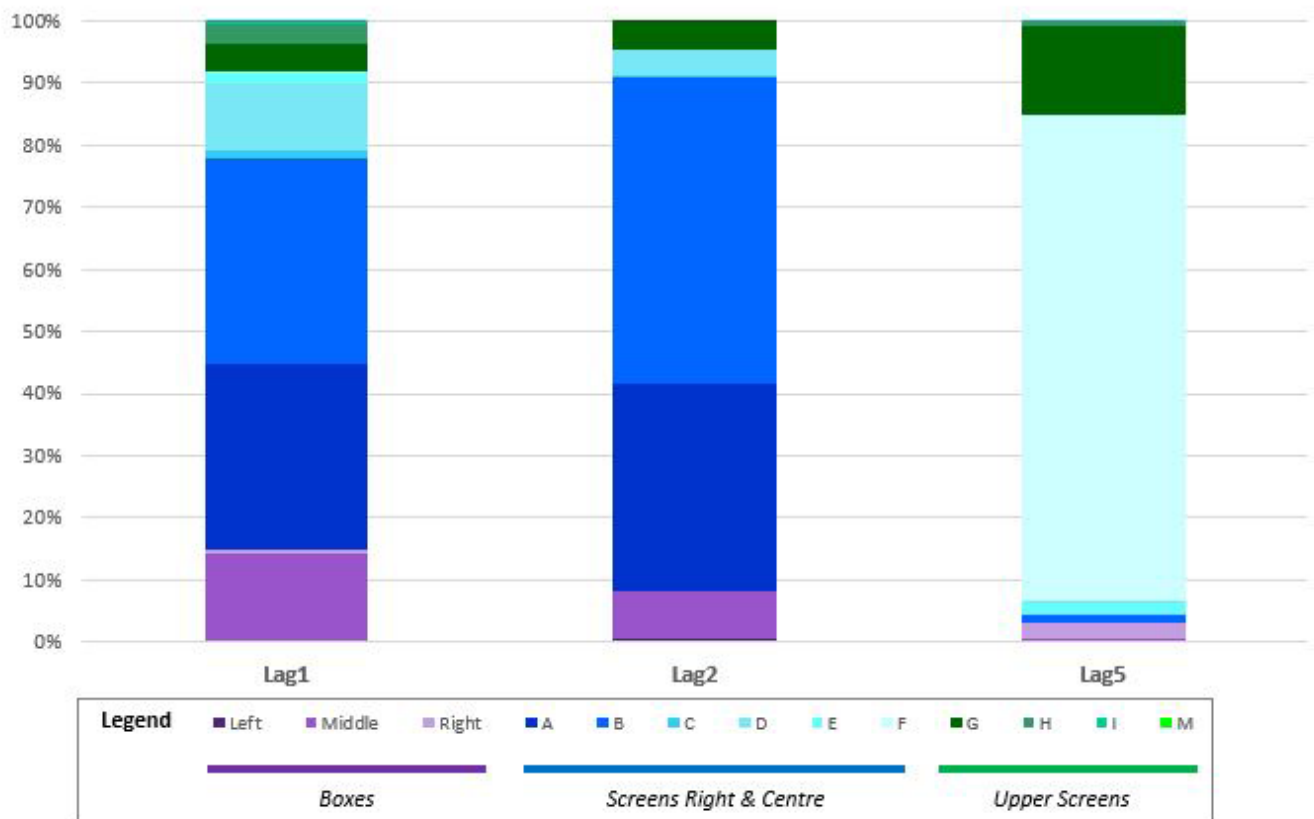
Appendix C

Example of a participant consent form for data privacy, storage, and processing

Consent to Participate in Research

Information about personal data handling

We are [COMPANY NAME], a [COMPANY TYPE (e.g., research)] company based in [ENTER LOCATION].
We will be recording your session partly or completely, including video and sound capture as well as
eye movements with an eye tracker.
If you are joined by anyone else today, they will have to give consent to be recorded as well. If you
agree to take part in the study, we will get you set up and begin the task. After you finish we would
like to complete a short interview with you.

Your participation in the research will remain anonymous and your identity will not be associated with
the recorded material. Any personal data captured will be excluded from any analysis and not shared
with any third party at any time. Captured data will only be kept for as long as is needed to complete
the research and be deleted afterwards. The purpose of the research is to [ENTER PURPOSE, e.g.,
creation of onboarding material]. Data may be shared with additional stakeholders in anonymized
form only, aggregated together with the data of other participants. Your identity will never appear in
any public material.
You are free to withdraw from the study at any time, your recording will then be removed immediately
upon request. Since the data is collected anonymously you will only be able to retract your recording
after participation with your unique participant ID. Please request your participant ID from the
researcher to have this opportunity. For more information about how [ENTER COMPANY NAME]
processes your personal information, read the [ENTER COMPANY NAME] Privacy Policy at [ENTER WEB
LOCATION] or email our Data Protection Officer directly [ENTER EMAIL ADDRESS].

☐ I am 18 years or older.
☐ I give my consent to [ENTER COMPANY NAME] for the use of the recorded data as described
above.

Place, Date: _____

Signature: _____

Name: _____

Respondent ID [to be filled by the moderator]: _____

"Get an eye for steel work" is a project run within the strategic innovation program Metal Materials and is a joint initiative by several stakeholders within the Swedish steel industry including companies, education providers, and unions. The project is a collaboration between the Research Institute of Sweden, Tobii, Bufab Lann, and Uddeholm. Modern eye tracking technology was used throughout the project. Operators were fitted with Tobii eye tracking glasses while they completed their regular workplace activities. Eye tracking allowed us to tap into the visual attention of workers and see things from their perspective, literally! Eye tracking accurately captures visual attention and elements of behavior that are instinctive or subconscious. This information can be used to identify methods of best practice and create learning materials for new staff . Because it's not language dependent, it overcomes many of the barriers attached to verbal or written instructions. The strategic innovation program Metallic Materials aims to realize the strategic research and innovation agenda National assembly on Metallic materials. The program is part of Vinnova's, the Swedish Energy Agency's and Forma's investment in strategic innovation programs and brings together Sweden's metal industries: steel, aluminum, cemented carbide, cast steel, cast iron and cast non-ferrous metals. The project budget was 6 354 000 SEK. Vinnova financed 40% and the participating companies and organizations financed 60%.