

DESIGN OF A DISPENSER FOR CRIME SCENES AND LABORATORIES

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Graduation project

Master's thesis

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TABLE OF CONTENTS

INTRODUCTION

1.1 Project partners	5	5.1 Development	57
1.1.1 Netherlands Forensic Institute (NFI)		5.1.1 Cycle 1	
1.1.2 TU Delft		5.1.2 Cycle 2	
1.2 Background	6	5.1.3 Cycle 3	
1.3 Project brief	7	5.1.4 Cycle 4	
1.3.1 Problem definition		5.2 Amount of disinfectant to dispense per wipe	68
1.3.2 Project scope			
1.3.3 The assignment			
1.3.4 The current setup at the NFI			

CONTEXT

2.1 Competitor analysis	14	DISCUSSION AND CONCLUSION	
2.1.1 Disinfectant dispenser		7.1 Discussion and conclusion	75
2.1.2 Wipes dispenser		7.2 Personal reflection	76
2.1.3 Insights			
2.2 Stakeholder map	17	REFERENCES	
2.3 Primary research introduction	18		
2.3.1 Research aim and questions		APPENDICES	
2.3.2 Research need		A Mind map	
2.3.3 Approach		B RNase AWAY™ data sheet	
2.4 Primary research 1: Questionnaire	22	C Pipette tip rack data sheet	
2.4.1 Key insights		D Amplitude™ Delta™ wipes data sheet	
2.5 Primary research 2: User observation study	23	E User study plan: Questionnaire	
2.5.1 Participants		F User study plan: User observation study	
2.5.2 The setup		G User study plan: Interviews	
2.5.3 Image processing method		H Consent forms	
2.5.4 Outcome		I Processed images	
2.5.5 Key insights		J Number of pixels	
2.6 Primary research 3: Interviews	34	K User observation study: Photos taken	
2.6.1 Interview outcome summary		L User observation study: Participant times	
2.6.2 Key insights		M User observation study: Notes	
2.7 Research synthesis	39	N User observation study: Interviews	
2.7.1 Design opportunities		O Interviews with the police	
2.7.2 User journey map		P Data Management Plan (DMP)	

DESIGN DIRECTION

3.1 Design vision and drivers	43	Q Human Research Ethics Committee (HREC)	
3.1.1 Design vision		approval	
3.1.2 Design drivers		R List of requirements and sources	
3.2 List of requirements	44	S Ideation session Miro board	

IDEATION

4.1 The process	47	T Idea processing	
4.1.1 Ideation session		U Idea(s) development	
4.2 Results	50		
4.2.1 From the ideation session			
4.2.2 Morphological chart			
4.2.3 Concepts			

1. INTRODUCTION

1.1 Project partners

This project is a collaboration between the Netherlands Forensic Institute (NFI) and the Delft University of Technology (more commonly referred to as TU Delft). Within TU Delft, two different faculties are involved. This subsection will describe these stakeholders in detail.

1.1.1 Netherlands Forensic Institute (NFI)

The NFI is the national forensics institute of the Netherlands and the oldest forensic laboratory here. They provide forensic products, such as multimedia file recovery software, and services, like fingermark individualisation, to their clients who are national and international organisations (e.g. the police). In this project, the police will also be involved as a stakeholder and future user of the project outcome through the NFI.

Role within the project

The NFI is the client of this project. They are the problem owner and the idea of this project originated from them. Guidance was provided from Fenneke de Vries and ir. Paul van den Hoven, in addition to collaborating on research and design.



Nederlands Forensisch Instituut
Ministerie van Justitie en Veiligheid

1.1.2 TU Delft

This project is an MSc Integrated Product Design graduation project. Additionally, it is a collaboration between the Industrial Design Engineering (IDE) and the Mechanical Engineering (3mE) faculties at TU Delft.

Role in the project

The guidance for and assessment of this project was provided from the graduation committee, who are the chair and mentor.



1.2 Background

This subsection gives an overview of why this project came to be.

Crime Scene Investigators (CSIs) from the police search for and collect evidence at crime scenes, which includes trace evidence (or transfer). According to the theory of Locard's Exchange Principle, microscopic debris on the surface of objects will transfer to each other when they make contact. These "traces" can help identify who they came from and thus potentially link a perpetrator to the crime scene, or a victim to a perpetrator (Bisbing, 2006).

Trace transfer may be described in different ways: active, where the direct trace transfer occurs during the crime itself, and secondary, where the transfer is unrelated to the crime event. An example of secondary transfer is investigator-mediated transfer, or contamination, where the investigator is an unwitting vector who transfers their own DNA to the crime scene or transfers DNA from one part of the crime scene to another (Gill, 2014). One such incident is the case of the death of Gareth Williams (figure 1) where DNA from the investigating officer was found on said subject's hand due to contamination at the scene. This caused the investigation to follow a misled direction and the credibility of the evidence found by the relevant company was called into question (Israel, 2022).

Therefore, in order to prevent this from happening, CSIs will regularly clean and disinfect the tools used to handle and collect evidence. One way to achieve this is with dry wipes and disinfectant. Figure 2 shows the newest dispensers that some of them may be using (as their implementation is on a rolling basis). The process can be briefly described as follows:

1. Open the box of wipes and take one wipe
2. Place the wipe on the push-down pump of the disinfectant-filled dispenser
3. Push down to dispense the disinfectant and moisten the wipe
4. Use the wipe

There is the concern that there is a risk of trace contamination during this process, although the intent is to prevent this exact problem from occurring. This is because there is unwanted contact from the user with the dispenser during use. The wipes are piled up which causes the user to inadvertently touch multiple wipes when taking one wipe from the dispenser. The dispenser is also physically touched. Furthermore, the same dispensers are

used in the laboratories at the NFI. Trace contamination from forensic tools is not an uncommon incidence and has been proven to happen from the point of their manufacture and throughout the entire investigative process (e.g. at the forensic laboratory, during autopsy) (Balk, 2015).

The aim of this project is to redesign the disinfectant and wipes dispensers to be contamination-safe. The dispenser(s) must adhere to the strict conditions at crime scenes and be ergonomically sound for the forensic investigators.



The image is a screenshot of a news article from the Evening Standard. The header reads "Evening Standard" with a small logo. Below the header are navigation links: REVELLER, THE OPTIMIST, COMMENT, TECH, ES BEST, ES MAG, and HOMES & PROPERTY. A red "CRIME" link is also present. The main title of the article is "Forensic DNA blunder hindered 'spy in bag' investigation for a year". Below the title is a photograph of a man in a red cycling jersey. A caption below the photo reads: "Code breaker: Gareth Williams was discovered dead eight days after he was last seen. He was found inside a locked sports bag". The photo credit is "By Paul Cheston Kiran Ranthawale | 30 March 2012". To the right of the main content, there is a "Trending" sidebar with three numbered items: 1. "Pandemic sparks 'worrying' rise in deadly fungal infections", 2. "When are the November 2022 rail strikes and why are workers striking?", and 3. "How tall was The Queen and the rest of the Royal Family?".

Figure 1. News article



Figure 2. Dispensers at the NFI

1.3 Project brief

In this subsection, the possible challenges that might be faced in this project are described in addition to how they will be addressed (the approach and deliverables), bound by the project scope. The current products being used as a solution are also introduced to provide more context.

1.3.1 Problem definition

The latest, and current, dispensers at the NFI came to be because the previous versions of the dispensers they were using will be phased out due to future inavailability and/or incompatibility with the new formula of disinfectant that the NFI and the police are developing together.

The problem with using these current products to dispense and moisten wipes is that the process has many steps (described on the previous page) and requires the use of both hands. As trace transfer occurs due to contact, there is a high risk of contamination occurring. Furthermore, there is no set procedure for how tools should be cleaned and thus the process varies from user to user - there is no clear overview to this yet. These users are CSIs, who work at crime scenes, and laboratory technicians, who work in laboratories, from two different institutions: the NFI and the police.

One challenge of this project was to determine whether the working environment and the individual user affect usage of the dispensers (current scenario). This rephrased as a question would be: "would who and where affect how the dispenser(s) is used?". To answer this, research was conducted to find out about user workflow, user background, environmental factors such as cleanliness, and frequency of use.

Another challenge is that the design solution must be suitable for both crime scenes and the laboratories which means that the similarities in requirements for both contexts should be integrated. However, there could be opposing points and in that case, the crime scene context takes precedence because it is not sterile like a laboratory environment. Thus, more care is required to ensure that the design solution remains contamination-safe.

Lastly, for the new design, the wipes should only be wet with the disinfectant at the point of use. According to the client, there were issues with mold growing on the wipes and the wipes drying out, with the "wet wipe" format.

1.3.2 Project scope

When considering the scope of this project, a dispenser(s) must be designed, which means that any other solution is irrelevant (e.g. removing traces from the current dispenser

after use) because cleaning tools with dry wipes and disinfectant is the method that is preferred at the NFI and the police. Also, for the new design, the wipes and disinfectants used currently must not be changed or altered in any way. Lastly, the focus will be on users in the Netherlands and not the rest of Europe.

1.3.3 The assignment

In a sentence, the assignment can be described as follows:

"Design and validate a device for dispensing and moistening (with disinfectant) wipes."

This project took the double diamond approach (Ball, 2022) which consists of four main phases: Discover, Define, Develop and Deliver. During the Discover and Develop phases, the designer(s) "diverges" by seeking out a vast multitude of ideas and information; and during the Define and Deliver phase, which are the converging phases, information and ideas consolidated to produce the desired outcome.

The assignment began with defining the current scenario via research, such as user interviews and observations, with the aim of understanding why and how the problem occurs. The product journey was mapped out to have a visual overview of what the users experience and so that issues can easily be pinpointed.

Then, the focus shifted to designing a new dispenser concept with multiple prototyped iterations based on the research insights. One purpose of the prototypes is to determine whether a part(s) works physically and another is to validate the ergonomics by testing with users where necessary.

Finally, at the end of this design process, the main aim should be achieved: reducing trace contamination, or the risk of. Additionally, the new design includes recommendations such as materials selection (i.e. the type of surface will affect how long DNA will persist on the object (Goray, Mitchell & Oorschot, 2010)) and manufacturing method(s) so that the product is viable.

Figure 3, on the next page, illustrates the process described in this subsection.

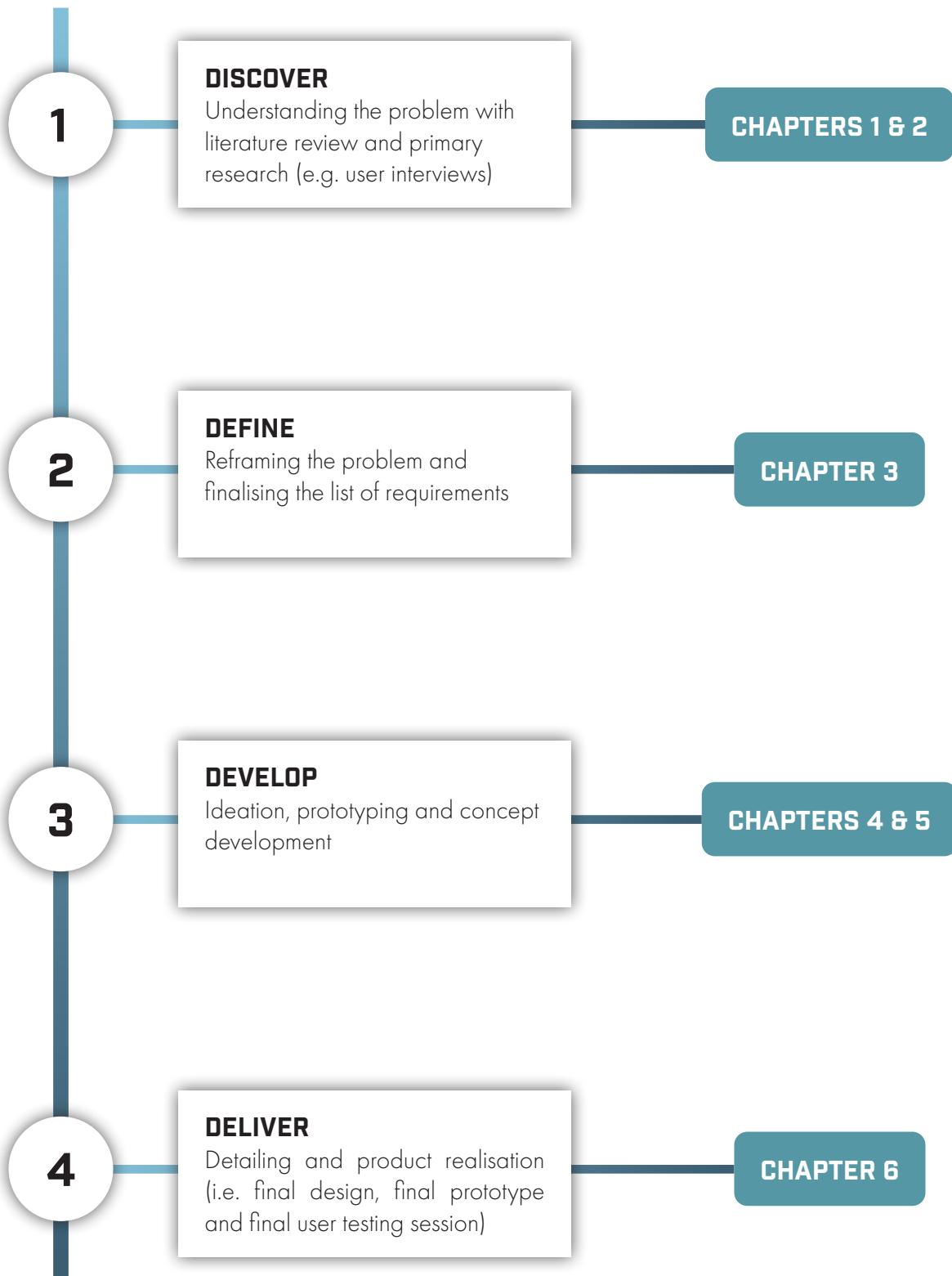


Figure 3. Approach

1.3.4 The current setup at the NFI

Disinfectant dispenser

The disinfectant dispenser is a push-down pump type dispenser. A wipe is placed on the top part of the dispenser (pump head) and pressed down to dispense the liquid inside. It is commonly used in nail salons to dispense nail polish remover.



Figure 4. The top of the dispenser



Figure 5. Product breakdown. This is a promotional picture for a nail polish remover dispenser sold on Amazon.

Disinfectant

The disinfectant currently in use is RNase AWAY™, produced by Thermo Scientific™. The new formula is FMD-away which is in the research phase at the moment. They are both colourless liquids.

RNase AWAY™ is composed of:

- water (>99%)
- sodium hydroxide NaOH (<1%)

FMD Away is:

- water
- sodium hydroxide NaOH 98% (1%)
- sodium dichloroisocyanurate NaDCC 96% (0.4%)
- sodium dodecyl sulphate salt SDS (0.25%)

According to the RNase AWAY™ data sheet (see Appendix B), it is recommended that the disinfectant does not come in contact with aluminium, soft metal or gaskets and seals. It should also be labelled according to Regulation (EC) No 1272/2008.



Figure 6. Example of a bottle of RNase Away™

Wipes dispenser

The wipes dispenser is a repurposed Rainin BioClean Ultra™ pipette tip rack. The tip deck (the coloured component in figures 7 and 8) is removed and the wipes are placed inside.

The pipette tip rack was designed with a removable lid that opens 120° wide. The safety latch that keeps the lid closed is meant to be opened with gentle pressure from the thumb and index fingers. The data sheet can be found in Appendix C.



Figure 7. Pipette tip rack



Figure 8. Tip deck filled with pipette tips

Wipes

The dry wipes used are the Amplitude™ Delta™ wipes from the manufacturer Contec. They are made of 100% nonwoven polyester with dimensions of 10cm x 10cm and have a weight of 71g/m². The data sheet can be found in Appendix D.

They are packaged in a clear plastic bag and there are 1200 wipes per bag. They do not come in a roll format, like toilet paper.

These wipes are recommended for ISO Class 5 - 8 environments. This ISO standard refers to the level of cleanliness of the air within a controlled environment.



Figure 9. A package of wipes

Additional details of the disinfectant and wipes dispensers



Figure 10. Open wipes dispenser

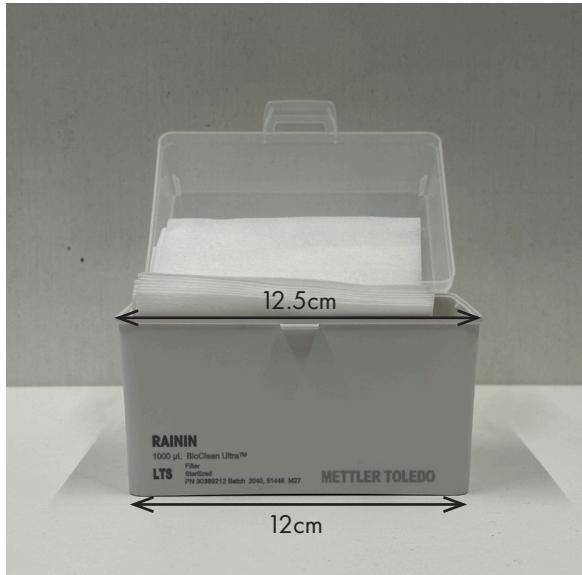


Figure 11. Widths of the wipes dispenser. There is a draft angle.

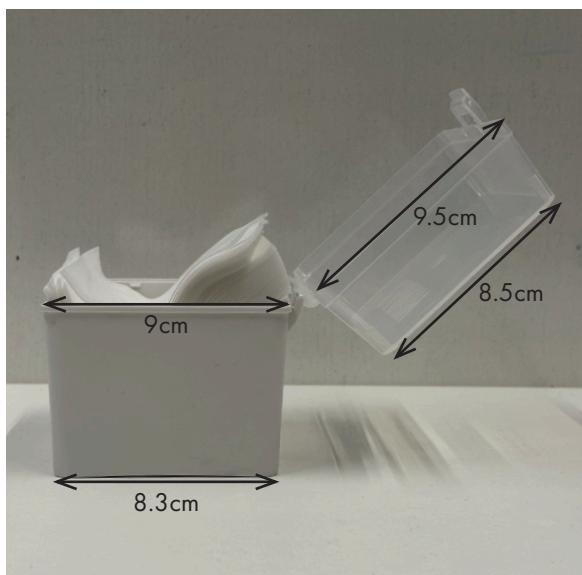


Figure 12. Lengths of the wipes dispenser

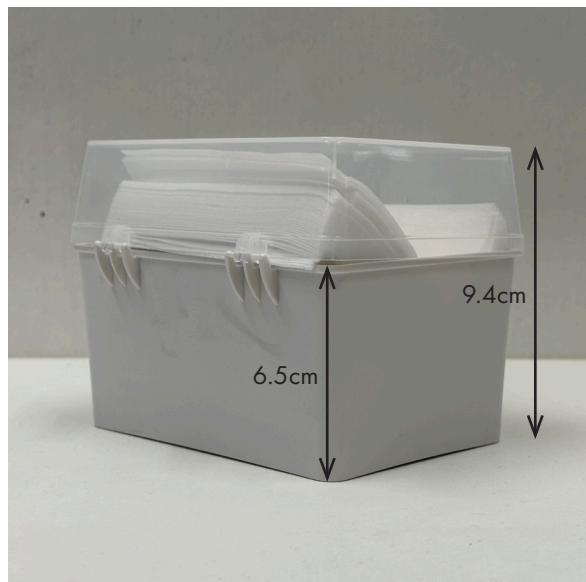


Figure 13. The back of the wipes dispenser. The heights are shown. The total overall height varies as the lid is unable to sit level on the bottom part because the tip deck was removed.



Figure 14. A stack of wipes. They are lightly folded because they do not fit in the wipes dispenser.

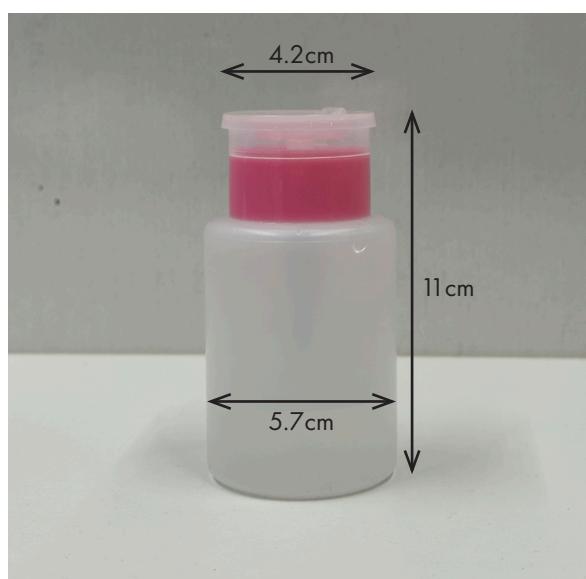


Figure 15. The diameters and height of the disinfectant dispenser

Storage

The dispensers are stored in the laboratories at the NFI. They are also stored in cases. Figures 16-19 on this page show an example of an empty case. There is no fixed way as to how items have to be arranged in them. Consequently, with the exception of being able to fit in the cases, there is no restraint for the new dispenser design regarding their storage in these cases.



Figure 16. Picture of the case closed

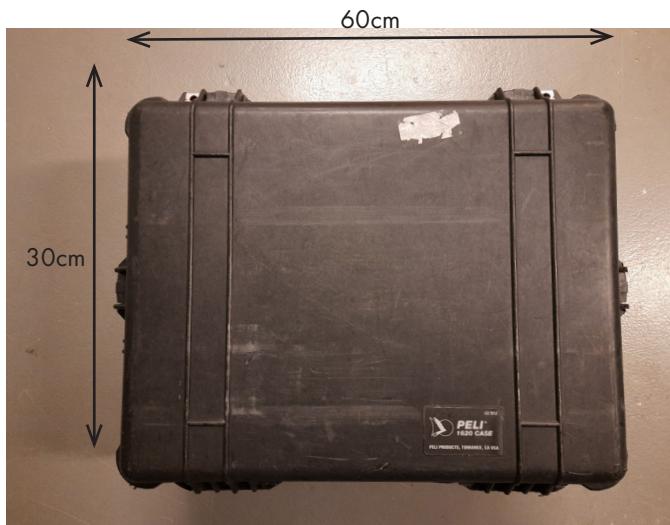


Figure 17. Top view. The width and length are shown here.



Figure 19. Picture of an open case



Figure 18. Close up of the interior

2. CONTEXT

2.1 Competitor analysis

This subsection presents examples of existing products for similar applications (dispensing wipes and disinfectant). Other methods that do not involve wipes and disinfectant, such as disinfecting with UV light or autoclaving, were disregarded. Products that used wipes that come in the form of a roll (e.g. toilet paper) were disregarded as well.

2.1.1 Disinfectant dispenser

Three main categories of liquid dispensers were explored: cosmetics and skincare, household cleaning, and hospitals. Table 1 below contains some typical examples. The push-down pump is not discussed because this is the current product used.

Table 1

Example	Name	Description
	Nyx Cosmetics setting spray	After removing the cap at the top, the user holds this product in one hand and depresses the nozzle with their index finger. A fine mist of setting spray liquid will be produced.
	Albert Heijn multi-purpose cleaner	The user holds the product at the top with one hand. After twisting the nozzle (red part in the image) to "unlock" it, they can squeeze the tab to spray out cleaner.
	Purell automatic dispenser	This product is an automatic dispenser, so the user places their hand under the dispensing nozzle and hand sanitiser will be dispensed. This product is also known as an alcohol-based hand rub (ABHR) dispenser. They can be manual as well (see figure X for the different types), and be wall or floor-mounted.

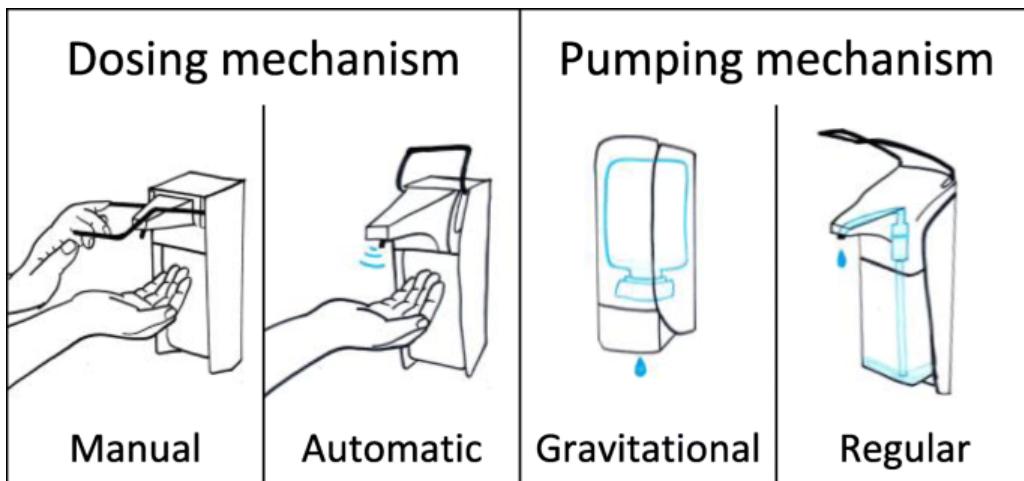


Figure 20. The different types of ABHR dispensers (Bánsághi et al., 2020). The manual dispenser relies on the user's force to operate, and the automatic one generally has a motion sensor and actuators. The gravitational dispenser generally has a valve mechanism and the regular, a pumping mechanism.

2.1.2 Wipes dispenser

Table X below gives some examples of wipes dispensers.

Table 2

Example	Name	Description
	Retro American diner style serviette dispenser	This product is placed on a surface, such as a table. There is an open window at the front where the user pinches a wipe with their fingers and pulls it out. This product is spring-loaded and will continuously apply pressure on the back of the wipes so that they are firmly against the window.
	Tork Xpressnap Fit® counter serviette dispenser	This product is similar to the product in the previous row. However, the front window is a small slot. Only one wipe can pass through at a time. The transparent section at the top allows the user to see if they should refill the wipes or not.
	Oxo PerfectPull™ Wipes Dispenser	The user pushes down on the lid and the lid will open (push latch mechanism). They can then pull the wipes out one by one. There is a weighted plate on top of the wipes to help dispense one wipe at a time (the wipes are folded). There is a silicone gasket on the lid to keep the wipes inside moist and a window on the bottom part so the user can see inside to the wipes. It also has "non-slip/skid feet". Finally, this product can be kept in a bag or left on a surface.
	Ubbi wipes dispenser	This product is similar to the one described in the row above. The differences are: the user lifts the lid up by using the finger notch. The seal is rubber instead of silicone.
	Safe Scan 2265 note counting machine	All the products shown here so far are for folded wipes (see figure X for the different types of folds). There are not many, or no, dispensers for unfolded wipes. Figure X shows a cash counting machine, a design that could be inspirational as it dispenses "unfolded sheets".

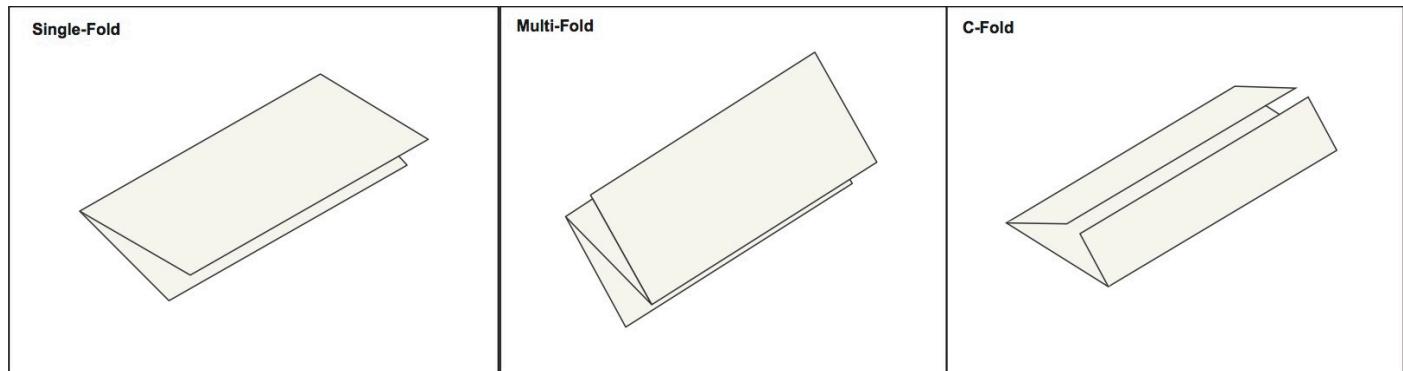


Figure 21. Examples of ways that wipes can be folded ("Folded towel", n.d.)

2.1.3 Insights

- Most, if not all, wipe dispensers in the market are designed for folded wipes.
- The RNase Away and FMD Away disinfectants are not alcohol-based. ABHR has an alcohol content of around 95% (Lyman, 2018), which makes it highly flammable. The new designs for the RNase Away and FMD Away dispenser do not have this design constraint.
- Silicone/rubber gaskets were used to keep wipes moist. This feature is unnecessary because the wipes for the new design are dry. Also, as mentioned in the previous chapter, the RNase Away disinfectant would not react well to it.

2.2 Stakeholder map

This section consists of a stakeholder map, which is helpful for knowing who is involved and/or will be affected by the outcome of this project.

Figure 22 shows a stakeholder map with lines illustrating the relationship between different stakeholders in the problem context. The core stakeholders have the most influence on the outcome of the design, the direct stakeholders are directly affected by the outcome, and the indirect stakeholders are those who may be interested in the outcome.

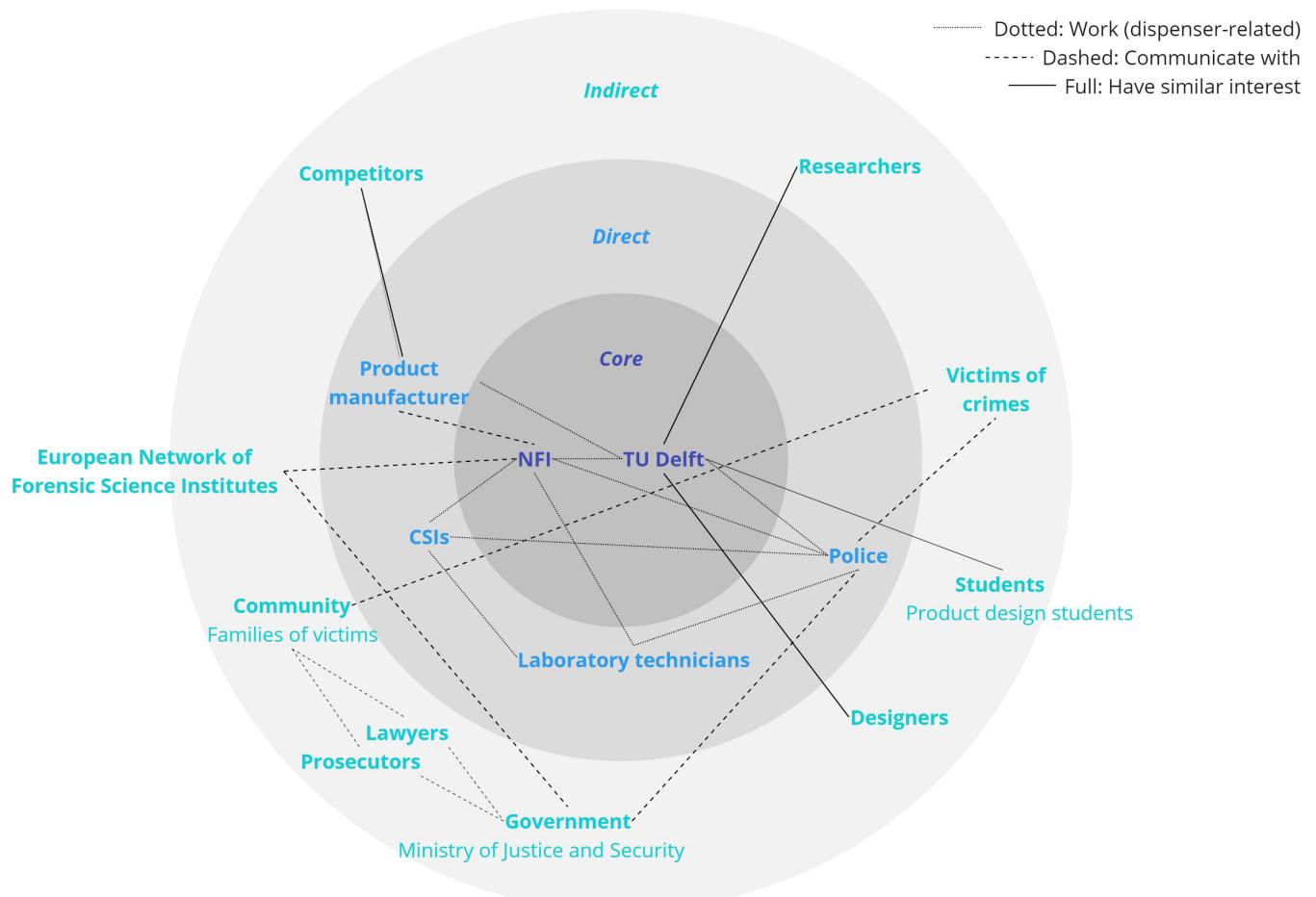


Figure 22. Stakeholder map

2.3 Primary research introduction

This subsection introduces the primary research conducted to establish solid understanding of the problem and context, to further the development of the project (such as design direction and constraints). Primary research is gathering data first-hand, meaning that data is collected directly by the researcher (which in this case would mean the author of this report); as opposed to secondary research which is collecting data from existing literature. The research outcome (i.e. insights and design implications) can be found in the next few subsections (2.4 – 2.7).

2.3.1 Research aim and questions

As stated earlier in 1.3.1 Problem definition, the details of the tool cleaning process for each user (i.e. CSI and laboratory technician) is not well-known because they differ from person to person. Thus, there is a need to gain these insights and have a firm understanding of the context in order to design for it. Three questions were formulated to guide the research:

1. Does the user have any impact on how the dispenser is used and the risk of trace transfer?

The users are CSIs, who work at crime scenes, and laboratory technicians, who work in laboratories, from two different institutions: the NFI and the police. This question will help to understand user behaviour (i.e. motivations and needs) in different environments, and how they differ or not.

2. How is the current user journey like?

There is no set procedure for how tools should be cleaned and thus the process varies from user to user. Thus, it is essential to create a clear image of the product journey which is an overview of all the steps a user takes before, during and after interacting with a product. This will also help find out where in the workflow the most issues occur, if any.

3. How does the current dispenser perform, in terms of ease of use and risk of trace transfer?

The answer to this will help create a baseline of how much contact happens with the current dispenser, amongst other things, to different. Furthermore, this will aid in the design process to see where the contact "hotspots" are and what product features could be improved or kept.

2.3.2 Research need

Before starting the ideation and concept creation phase, the insights required (answers to the research questions) are qualitative and context-specific. Hence, there was the need to carry out user tests (primary research) instead of merely utilising secondary research.

2.3.3 Approach

To answer the research questions, the following three methods were carried out:

1. A questionnaire
2. A user observation study with a short post-observation interview
3. Interviews

Figure 24 on the next page shows a visual overview of the research aims, approach and method. Further details can be found in Appendices E-G and in the later subsections (2.4 - 2.7).

In this subsection, the user observation will be explained first and then the questionnaire because the reason for requiring the latter is due to the former.

User observation study and questionnaire

The study had 3 parts to it:

1. **Tool cleaning with the current dispensers:** With green and blue UV powders (mixed with baby oil) applied on the participants' left and right gloved hands respectively, they were asked to clean 3 sets each of scissors, tweezers and rulers with 3 sets of dispensers respectively as they would normally do. They were also filmed during this.

These objects were determined via a questionnaire. In order to have consistent actions to test for in this observation study, a questionnaire was first sent out to find out the most common object cleaned during forensic work. Then the top three most used items were the ones used. Moreover, it is beneficial that the participants can clean something that is familiar to them so that they are able to work as they normally do during the study. In the least, the amount they might deviate from their usual work process would be reduced.

2. **Interview:** After the participants completed their task of cleaning the tools, a short 5-minute interview was conducted with them to find out how many years of work experience they had, their personal opinion of

the dispensers and their use process. They were also asked which was their dominant hand.

3. **Photographing the used dispensers:** Pictures were taken of the 3 sets of dispensers used per participant under UV light. For the wipe dispenser, pictures were taken of the: front, left, right, back, top and bottom (6 sides). For the disinfectant dispenser, pictures were taken of: the top, bottom, and 8 "sides" (by rotating the dispenser in 45° increments and taking a photo each angle).

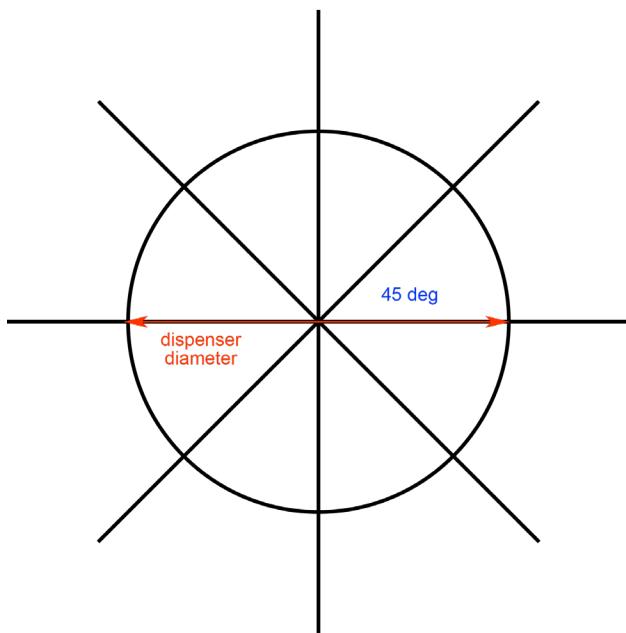


Figure 23. The template used to rotate the disinfectant dispenser

The participants were the laboratory technicians at the NFI because they are the only people familiar with using the latest dispenser, as everyone else (CSIs at the police) are still using the old dispenser until supply runs out, and they are readily available to volunteer for user tests.

Interviews

The limitation to having only NFI laboratory technicians participating in the user observation study is that the participants are not representative of the entire user group - CSIs are not included. Thus, as the final design is for CSIs as well, interviews were conducted with them to gain insights on their working environment, workflow and their opinions on dispensers and tool cleaning.

Participant data and privacy

All participants signed a consent form (found in Appendix H). A Data Management Plan (Appendix P) was created and TU Delft's Human Research Ethics Committee (HREC) approval (Appendix Q) was gained before commencing any user study.

RESEARCH AIM

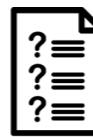
APPROACH

METHOD

PARTICIPANTS

1. To find out the **most common object cleaned**, in order to have consistent actions to test for in user observations

Questionnaire



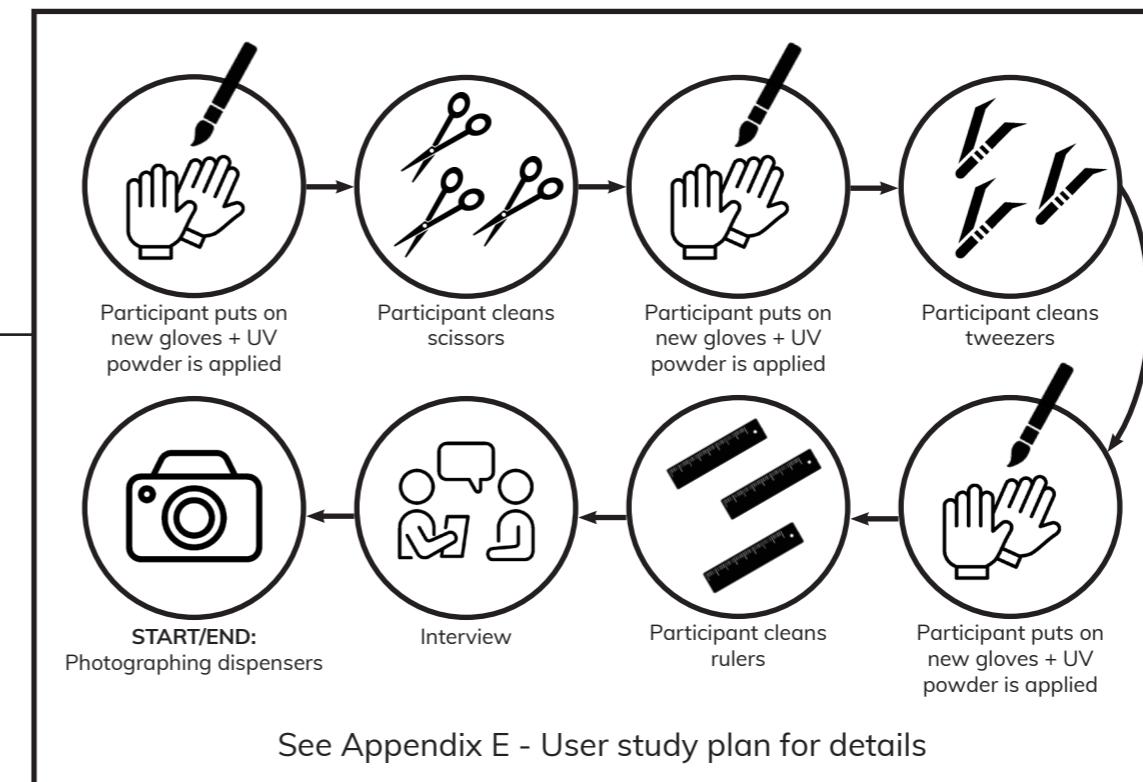
Microsoft Teams form (see Appendix E - User study plan)

16

2. To create a baseline of **how much contact happens with the current products**, to compare later with the final product.

This will give a definitive result as to how much the process is improved or different. Also, this will aid in the design process to see where the contact "hotspots" are.

User observations



7

3. To find out **where in the workflow the most issues occur**, if any, and thus help define the final user journey

Timeline/user journey



See 2.7.1 User journey map, page X

11

4. To determine **if the user affects** the amount of contact and the workflow

Interviews



Interview guide (see Appendix E - User study plan)

Topics include:

- Job description and experience
- Workplace
- Process/workflow
- Personal opinion and suggestions

4

Figure 24. This is a visual overview of the research aims, methods, approach and number of participants.

The black arrows show who/what contribute to the outcome at the end of the arrows.

2.4 Primary research 1: Questionnaire

This subsection presents the results of the questionnaire.

A questionnaire was designed on the Microsoft Teams platform and the link to it was sent out via e-mail to the police and within the NFI by the client. There were 16 respondents.

The pie chart (figure 25) shows the breakdown of the respondents' job titles. This tells us what the users do, which is an important factor to define the context. The respondents were: 1 forensic researcher, 1 DNA trace examiner, 3 CSIs and 11 laboratory technicians.

14 out of the 16 have used the newest dispensers at the NFI (figure 2, on page 3). Of these 14, 12 use them many times per day and the other 2, once a week on average. The two participants, that have not used those dispensers, use:

- Wet wipes, soaked with RNase Away, from a package.
- A container with a lid that has a roll of wet wipes in it. They pull out and tear off the required wipes.

Figure 26 shows the frequency for the most commonly cleaned tools and the top 3 are:

- Scissors
- Tweezers
- Ruler

2.4.1 Key insights

- Most of the respondents to this questionnaire work in the laboratory – only 3 are CSIs. It will be assumed that the most frequently cleaned tools are representative of the target user group, which is both laboratory technicians and CSIs.
- The two respondents that do not use the dispensers that the other respondents do also use wipes with disinfectant. It can be said that everyone essentially carries out similar actions when cleaning tools.
- The tools to be cleaned in the user observation study are scissors, tweezers and rulers.

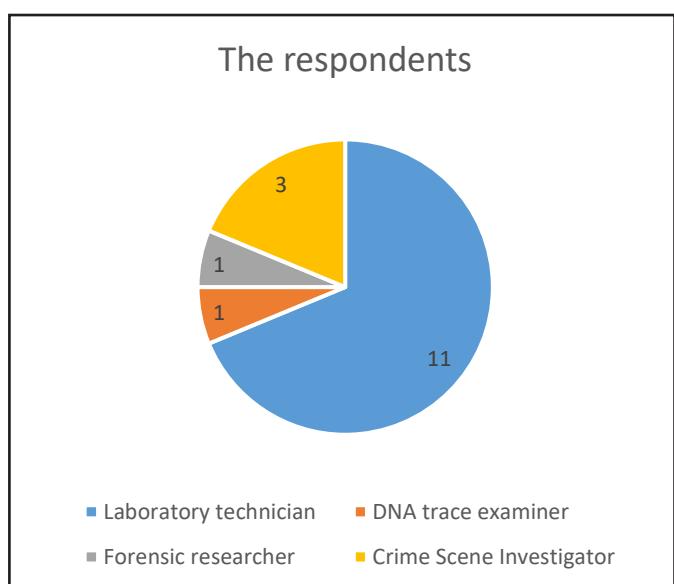


Figure 25. Pie chart

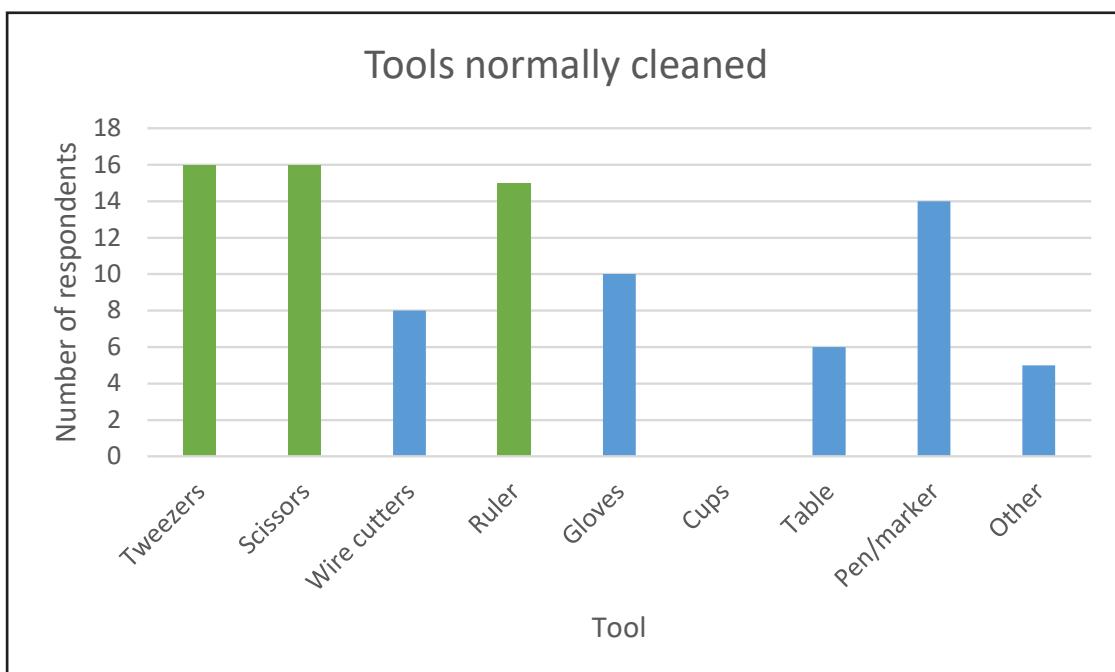


Figure 26. Tools normally cleaned

2.5 Primary research 2: User observation study

This subsection begins with a summary of the participants. Then it will go through the user observation study setup, post-study interviews with the participants, the method used to process the images taken, and the outcome.

2.5.1 Participants

All participants that took part in the primary research of this project have been pseudonymised for privacy reasons. Moreover, any post-observation interview transcripts will be summarised and be presented as insights in this report. On the advice of TU Delft's HREC, they will not be published as it is not necessary. Further details regarding data management and participant privacy can be found in Appendix P.

Table 3. The participants' years of work experience and dominant hand

Participant	Experience	Handedness
A	15.5 years	Right-handed
B	15 years	Right-handed
C	10 months	Right-handed
D	5 weeks	Right-handed
E	11 years	Right-handed
F	7 years	Left-handed
G	8 years	Right-handed

2.5.2 Test setup

The participants worked on a table where the dispensers and tools were set out (figure 27). There was a small (yellow) bin placed to their left so that they could dispose of the used wipes (figure 28). Opposite them, on the other side of the table, there was a camera on a tripod. This camera filmed the participants while they carried out their task. The participants' heads were not in the shot for privacy reasons.

There were two sessions of user observations. The first session had 3 participants and the second, 4. For the second session, photos of the dispensers were taken before and after the participants completed their attempts. whereas they were only taken after for the first session. It was discovered during the first session that the dispensers have random marks on their surface that glow under UV light. It was not possible to visually distinguish them from the areas that had UV powder. Therefore, there

was a need to have photos of clean dispensers to be used as a reference.

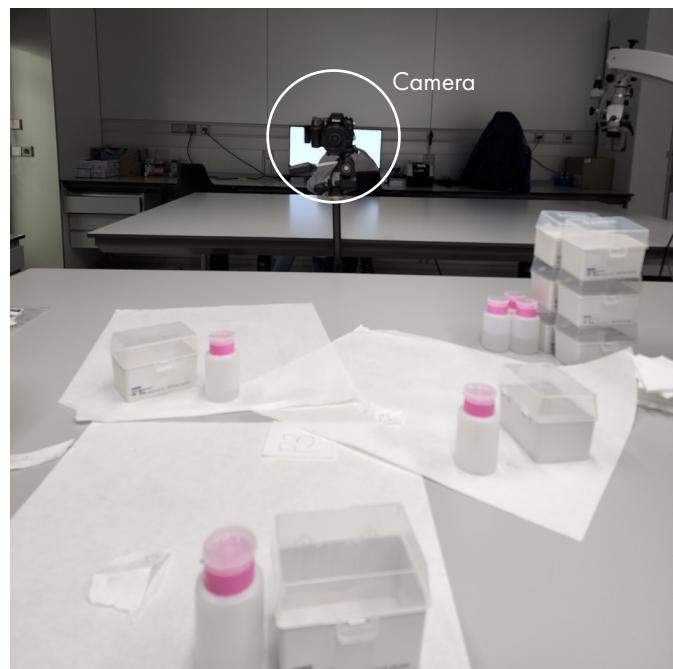


Figure 27. The setup from the participants' point of view. There are the 3 sets of dispensers which they used during the study, and some extra at the right side should they be required.



Figure 28. The setup on the left side of the participant

Table 4. Camera details and settings

Camera model	Lens model	Used for	ISO	Aperture	Shutter speed
Nikon D7100	Nikon AF-S 16-80mm f/2.8-4.0E ED VR	Taking photos of the dispensers under UV light	1250	f3.5	1/40
		Filming the participants cleaning	800	f9	1/100

Equipment/items used

The Crime-lite ML PRO, from "foster+freeman®", was used to illuminate the dispensers with UV light (wavelength: 350-380nm). Black paper was used as the backdrop. The template to guide the rotation of the disinfectant dispenser (see figure 23, page 19) was drawn on the black paper with highlighter.



Figure 29. The black backdrop, UV light and camera setup

Green UV powder from Allergenen Consultancy ("Bestel UV Poederset met Kwast (groen)", n.d.) for the participant's left hand and blue UV powder ("Bestel UV Poederset met Kwast (blauw)", n.d.) for their right hand, also from the same company, were used. They were mixed with Neutral baby oil ("Baby Huidolie Parfumvrij - 150ml", n.d.) so that they would stay on the participants' gloves.



Figure 30. Green UV powder, from Allergenen Consultancy



Figure 31. Blue UV powder, also from Allergenen Consultancy

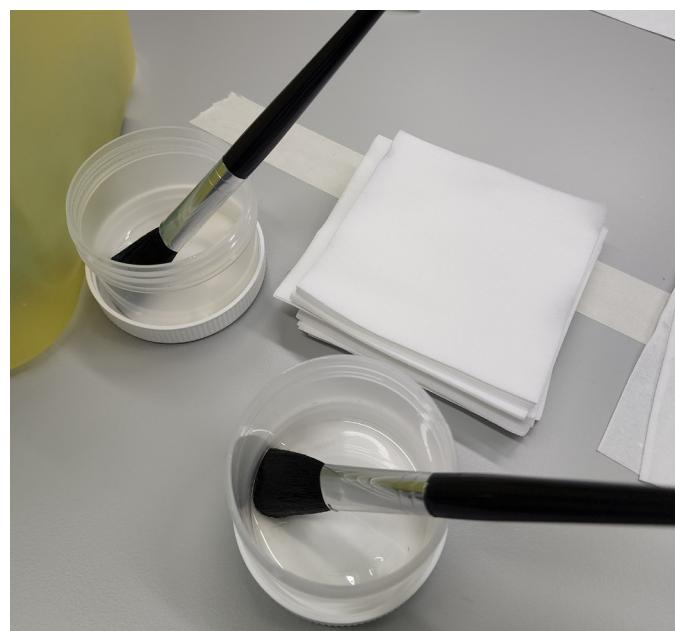


Figure 32. UV powders mixed with baby oil and the brushes used to apply them



Figure 33. The tools cleaned

2.5.3 Image processing method

Disinfectant dispenser

Step 1: Crop each image to 40% of the dispenser width with the crop area in the horizontal centre of the dispenser. 50% was initially used but it was found that there was still quite a lot repeated areas as the cropped images did not overlap each other enough (see figure 35), which would cause an area that is larger than the actual size to be counted in the results.

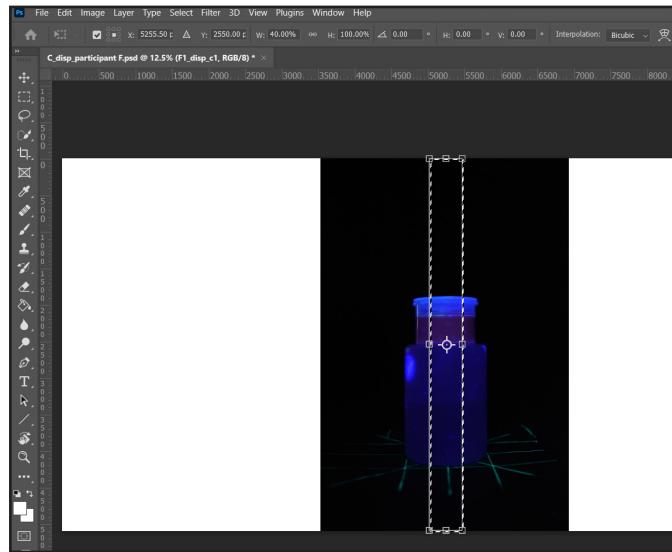


Figure 34. Crop area shown by the selection

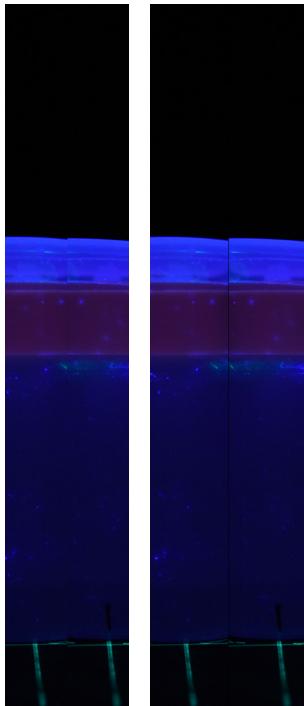


Figure 35. Left: 40% width and right: 50% width

Step 2: Place cropped images side-by-side. Use guidelines to help aid this process. There are many ways to create guidelines (e.g. View>New Guide Layout...).

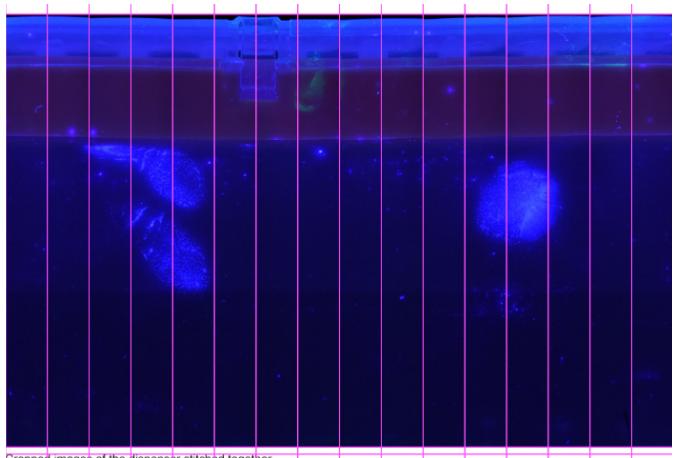


Figure 36. Guidelines in purple

Step 3: Repeat steps 1 and 2 for the reference (clean dispenser) images.

Step 4: Layer the reference images over their respective used dispenser images.

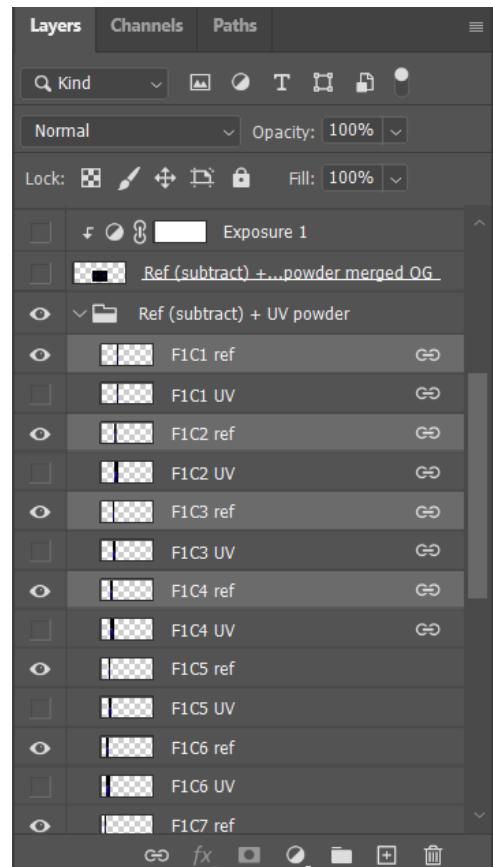


Figure 37. Layers

Step 5: Change the blend mode of the reference images from Normal to Subtract. This will produce the bottom left image(s), on each page of Appendix X. An Exposure adjustment layer was added to make the UV powder areas more visible (Windows>Adjustments>Exposure>Exposure: +3 to +7).

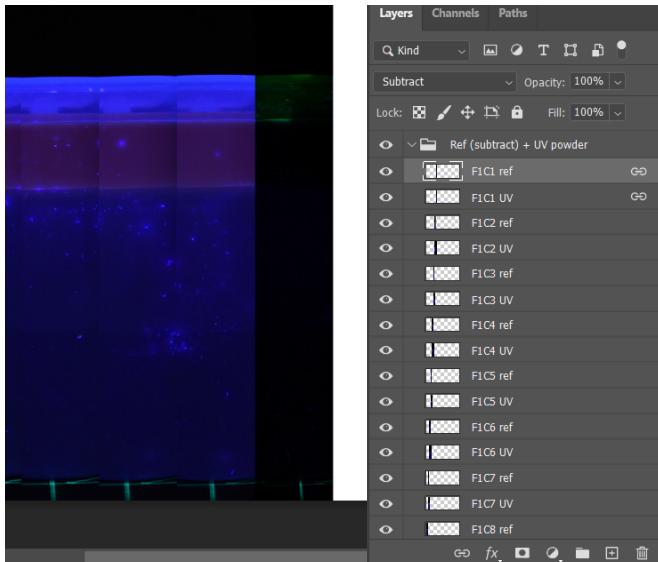


Figure 38. Subtract blend mode

Step 6: Duplicate the outcome in step 5 and merge the layers together. Layer style>Blending options>Blend if: Gray - This layer. Move the tab on the left (circled in red in figure 39) to make the areas with no UV powder transparent.

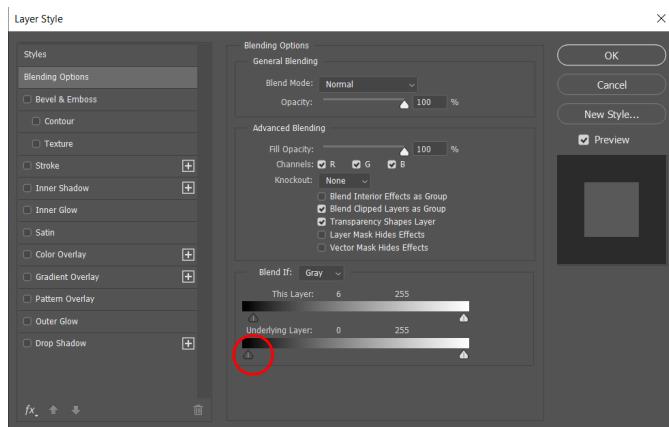


Figure 39. How to isolate areas with UV powder

Step 7: Apply a Threshold adjustment layer (Windows>Adjustments>Threshold>Threshold level: 128) on the layer from step 6. This step also allows the number of pixels in the UV powder areas to be obtained because it removes all the pixels in the areas without UV powder. The layer from step 6, although it has transparent areas, does not have any "blank" areas without pixels.

To find out the number of pixels of the UV powder areas is an extra step and can be achieved like so: Window>Histogram>Source: Selected layer. The

selected layer should be the layer that is the outcome of this step.

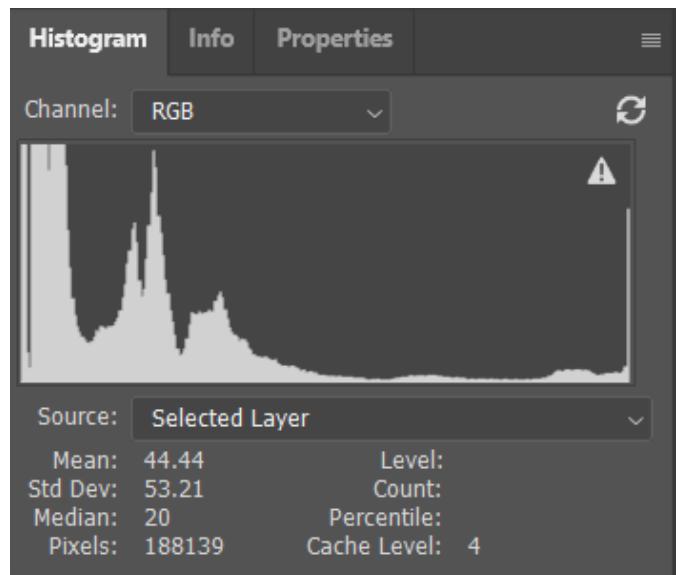


Figure 40. Histogram

Step 8: Apply a "Colour overlay" layer style on the isolated UV powder layer (from step 7). The blend mode stays as "normal". This makes the UV powder areas clearer to see.

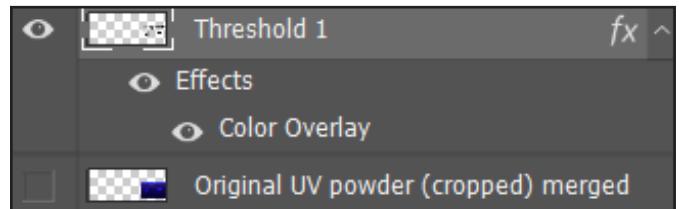


Figure 41. Colour overlay layer style

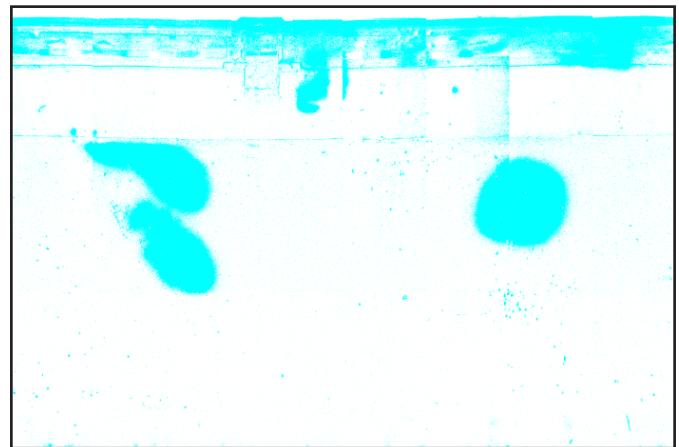


Figure 42. How the layer should look after changing layer style

Step 9: Place the "Colour overlay" layer over a copy of the layer from step 2 (cropped images stitched together) to achieve an image of a used disinfectant dispenser with highlighted UV powder areas (which would be the bottom right image on each disinfectant dispenser page of Appendix I).

Wipes dispenser

Step 1: Crop the background out of the dispenser images.

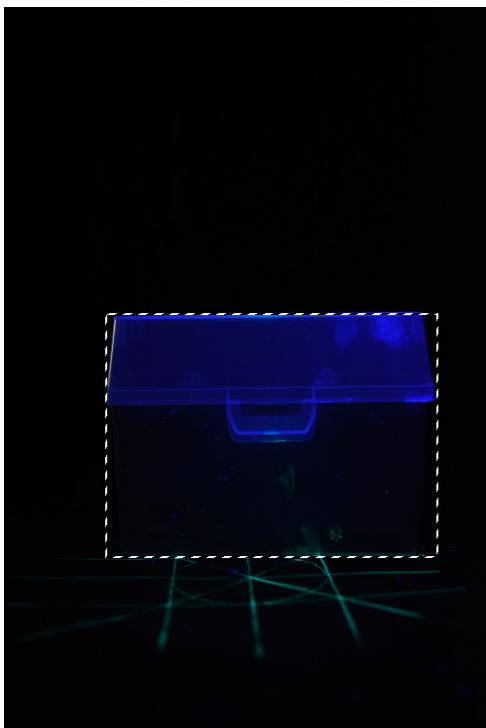


Figure 43. Remove the background

Step 2: Place the images together as shown in the diagram (figure 44).

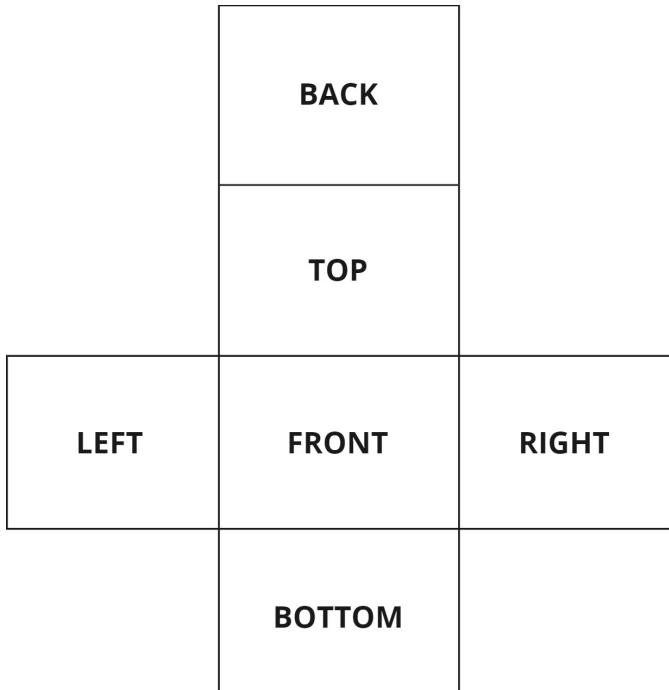


Figure 44. Template for arranging wipe dispenser images together

Step 3: Carry out steps 4-9 from the disinfectant dispenser steps for the wipes dispenser images.

Remarks

Only images from the second session were processed. The first session had no reference images. There is a perspective difference in the images from the first and second session, due to an unintended shift in camera position (figure 45), and thus, the reference images from the second session could not be used to process the first session's images.

Additionally, most of the images of the tops and bottoms of the disinfectant dispenser(s) were disregarded as not all were photographed each attempt due to a mistake in monitoring the images taken. The implication of this is that the total area of where the participants had contact with the dispensers cannot be accurately found. However, the results remain useful in that they provide information about the rest of the dispenser which will be further discussed in this report. Those that were photographed and had reference images were processed (see Appendix K for an overview of what was photographed).

Also, as can be seen in the figure 46 below, due to the position of the camera, the disinfectant dispensers were not photographed in the correct perspective and thus, not the whole top part is visible.

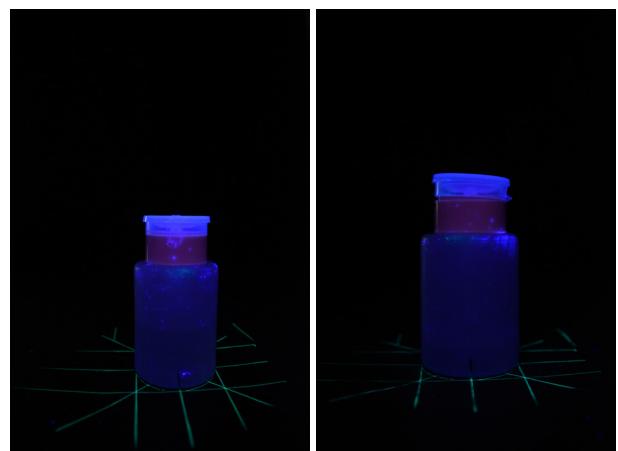


Figure 45. Photo from session 1 on the left and photo from session 2 on the right



Figure 46. Photo of the top of a disinfectant dispenser

2.5.4 Outcome

Processed images

For this subsection (Processed images), only participants D-G will be discussed because the images from participants A-C were not processed. It can be seen from the processed images that each participant has their own distinct way of opening the dispensers. A few examples have been selected to illustrate this. The rest of the processed images can be found in Appendix I. Figures 47-49 shows participant D's attempts and figures 51-53 shows participant F's, with the disinfectant dispenser.

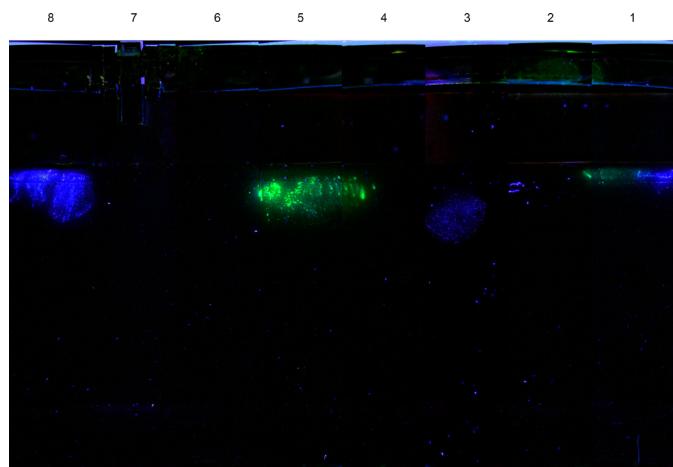


Figure 47. Participant D - attempt 1

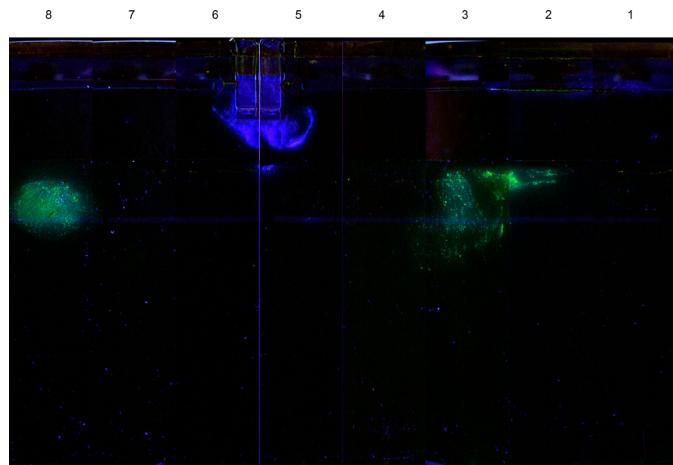


Figure 48. Participant D - attempt 2

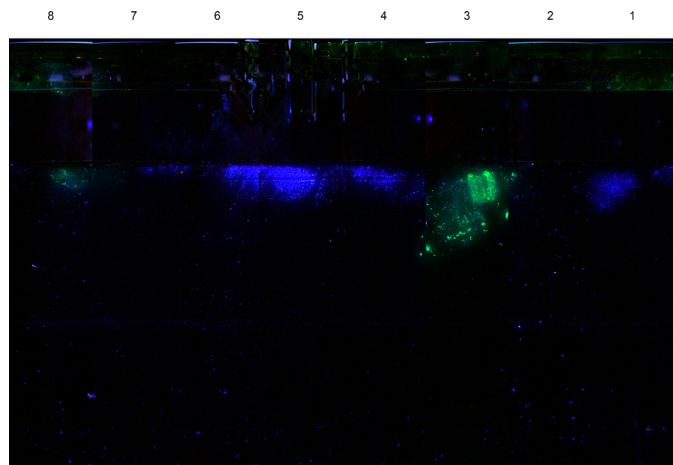


Figure 49. Participant D - attempt 3

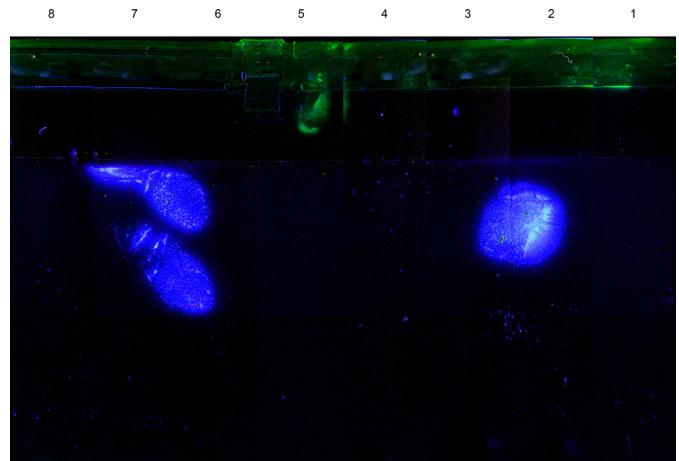


Figure 51. Participant F - attempt 1

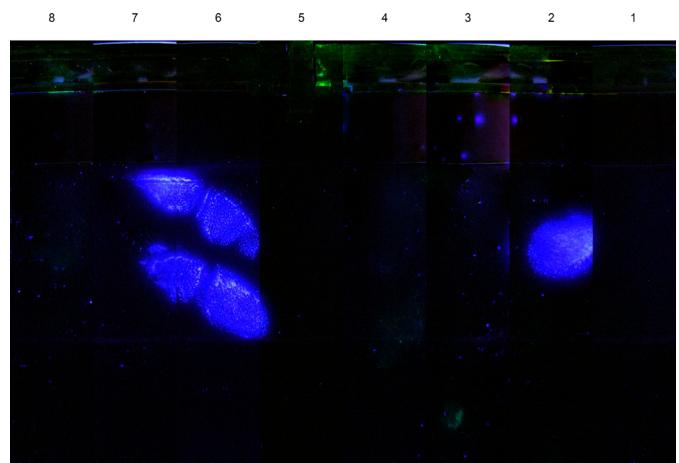


Figure 52. Participant F - attempt 2

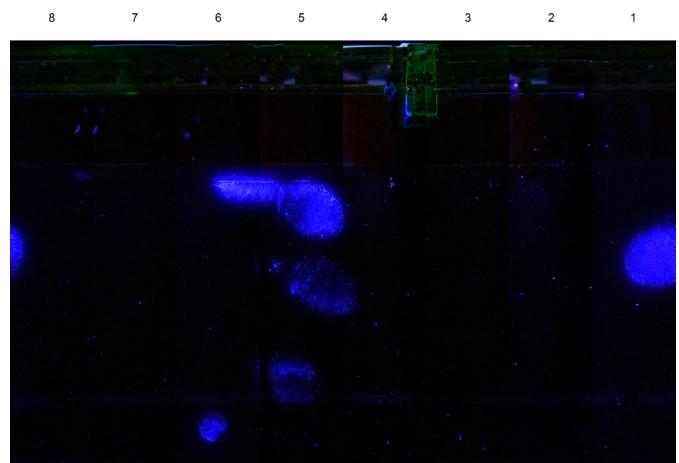


Figure 53. Participant F - attempt 3

Moreover, it can be seen from the blue and green colours in the figures 47-53 on this page that the participants used both their hands when handling the dispensers. From the user observation study, the participants would use both hands to open/close the dispensers 46.4% of the time.

In addition, the manufacturer of the product used as a wipes dispenser intended the lid to be opened with one hand (with the thumb and index finger) which most of the participants did not consistently do, if at all.

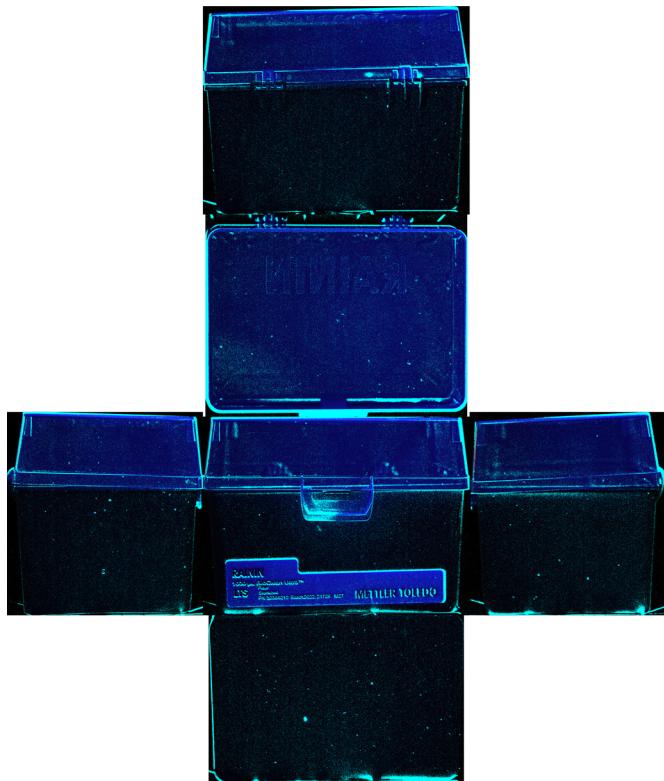


Figure 54. Participant E - attempt 1. They pinched the small tab on the lid with the thumb and index finger of their left hand to open it.

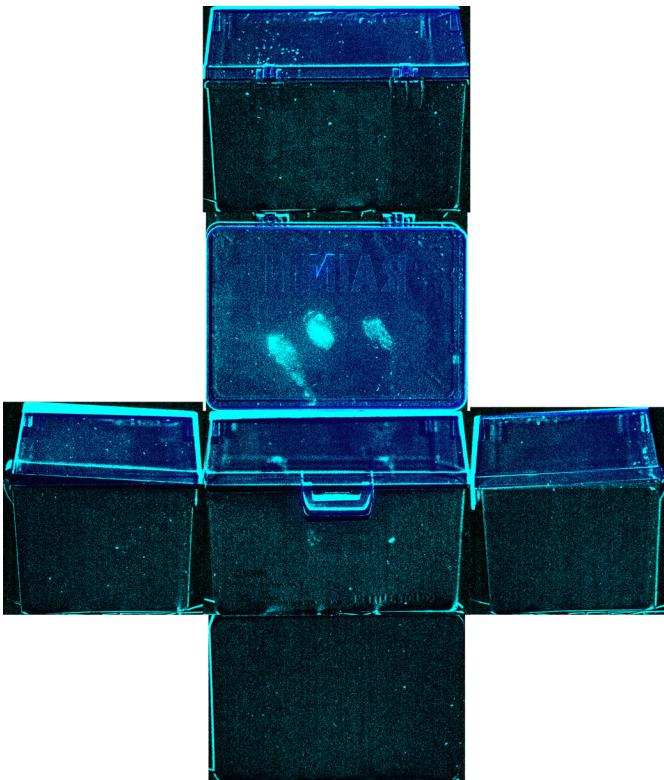


Figure 55. Participant E - attempt 2. They placed a thumb under the tab and 3 fingers on top of the lid to grip it to open.

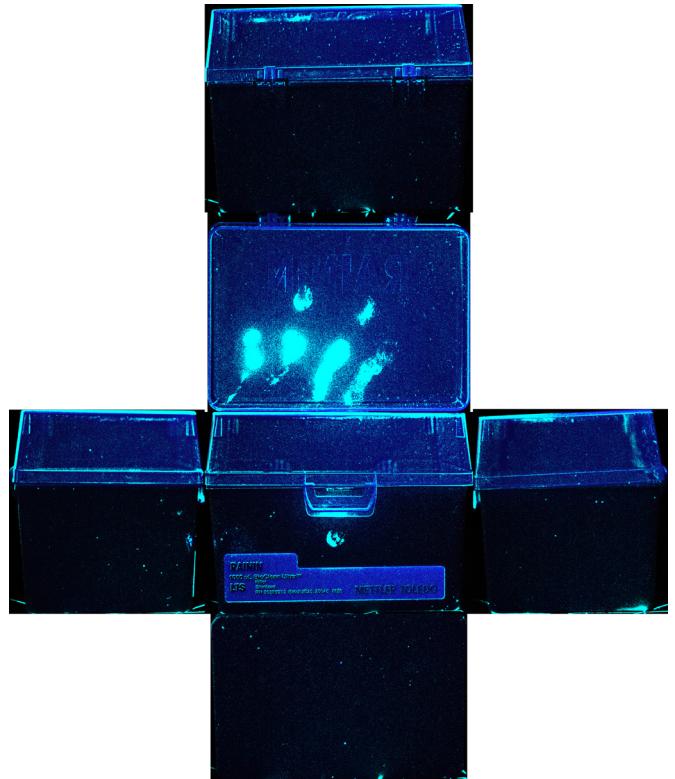


Figure 56. Participant F - attempt 1. They used their whole left hand to grip the lid to open it.

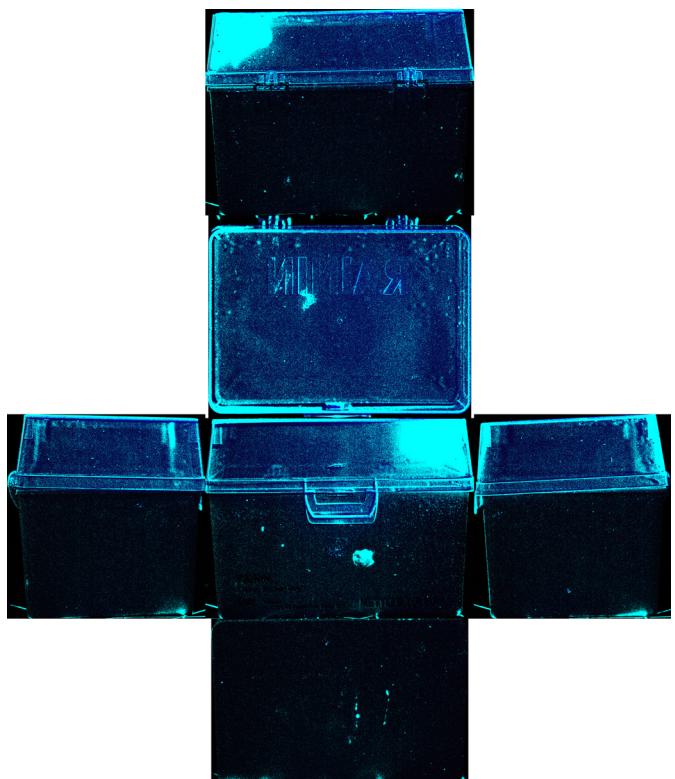


Figure 57. Participant G - attempt 3. They placed their thumb on the front right side of the lid and 3 fingers on the back (right hand) to grip it.

Tables 5 and 6 show the average values of the number of pixels that the reference images and isolated UV powder areas have. The reference images have different values and it may be due to the fact that the cropping and arranging of the original images were manually done. Since the reference images have different, the percentage of areas with UV powders were calculated as well.

Table 5. Disinfectant dispenser - average values

Participant	UV powder areas (pixels)	Reference image (pixels)	Percentage of UV powder areas (%)
D	45615.67	188162.33	24.24
E	118496.33	188149.67	62.98
F	82832.33	188139	44.03
G	135824	188025.33	72.23

Table 6. Wipes dispenser - average values

Participant	UV powder areas (pixels)	Reference image (pixels)	Percentage of UV powder areas (%)
D	344010	456517	75.36
E	404895.67	464016.67	87.26
F	349343.33	462286.67	75.55
G	332463.67	461322.33	72.07

There is a higher average value for the percentage of UV powder areas with the wipes dispenser. This may be because the participants had more contact with the dispensers. It may also be due to the fact that the lids of the wipes dispensers are not able to sit level on the bottom part, which would mean that more area is included unnecessarily as the Subtract blend mode method was used (Step 5 described in 2.5.3 Image processing method). In addition to that, as will be described in the next subsection (User observations), the participants accidentally tipped the wipes dispenser over frequently. This only happened once with the disinfectant dispensers.

However, the values for the disinfectant dispensers may not be very accurate as well because sometimes the participants did not close the lid properly.

User observations

The time taken for each participant to use the dispensers and to clean their tools were calculated. It was found that each participant takes approximately 1 minute on average for each attempt (cleaning 3 objects from start to finish) and this figure was not affected by whether they had any mishaps with the dispensers (i.e. the dispenser falling over or the dispenser moving backwards unintentionally when being opened). The details are in

Appendix L and Appendix M.

Table 7 on page X presents a summary of the participants' actions during the study and the difficulties they faced when carrying the actions. More details can be found in Appendix M.

Post-observation interviews

The participants were asked what their tool cleaning process is - what happens before, during and after cleaning their tools. Their responses can be found in Table 8 on page X.

When asked if there was any part of the tool cleaning process they disliked, there were 2 main things that they talked about. All 7 participants responded "taking the wipes out of the dispenser" and gave their reasons why. Here is a list of all their responses:

Taking wipes out of the dispenser

- It is difficult to take just one wipe out of the dispenser.
- It is time-consuming to just take one wipe.
- They think that using more wipes than necessary is expensive. They also think that using more than one wipe to clean their tools does not affect their cleaning process.
- They do not always have clean gloves so if they take a few wipes, they will use the wipes and not put them back.

Dispensing disinfectant

- The disinfectant dispenser tends to splash disinfectant when the pump part is pushed down.
- They sometimes pump out too much disinfectant. However, it is nice that the wipes get wet enough and that they can get as much disinfectant as they want.

Other

- It is annoying that the wipes do not fit exactly in its dispenser.
- The wipes dispenser lid does not close easily sometimes. It falls off as well.
- Opening the dispenser is inconvenient.

Appendix N contains a table with more details about the post-observation study interviews.

Table 7. The participants' actions during the user observations

Actions	Description	Difficulties faced
Opening wipes dispenser	<ul style="list-style-type: none"> Used both hands to open – one hand to hold the bottom part and the other to pull open the lid Used both hands on the lid of the dispenser to open it Opened the lid with one hand 	<ul style="list-style-type: none"> The dispenser tipped backwards (but did not fall) The dispenser fell backwards and the participant tipped it upright again with the same hand used to open the lid/other hand/both hands The dispenser moved backwards, and the participant stopped it with their other hand (that they did not use for opening)
Opening disinfectant dispenser	<ul style="list-style-type: none"> Used both hands to open – one hand to hold the bottom part and other to pull open the lid (and sometimes without using their fingertips) Opened with one hand 	<ul style="list-style-type: none"> They rotated the dispenser until the right way was facing them They lifted the dispenser to reposition it They attempted to open the dispenser with one hand only but failed. They then used their other hand to hold the bottom part and open the dispenser. Used a hand to nudge the bottom part down (it lifted up) while opening the lid with the other hand
Taking a wipe	<ul style="list-style-type: none"> Used one hand only Took a wipe with one hand, passed it to their other hand and then back again Some wipes were partially vertical, instead of lying flat in the dispenser, and it seemed to make it easier for them to take a piece. 	<ul style="list-style-type: none"> They took some time/they struggled to take one wipe and would generally use multiple wipes. Here are some examples: <ul style="list-style-type: none"> They repeated the pinching motion multiple times to try and grab a wipe. They used both hands to separate a wipe from other pieces in the dispenser. They tried to separate "multiple" wipes but there was only one in their hand. They unintentionally took 2 wipes – there was a piece stuck to the bottom of the top wipe. They shook them to try to discard the bottom wipe but was unsuccessful, and so they put the wipes back down and tried again successfully. They accidentally moved the dispenser in the process.
Pumping disinfectant onto wipes	<ul style="list-style-type: none"> They used both hands to hold the wipe and pump the dispenser Used one hand to pump. They were holding a tool in their other hand sometimes. They generally pump 2-4 times. 	<ul style="list-style-type: none"> They started cleaning a tool but throws the wipe away halfway. They took a 2nd wipe and then pumps the disinfectant dispenser 7 times. They looked at the wipe after pumping disinfectant and then started using it. They looked at the wipe after pumping disinfectant and then pumped again. It seemed like some force was needed to push down on the dispenser pump.
Closing wipes dispenser	<ul style="list-style-type: none"> Closed the lid with one hand Used both hands – one hand to hold the bottom part and other to close the lid After closing the lid, they sometimes tapped/pressed the top of the lid with their hand, thumb or knuckle. 	The dispenser tilted backwards.
Closing disinfectant dispenser	<ul style="list-style-type: none"> Closed the lid with one hand Used both hands – one hand to hold the bottom part and other to close the lid After closing the lid, they sometimes tapped/pressed the top of the lid with their hand/fingers. 	<ul style="list-style-type: none"> Used only one hand at first to close the dispenser but it wobbled. They then used the other hand to hold it still and successfully close it. They had one hand on the lid and dispenser tilted and moved but did not close until after a few attempts. The dispenser tipped sideways, rotated and fell over. They caught it as it was rolling away and placed it upright again. They pressed down on the lid with some force.

Table 8. The participants' tool cleaning process, from the post-observation study interviews

Participant	Before	During	After
A	They take their tools from the drawers and place them on top of said drawers. Then, they clean the table with disinfectant.	The dispenser is always on top of the drawers which they drag from its original location by the wall to the side of the table. They never place the dispenser on the table. After cleaning their tools, they dry them with tissue papers but if they have more time, they leave it to air dry.	They clean the table again and the camera sometimes. They close the dispensers every time after use because there might be a lot of blood with their work and they do not want to contaminate the dispensers. They never clean the dispensers.
B	The dispensers are always in or on the drawers.	The chest of drawers is placed by the table. They leave the dispensers open the whole day.	They close the dispensers after work and place them in the drawers.
C	They place the chest of drawers by the table. The dispensers are on the drawers most of the time but not in every lab. Then, they lay out their tools/instruments on a piece of tissue paper.	The dispensers are always open during their investigation (work).	They always leave the dispensers on the table and never put them back themselves, not even when they leave the lab. They will close them when they leave the lab, but not always.
D	They get their tools from the "sluis" (a room adjacent to the lab where they get dressed and where equipment is stored). They clean the table. The dispensers are already in the laboratory.	They clean the tools and place them on a sheet of tissue paper (or paper) on the table. The dispensers stay on top of the chest of drawers. They do not clean the dispensers. The dispensers stay open the whole time they are working.	They close the dispensers when they leave the lab.
E	The dispensers are normally on the chest of drawers or sometimes in them.	They dry their tools with wipes so they do not get any disinfectant on the evidence. Clean tools go on a piece of tissue paper on the drawers.	They close the dispenser when they are finished with the item they are working on but not everytime.
F	They place all the tools on top of the chest of drawers.	They clean the tools with disinfectant and wipes. They then dry them. After that, they place the tools on a sheet of tissue paper.	They always close the disinfectant dispenser after use but not the wipes dispenser. They clean the dispensers depending on the case that they are working on. If there is a lot of blood and if they think they will get a lot of DNA from the evidence on their gloves, then they will clean the dispensers.
G	Most of the time, they find the dispensers are already on top of the chest of drawers.	They clean the tools and while letting them dry, they open the evidence bag or work on the computer. If the tools are still wet, they take a dry piece of tissue paper and place them on it. If there is a lot of work to be done on one evidence item (e.g. a lot of blood), they place the tools and dispensers on the table, instead of the drawers, because it is more convenient for them.	-

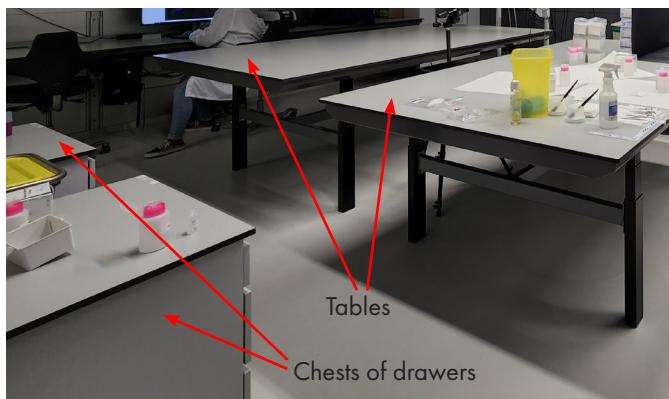


Figure 58. The chest(s) of drawers and the table(s) mentioned by the participants

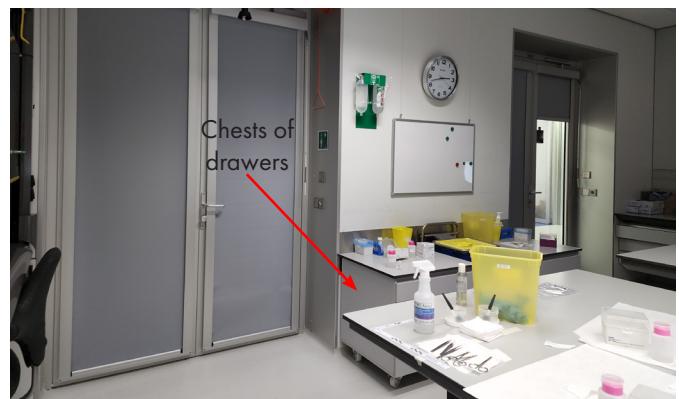


Figure 59. Another angle of the laboratory

2.5.5 Key insights

User observation insights

- Sometimes they have to use both hands to open/close the dispenser because it is unstable.
- They press the lid of the dispenser again after closing to ensure that it is closed.
- The wipes dispenser tips backwards or falls over when being opened.
- A participant threw away a wipe after starting to clean a tool when they realised it was not wet enough. They had to take another wipe.

Post-observation interview insights

- They move the chest of drawers, where they occasionally store the dispensers, from their original position by the wall in the laboratory to the side of the table (figure 58 on the previous page). The dispensers are almost always on the chest of drawers.
- Most do not clean the dispensers but one participant said that they will clean them depending on the case they are working on (i.e. there is a lot of blood involved).
- Some close the dispensers after use, especially if the case has a lot of blood, but most leave them open the whole day and only close it when they are finished.
- 100% of the laboratory technicians at the NFI say that taking the wipes out of the dispenser is inconvenient because it is difficult to take one wipe easily.
- The disinfectant splashes everywhere when the pump is pressed down.
- Sometimes they pump too much disinfectant.
- The lid of the dispenser does not close easily sometimes, or it falls off.

Insights from processed images

- All participants have their own distinct way of opening the dispensers and this can be visually identified through the processed images. One similarity is that they would generally use one hand on the lids of the dispensers to open them and the other to hold the bottom part of the dispensers.
- Most of the participants did not open the wipes dispenser the way its manufacturer intended for it to be opened. This is something to note when creating a new design.

2.6 Primary research 3: Interviews

This subsection will present the insights from interviews with the police.

2.6.1 Interview outcome summary

Four interviews were conducted with the police, 3 of whom are CSIs and 1 works in the laboratory. All were interviewed online, via Zoom meetings, except for one CSI who was interviewed in person at their place of work.

Details of the interview procedure and the interviews can be found in Appendices G and N respectively. The transcripts will not be made available, at the recommendation of TU Delft's Human Research Ethics Committee (HREC), because the participants may be identifiable through it even if they were made anonymous.

Participants

Figure 60 below shows an overview of the participants in the interviews. The diagram starts with their job titles, the number of participants and their years of work experience, and ends with their work locations. The participants who work at crime scenes are referred to as CSIs and the participant who works in the laboratory is referred to as laboratory technician, in keeping with the rest of this report.

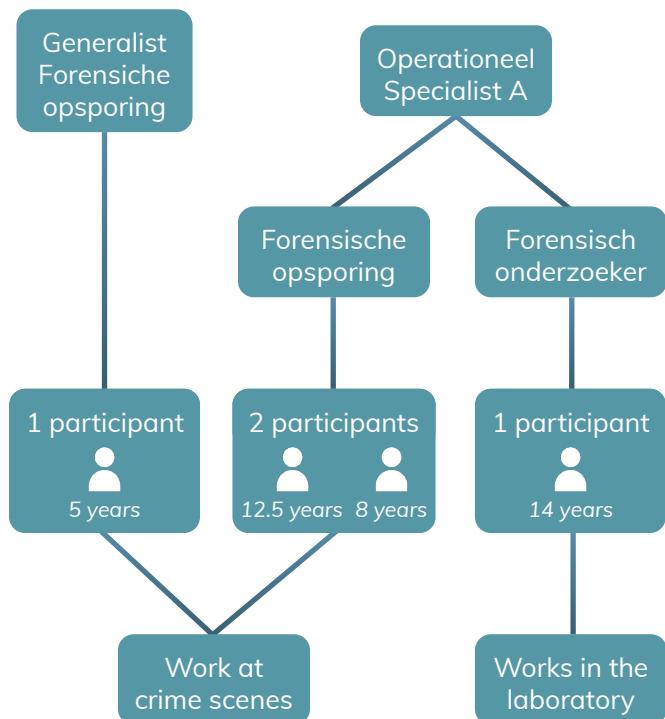


Figure 60. Participant overview showing their job titles, years of work experience (in *italics*) and work locations

Dispenser/item used to clean tools

The participants do not use the same items to clean their tools. Table 9 below shows the dispenser/cleaning item the CSIs use and their opinion of them.

Table 9. Dispenser/item used for tool cleaning and relevant comments from the participants regarding them

Dispenser/item used to clean tools	Participants' comments
A cardboard box of dry wipes and a 0.5L sprayer (similar to a household cleaner spray) of RNase Away	The use process is not quick and easy because it is a two-step process (first, spray the disinfectant and then wipe). They might also spray too much disinfectant. The sprayer is disposed of when empty.
A cylindrical container of wet wipes (figure 63)	It is difficult to open the lid of the dispenser with gloves on. They also have to hold the dispenser, else they are unable to pull out the wipes.
A 1L bottle of RNase Away (see figure 64) and a roll of tissue paper	The use process is "not really practical". It is stored in their vehicle which is not a sterile place and so when they pick up the bottle, they think that their gloves get dirty. However, they do not clean the bottle before use.
Individually packaged alcohol wipes (figure 67)	Easy and good to use.

The laboratory technician uses a cylindrical container of wet (RNase Away) wipes (see figure 61). They think that it is easy to use because they just have to pull out the already moistened wipes. If this dispenser stayed available, they would continue to use it. However, they must refill their dispensers and there is a risk of contamination. Thus, the dispensers have to be cleaned thoroughly before refill. In addition, the dispenser is made of plastic and the lid breaks over time (generally after one year of use).

Storage

CSIs: Their tools/equipment are always kept in small, labelled cases (figures 69-71) in their vehicle which they share with their colleagues. However, specialist equipment, such as expensive lights, are kept in storage at the police station. They take the required cases to the crime scenes as necessary and normally bring one disinfectant dispenser with them. They do not know who might have used the car, and the tools, before them. Furthermore, how the dispensers are stored varies vehicle to vehicle.

Laboratory technician: They keep the disinfectant dispenser in a cabinet in the laboratory. They take it out during work and put it back after. The laboratory is shared between the same 3-4 colleagues.

Tool cleaning process

Laboratory technician: Firstly, they will clean the table. The dispenser is cleaned and put on the table. Then they will clean every tool they plan on using and after each piece of evidence they process, they will clean them again. The dispenser is cleaned before it is put back into the cabinet.

CSIs: They begin by setting up their workspace at the crime scene though how this is done depends on the crime scene itself. It can be indoors or outdoors. If it is raining, they will set up tents. The CSIs may also have to work kneeling on the ground.

"Crime scene investigation is sometimes improvising with weather, with space you have; you have to be flexible about where you're working." - Generalist forensische opsporing

Generally, they first create a "clean area" by laying down a sterile sheet (figures 72 and 73) where they then place their cases containing all the required equipment. This can be at the entrance to a crime scene. They will put on their PPE (a suit, gloves, a face mask and a hairnet) while standing on the sheet, which can be 150x180cm or 45x75cm in size. After that, they will clean their tools. They do not clean all their tools before use (camera, for example).

"We do not work as surgeons. We are not sterile but we are very keen on how do we avoid contamination from DNA." - Operationeel Specialist A

Ideal dispenser design

Here is a list of the participants' responses when asked what their ideal disinfectant and wipes dispenser design would be:

- Easy to clean
 - ◊ Suggestion 1: It would be made of plastic, instead of cardboard. The chance of transferring DNA onto it might be smaller as well
 - ◊ Suggestion 2: Has as few edges as possible
- Contact-free or does not require much contact to use
 - ◊ Suggestion 1: An automatic dispenser (with a motion sensor), where there is no need to touch it operate

- ◊ Suggestion 2: Useful to have a dispenser that is placed down on a surface and does not require picking up to use
- Easy to take and to put away
- A smaller size disinfectant dispenser because they think that it would reduce the number of colleagues using expired disinfectant. They think that it would be easier to manage the contamination risk as well with a smaller size.

2.6.2 Key insights

- There is a variety of disinfectant and wipes dispenser used amongst the 4 interviewees. They all come with their own negatives:
 - ◊ Difficult to open
 - ◊ Risk of contamination when refilling disinfectant
 - ◊ Spray too much disinfectant
 - ◊ Not durable enough
 - ◊ Waste from individually packaged wipes after use
- CSIs store their dispensers in their vehicles, which they share with their colleagues. How they are stored varies vehicle to vehicle. The laboratory technician stores theirs in a cabinet in the laboratory.
- The CSIs' workspace at crime scenes is variable. They may have to work:
 - ◊ On the ground, kneeling
 - ◊ Indoors/outdoors
 - ◊ In bad weather
- The interviewees' ideal dispenser would have the following features:
 - ◊ Easy to clean
 - ◊ Easy to take and to put away
 - ◊ Not require contact to use, or as little contact as possible
 - ◊ Manages the expiry date of the disinfectant



Figure 61. Cylindrical container of wet (RNase Away) wipes



Figure 62. The top of the container in figure 61

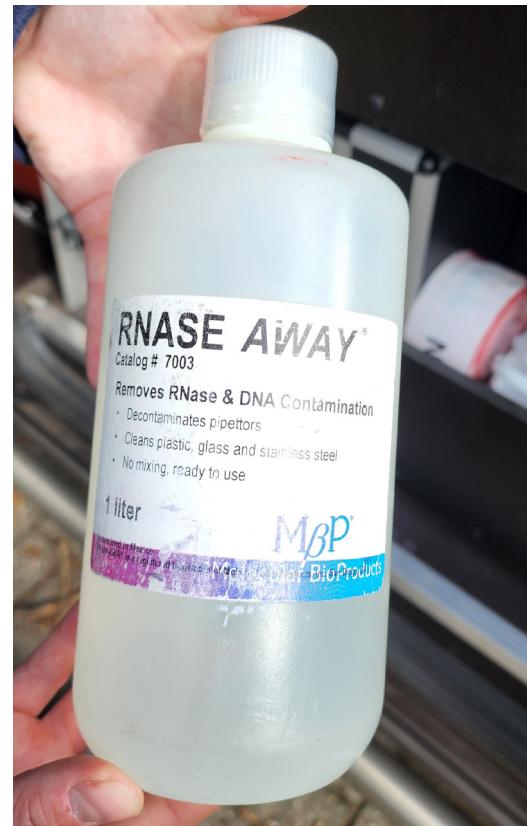


Figure 64. 1L bottle of RNase Away



Figure 63. Container of alcohol wet wipes



Figure 65. The label on the back of the bottle in figure 64. It can be seen that the expiry date is March 2020 (circled in red).



Figure 66. The mouth of the bottle in figures 64 and 65



Figure 67. Alcohol wipes

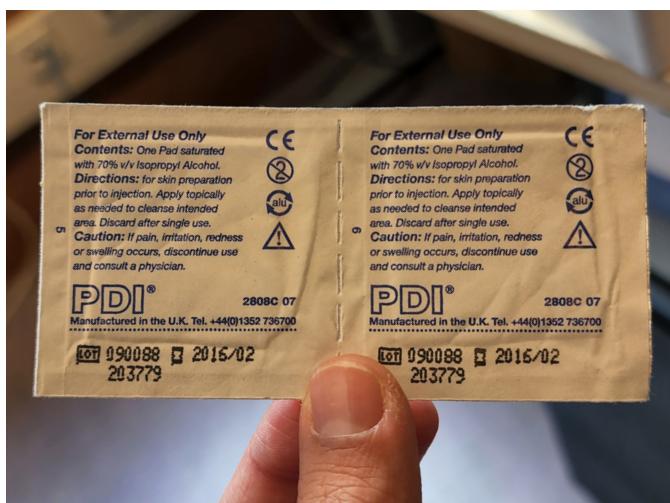


Figure 68. Back of figure 67



Figure 69. In the car boot of a CSI's vehicle



Figure 70. The cases can be unlatched from their rack and pulled out



Figure 71. Inside a CSI's vehicle. The disinfectant bottle in figure 64 is circled in red.



Figure 72. Large size sterile sheet (150x180cm)

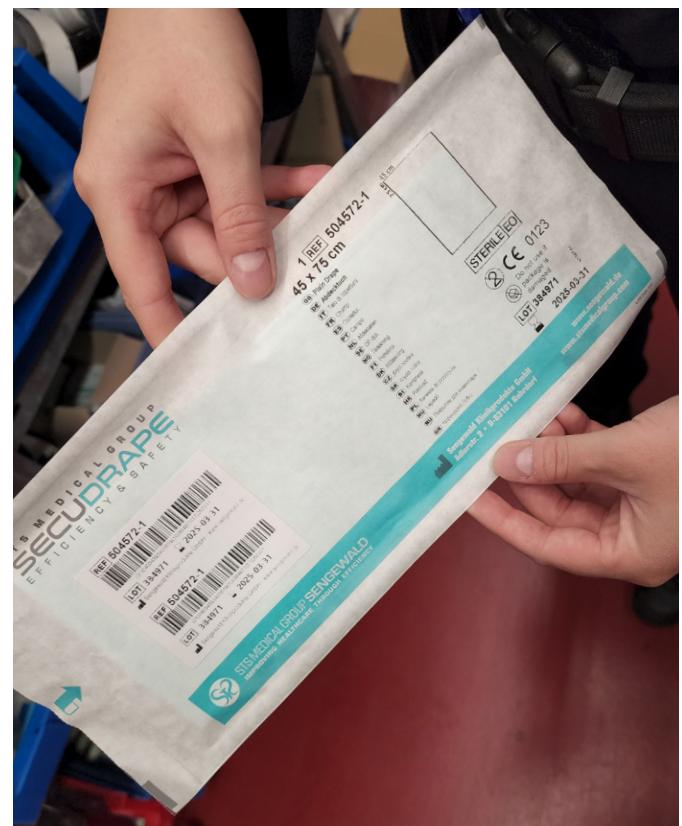


Figure 73. Small size sterile sheet (45x75cm)

2.7 Research synthesis

This subsection presents the design opportunities that arose from all the research conducted so far. It will also present a user journey map as a result of synthesising the primary research conducted.

2.7.1 Design opportunities

Suggestions from the participants

- The process of dispensing a wipe and moistening it with disinfectant should be reduced to only 1 step to execute.
- It should be easy to clean.
- It could be made out of plastic to make it easier to clean, as opposed to cardboard for example.
- It should contain as few edges as possible, for the same reason as the point above.
- The use process could be contact-free.
- The size of the disinfectant dispenser should not be too big (i.e. 1L) because of the expiration date of the disinfectant and risk of contamination.

From issues identified in the primary research

Table 10 below lists the issues identified and the relevant design opportunity they provide.

Table 10

Issue	Design opportunity
Pumping too much/little disinfectant	The new design dispenses the ideal amount after one pump
The dispenser falls over when opening or closing it	Heavier/larger base
Using 2 hands to open/close the dispenser	One-handed operation
Pressing the lid of the dispenser again after closing to ensure that it is closed	The new design gives the user feedback to know that the dispenser is closed
Using the whole hand to open/close the dispenser	One-finger operation, to reduce the amount of contact as much as possible, if not contact-free

Points to consider

During the Develop and Deliver phase, there are some points to consider with the new design:

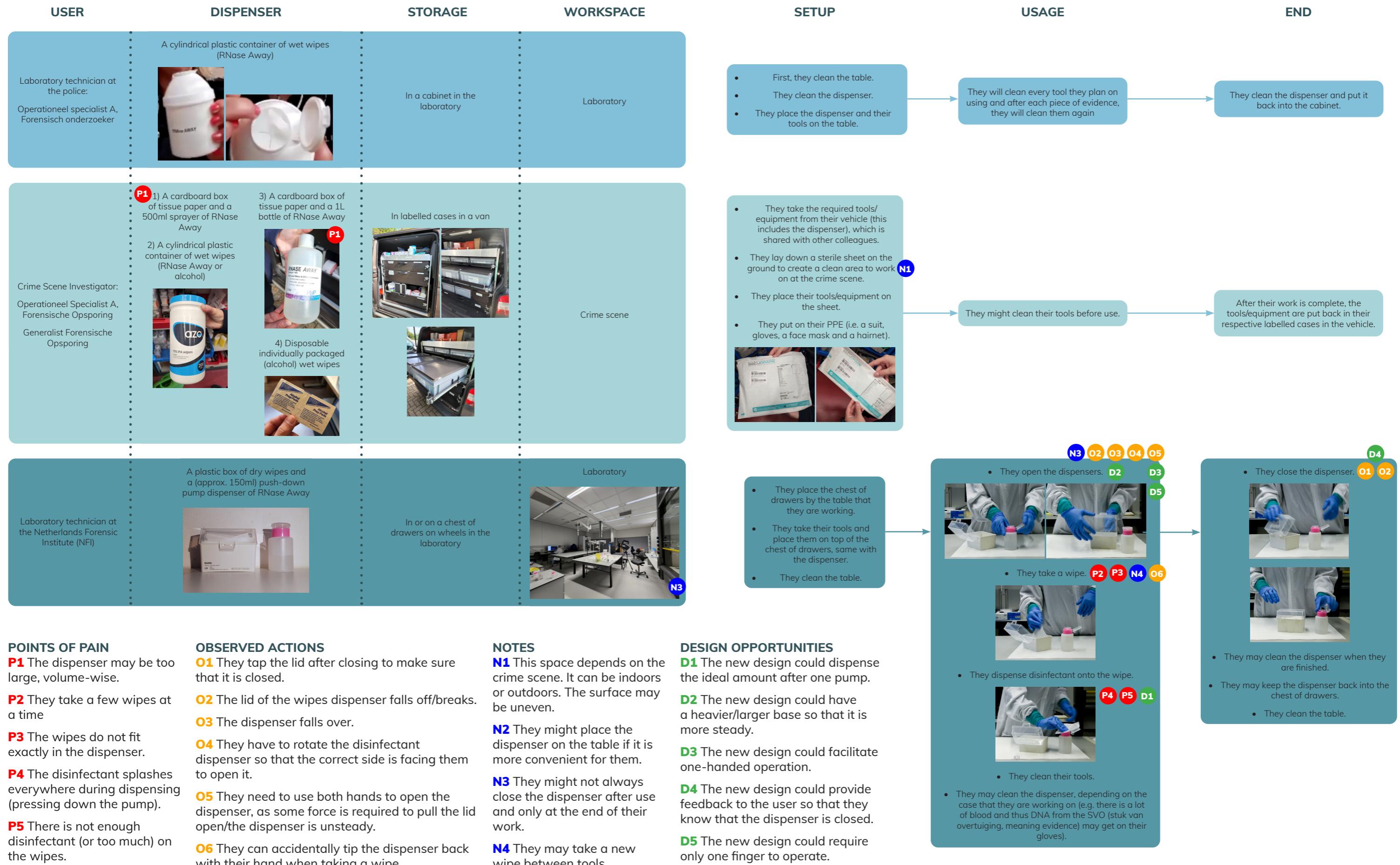
- The disinfectant should not come in contact with aluminium, soft metal or gaskets and seals.
- The disinfectant should be labelled according to Regulation (EC) No 1272/2008. The new design can follow the manufacturer's labelling (figure 6, page 9). On the other hand, the current dispensers at the NFI are not labelled (figure 15, page 11).
- Care should be taken with the product-user interaction in regards to the unintended ways that the user may use the new design.

2.7.2 User journey map

The user journey map is on pages 40 and 41.

USER JOURNEY MAP: DISINFECTANT/WIPES DISPENSER AND DIFFERENT USERS

This map gives a visual overview of the current experience of using a disinfectant/wipes dispenser to clean tools, based off of interviews and user observations with the relevant users. The map is divided into 2 parts: 1) the context to explain who the users are, the dispenser(s) they use and how they are stored, and 2) the user journey from setup to end. Points of pain (derived from user interviews), relevant observed actions (from the user observation study), notes (for extra explanation) and design opportunities are shown as well.



3. DESIGN DIRECTION

3.1 Design vision and drivers

This subsection presents the design vision and drivers along with the list of requirements that will be used for concept selection. Throughout the Define and Develop phase of the design process, this list was constantly amended and updated as necessary.

3.1.1 Design vision

The initial problem statement (in 1.3.3 The assignment, page 7) was "Design and validate a device for dispensing and moistening (with disinfectant) wipes.". A new problem statement, or design vision, was formulated to present the assignment more accurately:

"Create a new dispenser(s) for disinfectant and dry wipes that is contamination-safe with a streamlined use process, to be used by both laboratory technicians and CSIs from the police/the NFI in the laboratory or at crime scenes."

The word contamination-safe is used to mean low level of contact, from the user, with the dispenser to operate.

3.1.2 Design drivers

Design drivers are words or phrases that describe the motivation(s), such as solving a problem or improving something, behind a design. They help during the ideation phase to focus on what the design should be and for quickly identifying whether an idea is suitable or not. From the analysis in the previous chapters, the following list of design drivers was created:

- **portable**, because CSIs have to carry the dispensers from their vehicle to the crime scene and vice versa
- **compact**, so that the new design fits within their storage cases
- **no electrical outlet required to power the design during use**, so that it is readily available to use (not much preparation needed)
- **stable**, so that the new design does not tip over during use
- **as little contact as possible**, to reduce the risk of contamination during use

3.2 List of requirements

This subsection presents the list of requirements that will be used for concept selection. Throughout the Define and Develop phase of the design process, this list was constantly amended and updated as necessary.

The list of requirements in this section of the report are based off of requirements from the client (NFI) and insights from the user studies (i.e. interviews and user observations). A more detailed breakdown of the sources behind each requirement can be found in Appendix R.

This list was used to help in making decisions during the ideation and concept design stages. Any ideas and concepts that do not meet the criteria will be discarded.

The demands, which are what the new design "must have", are indicated with a D, in blue. The wishes, which are "nice to have", are denoted similarly but with a W instead and in the colour pink.

They are categorised according to the different criteria the new design should/could fulfill.

Dimensions

D1 The product should not exceed 30cm in height. As for the other dimensions, the aim should be to make the product as compact as possible.

D2 The product should be able to fit into the cases that CSIs use for storage in their vehicle and the cases used at the NFI.

D3 The volume of disinfectant that the product can contain, if refillable, should be <250ml to ensure that the disinfectant is used up before the expiry date. In the case of disinfectant contamination or the case that the disinfectant's efficacy reduces from, for example, being stored in the uncertain conditions like in the CSIs' vehicles, a smaller volume can be disposed of with less corresponding waste produced.

Weight

D4 The product should not be more than 1kg, without the disinfectant.

D5 The product must be portable.

Material

D6 The material(s) used should be easy to clean with wipes/tissue paper and disinfectant (i.e. smooth finish).

D7 The product should be able to withstand being cleaned with disinfectant.

D8 The product should be suited for cleaning with UV light.

Quantity

D9 The total number of units to be produced is >1000. The NFI would require ~20 and the police would require 1000+ (this figure is based on FreeRef, a measuring equipment mounted on cameras, and each police unit should have one).

Aesthetic/Appearance

W1 The product should have the logo of the NFI and the TU Delft displayed on it.

W2 The product should have a section that is transparent so that the level of disinfectant inside can be easily seen for refills.

D10 There should be an area on the product to display information about the disinfectant and wipes (such as a code, number and/or expiry date).

W3 The product should have as few edges as possible to facilitate easier cleaning.

Environment

D11 The product should be suitable for indoors and outdoors use. This would include considerations for varying ambient temperatures and uneven surfaces.

D12 The product should be suitable for use in both the laboratory and at crime scenes.

(continued next page)

Product lifespan

W4 The product lifespan should be >1 year if it is refillable. There is preference for the product to be refillable to keep total overall costs down as disinfectant and wipes will be used frequently.

D13 If the product is not refillable, then the lifespan should be one use only.

D14 The product should be durable and thus parts should work optimally for the entirety of its lifespan.

Target product cost

D15 The product should cost 0 – 20 EUR. If the product lifespan is longer, then the cost can skew towards the higher end of the range and vice versa.

Performance

D16 The product must dispense either the RNase Away or FMD Away disinfectant.

D17 The product must dispense the Contec AmplitudeTM DeltaTM 10cm x 10cm wipes.

D18 The product should perform better than its predecessor (i.e. more convenient and quicker for the user to use). This could be tested by carrying out the same user observation study that was conducted with the predecessor.

W5 The product should dispense the equivalent of 3 pumps of disinfectant (with the current dispenser) each time.

Usability

W6 It should be a one-step process to use the product, meaning that the user only must carry out one action to dispense disinfectant and wet the wipe.

D19 Usage should be contact-free from the user or involve as little contact as possible (e.g. one-handed operation).

W7 There should be feedback to the user after closing the product so that they know that it is closed.

D20 The use cues of the product should be easily understandable.

D21 The product should be easy to refill, if refillable.

4. IDEATION

4.1 The process

This subsection details the approach used to generate and process ideas, and transform them into concepts.

The first step of the Develop phase was an ideation session with participants, which consisted of: an introduction, brainstorming a concept, brainstorming with prompts, voting for their favourite idea and session feedback. The next subsection (4.1.1 Ideation session) goes into the details.

Figure 74 on the right shows what proceeded after the ideation session. The figures in the lightbulbs are the number of ideas left as an outcome of each stage.

In the clustering stage, similar ideas were discarded so the total number ideas went from 80+ to 70+. In the third stage (discarding, combining and refining ideas), ideas that did not fit the design drivers were first discarded. Then, a method called SCAMPER was used. SCAMPER stands for substitute, combine, adapt, modify, put to another use, eliminate and rearrange (Boeijen et al., 2020). These “actions” were applied to the remaining ideas to create an overall of 7 categories, or clusters, of ideas (described in subsection 4.1.1). In addition, these ideas were included in the morphological chart (figure 77).

A C-box, which can be found in Appendix T, was used to evaluate these ideas (Boeijen et al., 2020). A C-box has 2 axes and the parameters selected were feasibility (x-axis) and desirability (y-axis). All ideas that were not in the top right quadrant were discarded. This is a rough way to quickly determine how promising each idea is.

The remaining ideas were then further developed to create 3 concepts. Ideas that did not seem promising (e.g. difficult to produce, has tricky mechanisms) were discarded.

Finally, to create the final concept, a series of prototyping, testing and redesigning was carried out. It is a non-linear and iterative process, also known as “design thinking” (Dam & Siang, 2023). This stage is discussed in Chapter 5 - Conceptualisation.



Figure 74. Develop phase approach

4.1.1 Ideation session

An ideation session was held with the aim of generating as many ideas as possible, from as many different angles, to create a new dispenser concept. The participants were seven master's students and graduates from the Integrated Product Design programme at TU Delft. Five of them participated in person at the university and two participated online via Zoom.

The platform used was a Miro board where the different parts of the session – project introduction, brainstorming and reflection – were presented in a structured way to the participants (see Appendix J – Ideation session Miro board). Each participant had access to the same board on their own computers via a link. They were also provided post-it notes and pens for sketching.

Firstly, there was the introduction. The participants were introduced to the project with the problem statement and user journey map. Any questions they had throughout the session was answered by the facilitator (me, the author). The facilitator also kept the time and updated the participants when there was only a minute left for their task.

Then, the brainstorming part commenced. The participants were encouraged to create whatever ideas they wanted, unbound to any rules (blue sky thinking). They started with creating a concept. After that, they could modify it or create a new one by going through the "How To cards". The "How To" technique helps direct people, who are the participants in this case, to solve specific issues (Tassoul, 2009). These cards describe a variety of problems, such as "reliable" or "combine dry wipes and disinfectant". When combined with the query "how to", questions like "how to make it reliable?" or "how to combine dry wipes and disinfectant?" are created.

The brainstorming part ended with 2 rounds of "What If cards". These cards provide scenarios that participants could imagine their ideas in. An example of a scenario is: "what if the design is placed in a new environment?". They then can create new ideas related to the scenarios.

Lastly, there was the reflection part. This consisted of voting and giving feedback:

- Giving feedback: The participants were asked what they thought about the ideation session. The general consensus was that it was fun and that there are similarities between their ideas, but that the original planned duration was too short.

The duration of the whole session was intended to be 45 minutes. However, it ran up till 1 hour and 15 minutes as the participants requested for more time to write and sketch out their ideas. This session yielded approximately 80 ideas.



Figure 75. Photo of the ideation session held at the university. Participants attending online were projected onto a screen.



Figure 76. Another photo from the session

4.2 Results

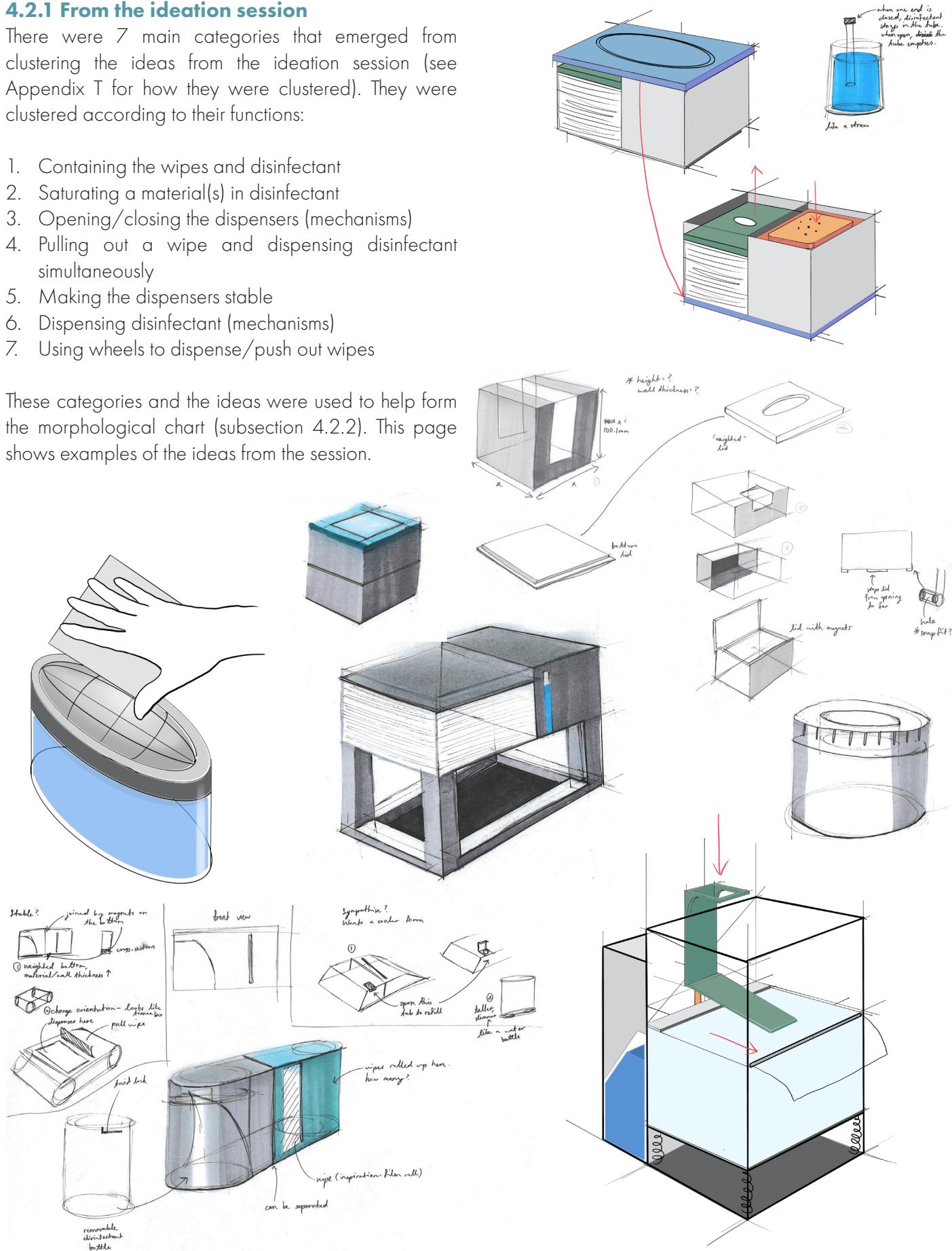
This subsection presents a summary of the ideas from the ideation session, a morphological chart and the 3 concepts chosen to be developed further.

4.2.1 From the ideation session

There were 7 main categories that emerged from clustering the ideas from the ideation session (see Appendix T for how they were clustered). They were clustered according to their functions:

1. Containing the wipes and disinfectant
2. Saturating a material(s) in disinfectant
3. Opening/closing the dispensers (mechanisms)
4. Pulling out a wipe and dispensing disinfectant simultaneously
5. Making the dispensers stable
6. Dispensing disinfectant (mechanisms)
7. Using wheels to dispense/push out wipes

These categories and the ideas were used to help form the morphological chart (subsection 4.2.2). This page shows examples of the ideas from the session.



4.2.2 Morphological chart

Figure 77 shows a morphological chart for the new design. The morphological chart breaks down the desired product into its parts so that the designing is more approachable. It also ensures that all components in the design are considered. The chart consists of the subfunctions (the most left column) that the new design should have, and all the possible solutions - some of which are from the ideation session - that could achieve the subfunctions (in the relevant rows). Related solutions are grouped together with a dotted line outlining them. The final design is potentially a combination of the solutions.

Disinfectant dispensing mechanism	Push-down pump	Sprayer (like household cleaner spray)	Sponge saturated with dispenser	Air pressure, like a straw with one end closed	Disinfectant infused rollers - wipes feed through them
Dry wipes dispensing mechanism	Wheels to push out wipes (like in a printer)	Spring-loaded or similar mechanism	The user pulls the wipes out	From the edge/ corner of the wipes	Wipes are vertical - perpendicular to the surface
Combining dry wipes & disinfectant	The user does this	The dispenser does this	One wipe at a time	Multiple wipes at a time which are then stored	Pulling out wipes and dispensing disinfectant simultaneously
Disinfectant / wipes container	Disposable	Disinfectant in plastic bag which is thrown away and replaced when empty	Refillable - the user directly refills into the container	The container is transparent - fully or partially	Plastic or glass
Dispenser lid	Has magnets to keep it closed	Snap fit	Clicks closed (push latch mechanism)	Self closing	Manually closed
Stability	Weighted base	Place lid with suction under dispenser	Rubber feet	Larger base and smaller top	
Modularity	Wipes and disinfectant dispensers are separate	Wipes and disinfectant are contained in one component (no modularity)	Can be joined with magnets	Can be joined mechanically (with slots)	
Feedback to the user	Sound	Magnets in the lid will make a sound when closed	A click sound when the lid is twisted closed (like lipgloss/ lipstick tubes)	Makes a sound when enough disinfectant is dispensed	Tactile
User-product interaction	Two hands	One hand	One finger	Hands-free (contactless)	Press a button to dispense
					Open the dispenser lid to dispense
					Twist to push wipes out/ dispense disinfectant

Figure 77. Morphological chart

4.2.3 Concepts

Here are the 3 concepts that were created as an outcome of the idea development stage:

- **Concept 1:** A wipe gets attached to the lid of the dispenser and is pulled out each time the lid is opened. The lid opening also triggers the disinfectant dispensing onto the wipe.

- ◊ Idea: The user pulls a wipe out with the lid and disinfectant gets sprayed on the wipe when the lid is open.
- ◊ Iteration 1: The design was made modular so that the disinfectant container can be quickly replaced with a full container when empty. A button was added so that the user can spray more disinfectant on the wipe if desired.
- ◊ Iteration 2: The lid now has two parts to it: a disinfectant spray nozzle that snaps upright and a moveable part that picks up wipes. This way, the nozzle is closer to the wipe to ensure that it gets moistened. Possibilities on methods to pick up a wipe are pins and velcro.
- ◊ Iteration 3: The disinfectant spray nozzle was made to be on top of the disinfectant container. The disinfectant spray nozzle and the part that picks up a wipe (in open position) should be on the same line as each other so that the wipe can be easily sprayed.

- **Concept 2:** The user dispenses a wipe that gets moistened with dispenser in one single motion of their hand.

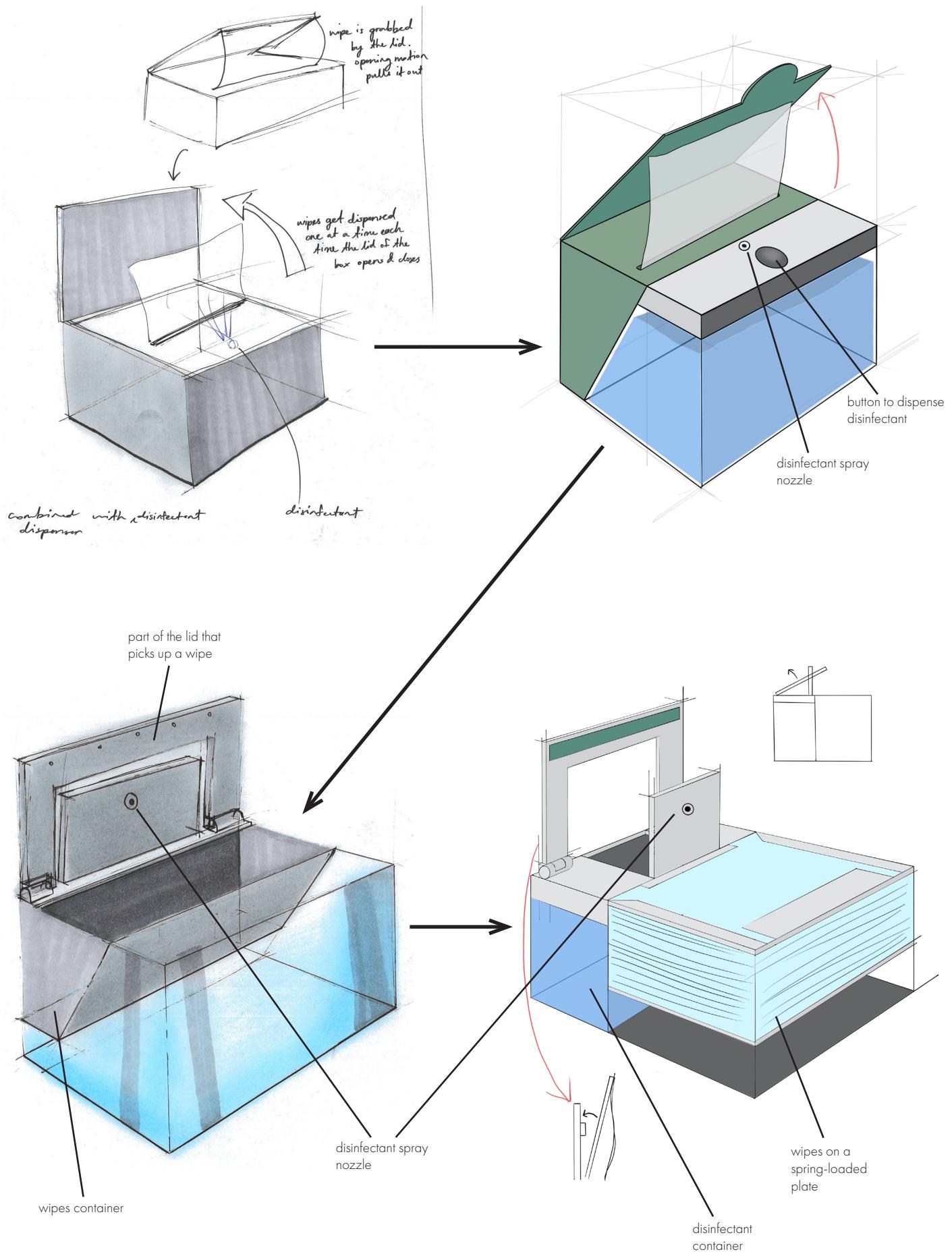
- ◊ Idea: The user presses down on the dispenser and this motion causes a wipe to be pushed out and the disinfectant to dispense simultaneously.
- ◊ Iteration 1: Instead of the user pushing down on the dispenser, they now pull a (spring-loaded) tab which pushes a wipe out, dispenses disinfectant and then goes back to its original position after a pull. The wipes are on a spring-loaded plate so that they are at the correct level to be pushed out.
- ◊ Iteration 2: In the previous iteration, the tab moved on a "straight track". In this iteration, there is a diagonal motion downwards to push a wipe forward so that the mechanism will not catch on a wipe when moving back into its original position. There is also a slanted part for the dispensed wipe to rest on, where it will get sprayed with disinfectant.

- **Concept 3:** The user pulls a wipe out with their hand and then disinfectant gets sprayed onto the wipe by the dispenser.

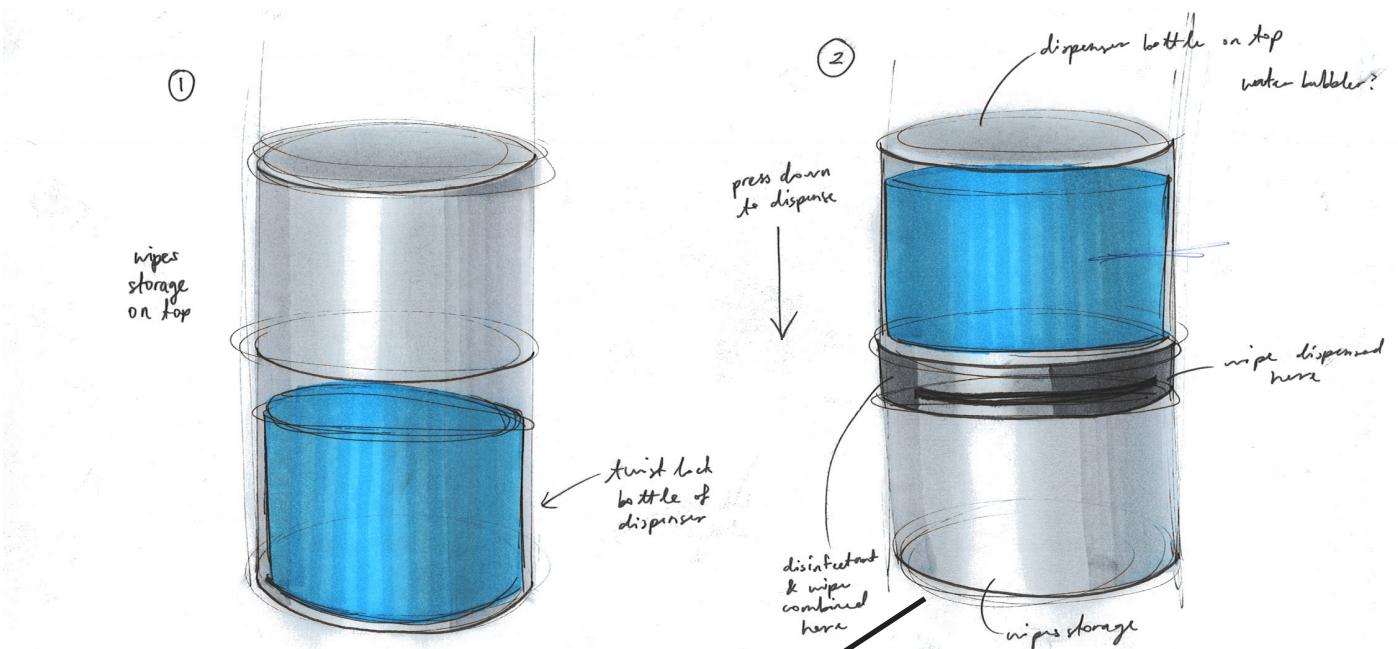
- ◊ Idea: The user pulls out a wipe through disinfectant in one motion.
- ◊ Iteration 1: Instead of the wipe going through a "pool" of disinfectant, the wipe is sprayed.
- ◊ Iteration 2: The wipes are on a spring-loaded plate. This is useful to ensure that the wipes are near the outlet (opening where the user takes a wipe). This will prevent any hassle with fumbling to find a wipe at the bottom of the dispenser. After pulling a wipe out, a motion sensor will detect this action and spray disinfectant onto the wipe. There should be a time delay so that the user has time to hold the wipe at the disinfectant spray nozzle.

These concepts were further tested via prototyping and further developed to determine a choice for the final design.

Concept 1



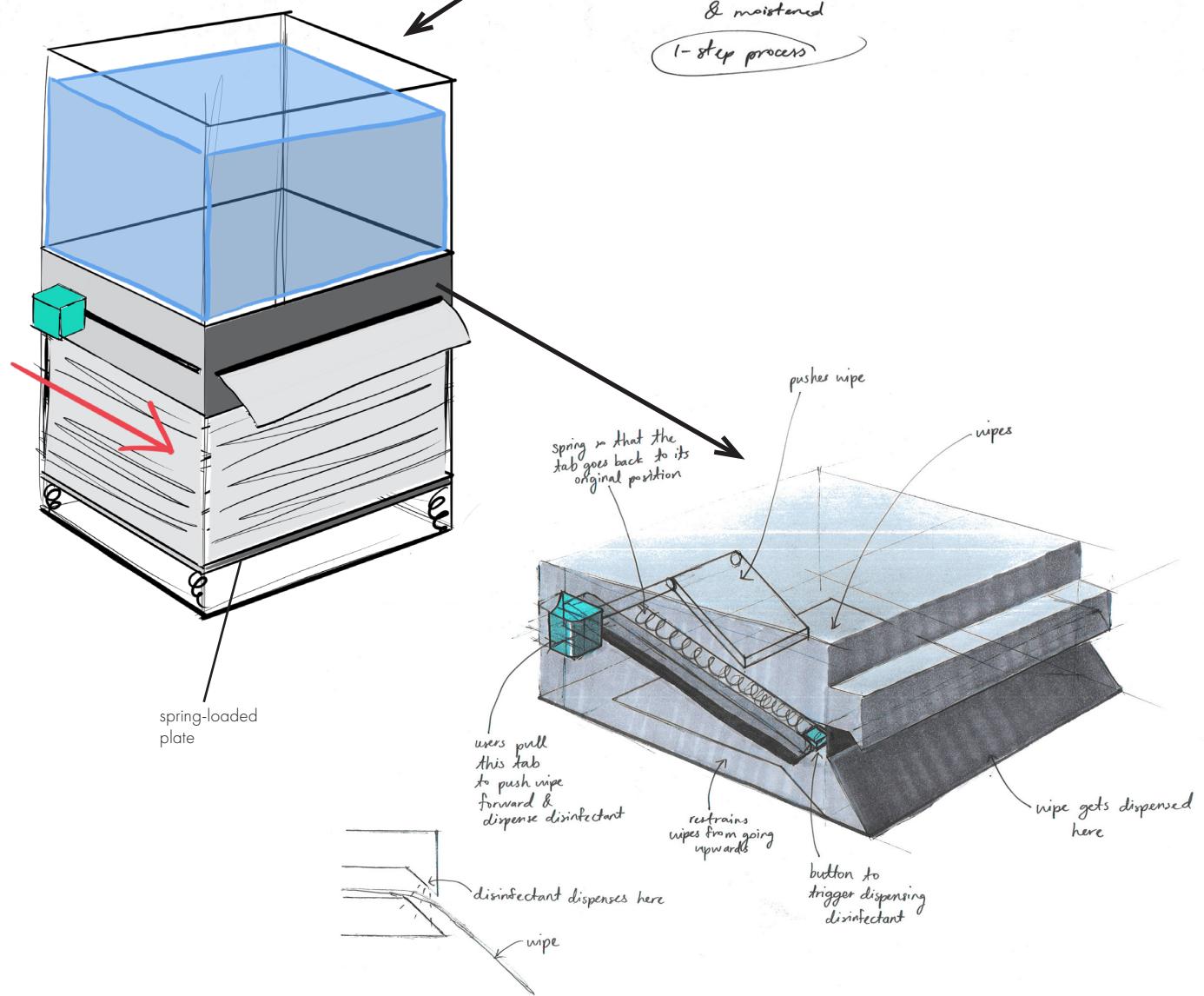
Concept 2



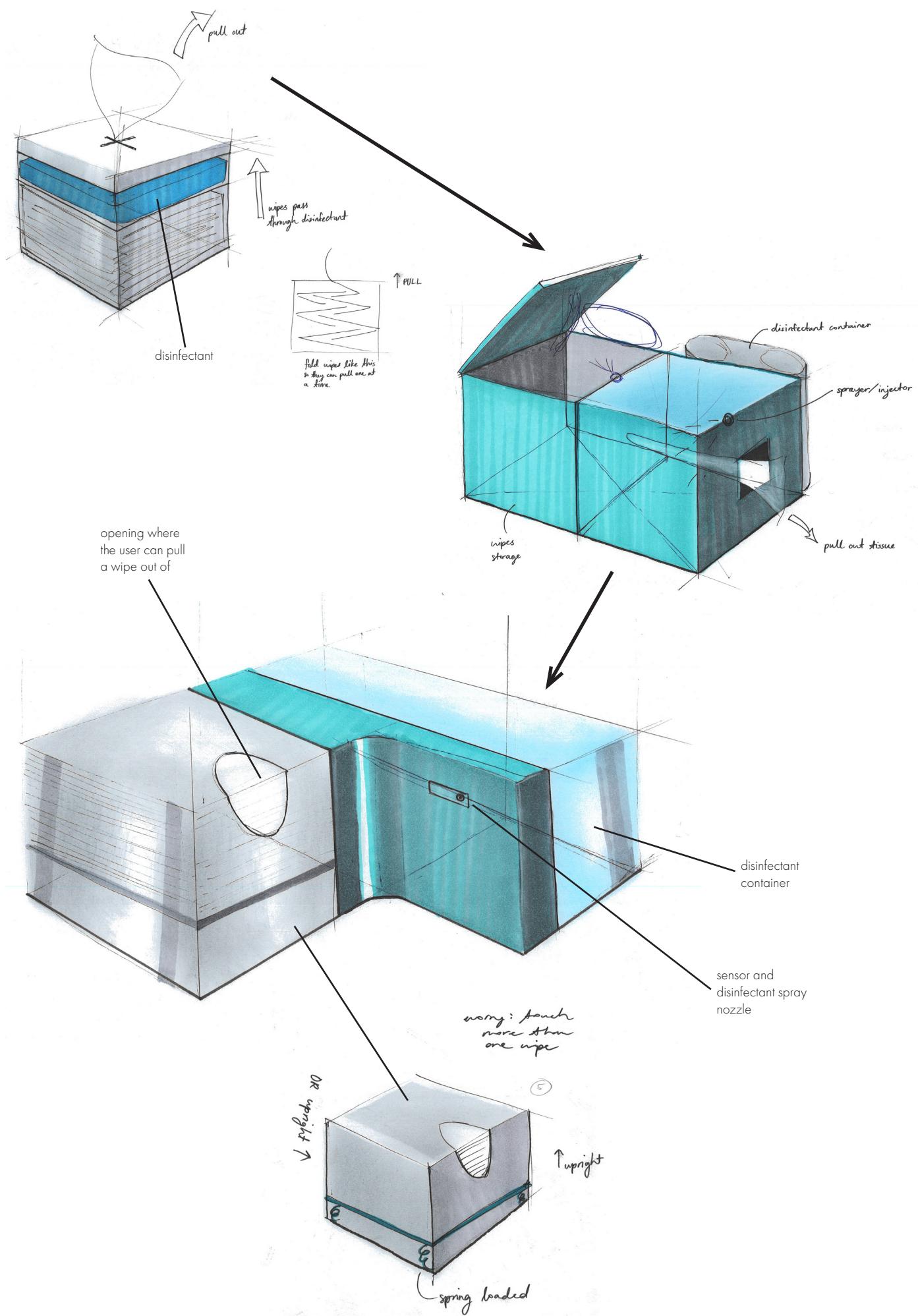
* normally refill wipes more than liquid

💡 - one wipe is pushed out at a time & moistened

1-step process



Concept 3



5. CONCEPTUALISATION

5.1 Development

This subsection shows how the 3 concepts from the previous chapter are developed, via prototyping and secondary research, to create 1 final concept.

Generally, during the design process, concepts are created from an ideation session(s) and of these concepts, one is selected by methods such as a weighted decision matrix. However, after the first round (referred to as cycle in this report) of prototyping and testing, it was found that this approach is unsuitable for this project. This will be further elaborated in this chapter. Consequently, the design thinking process was used. This is visualised in figure 78. The three concepts detailed in the previous chapter are the starting point. Features in each concept were designed, prototyped, and tested and evaluated. If the design is not sufficient after evaluation, they are redesigned and the cycle repeats until a satisfactory solution(s) is found.

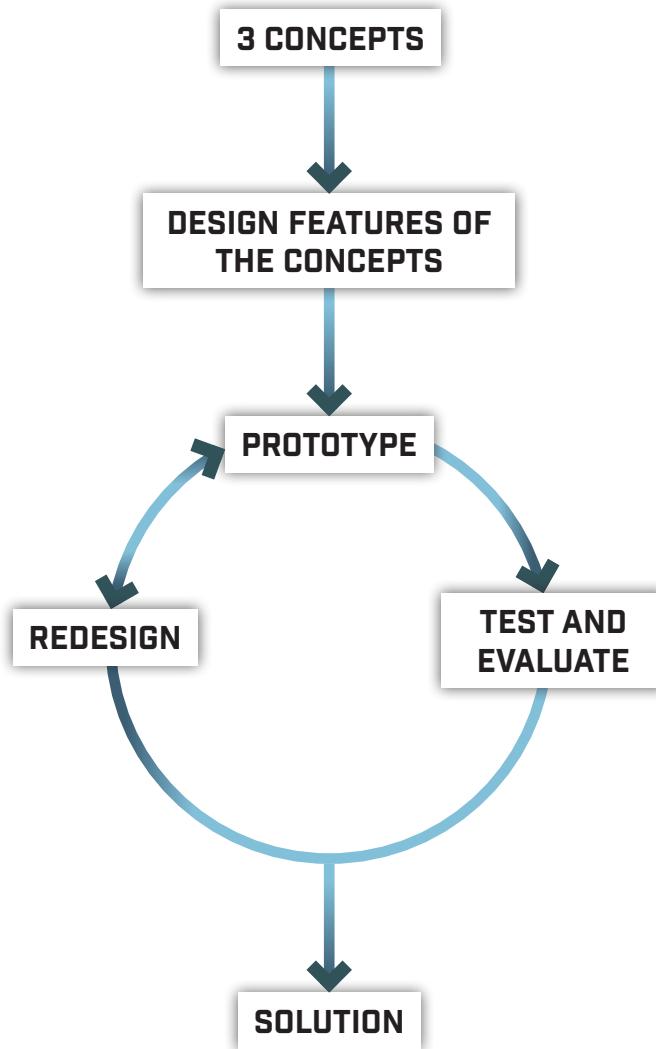


Figure 78. Concept development process

5.1.1 Cycle 1

Concept 1

This concept involves the dispenser picking up one wipe at a time, which was determined to be the main issue to tackle in order to make the concept successful. A few different methods, with 5 attempts each, were tried with a stack of wipes:

- Pinching and picking up with fingernails: This works well.
- Pinching and picking up with silicone tipped kitchen tongs: It works but not reliably. There was not enough grip/friction so the tongs sometimes were unable to pinch a wipe and just slid over them.
- Pinching and picking up with metal kitchen tongs: This does not work at all. The tongs slid over the wipes during the pinching motion as there was no friction between them.
- Swiping over the surface of the wipe with velcro: This does not work and frays the surface of the wipe.
- Pressing on the wipes and lifting up with masking tape: This worked the best but they do not last long. After ~10 attempts, the tape lost their tackiness.

Other ideas that stemmed from this series of prototyping were using a rubber suction cup, which are used to handle materials such as paper and glass during various manufacturing processes ("Suction Cups SFF / SFB1", n.d.), and pins.

The former creates a vacuum and is then able to lift up the item it is in contact with. However, the setup is complex - components such as pneumatic hoses for compressed air, vacuum generators and pressure gauges are required ("Vacuum pick and place applications", n.d.). Furthermore, the wipes are not airtight so the vacuum would not hold them. This idea was thus discarded.

Concept 2

With this concept, the dispenser pushes forward a wipe. Two different prototypes were built out of cardboard and explored (figures 81 and 82). A stack of wipes were placed in these prototypes and there was a spring-loaded (20mm diameter, 50mm length, low stiffness but spring constant unknown) base underneath them to constantly push the wipes upwards so that the topmost wipe always stays in the same position.

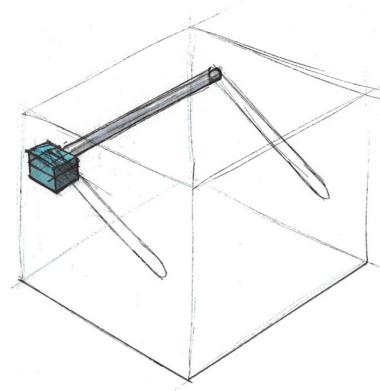


Figure 79. Concept sketch of user-product interaction and internal mechanism. The user pulls the green tab forwards and the dispenser pushes out a wipe.

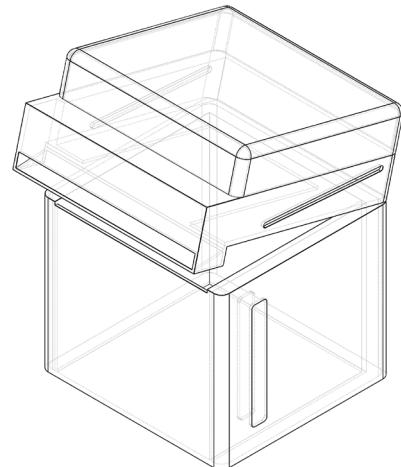


Figure 80. CAD model of an idea of the overall concept, to visualise how it might look



Figure 81. Prototype 2A. The 3 sides on the top are 20mm wide.

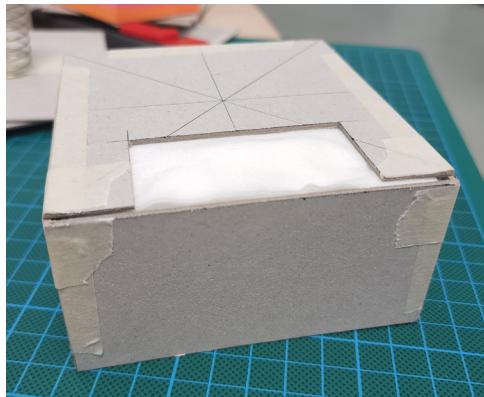


Figure 82. Prototype 2B, with an opening of 30mm x 60mm

It was found that the stack of wipes did not stay flat at the opening at the top (see figure 83) especially when the pressure exerted on the prototype by the wipes was high, which is the condition when the stack of wipes is large and the spring beneath them was more compressed (figure 84). This means that as more wipes were dispensed/taken out, there was less pressure and the wipes would not curve up as much at the opening.



Figure 83. The wipes curving upwards at the opening

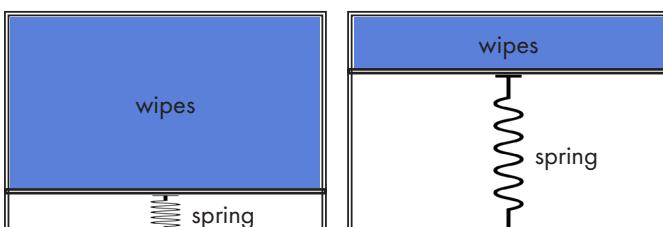


Figure 84. More wipes, more compressed spring on the left.
Opposite on the right.

The wipes were pushed out of the prototypes manually. When the pushing force was perpendicular to the direction of the fibres in the wipes (the fibres are in horizontal orientation when viewed top-down), it was easier to push out one wipe at a time compared to when the pushing force is parallel to the direction of the fibres (vertical orientation). In addition, it was also easier to pinch and pull out one wipe at a time with the wipes in "horizontal orientation".

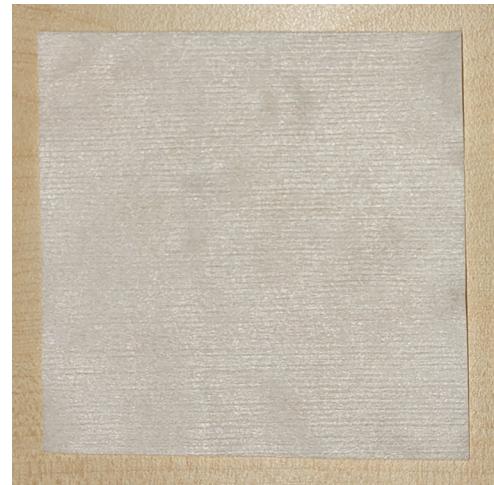


Figure 85. Direction of the wipe is in horizontal orientation

Prototype B has a smaller opening than prototype A. There is more friction when pushing/pulling a wipe out. The force applied on the wipes to pull them out deforms them slightly (see figure 86).

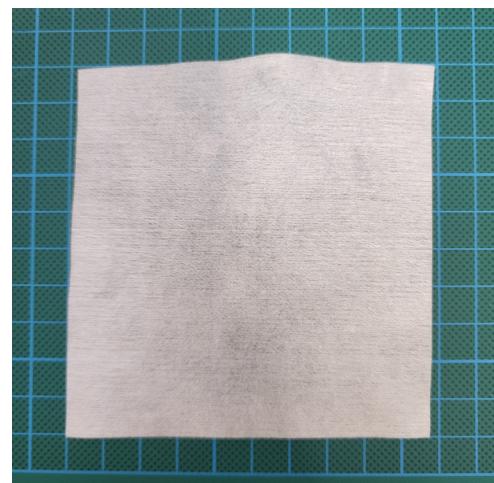


Figure 86. The (top) part of the wipe is slightly deformed where a force was applied to push/pull it out of the prototype

Aside from that, with both prototypes, a gap was needed at the front so that wipes can pass through smoothly (figure 87). Without a gap, the wipes catch on the edge of the front wall.

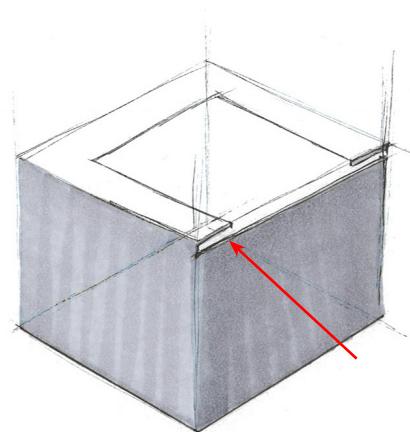


Figure 87. Gap indicated by the red arrow

Concept 3

This concept requires the user to manually take the wipes themselves out of the dispenser. 4 different prototypes of wipes dispensers were constructed with a spring-loaded plate for the wipes to rest on (see figures 88-91), out of cardboard, similar to the prototypes of concept 2. To test the prototypes, the wipes were pulled out of the openings whilst wearing nitrile gloves, which are what is used in the NFI laboratories and by the CSIs with the police.

- Prototype 3A (figure 88): This prototype has two 20mm diameter semicircles cut out of the top and front sides to form an opening. The hole is small and it was difficult to pull out a wipe, let alone one wipe at a time, especially when the wipes were not placed inside well (not completely stacked straight).
- Prototype 3B (figure 89): This prototype has a 60mm x 60mm square opening on the top. It was not so easy to pull out wipes as there was a lot of friction from the sides of the opening. It was possible to take one wipe at a time, with reasonable reliability.
- Prototype 3C (figure 90): This prototype has a 80mm x 80mm square opening on the top. It was easier to pull out wipes with this than prototype 3B. It was possible to take one wipe at a time, with reasonable reliability.
- Prototype 3D (figure 91): This prototype has a 30mm x 30mm rhombus-shaped opening on the top. It required more effort to take out a wipe when compared to the other 3 prototypes. It was also possible to pull out one wipe at a time. Moreover, after pulling a wipe out, the wipe that was below it, tents (figures 92 and 93). This made it easier to pinch the wipe between fingers.

The difficulty of using these prototyped dispensers went up when a user with larger fingers tried them because they struggled to pinch a wipe between their fingers.



Figure 89. Prototype 3B



Figure 90. Prototype 3C

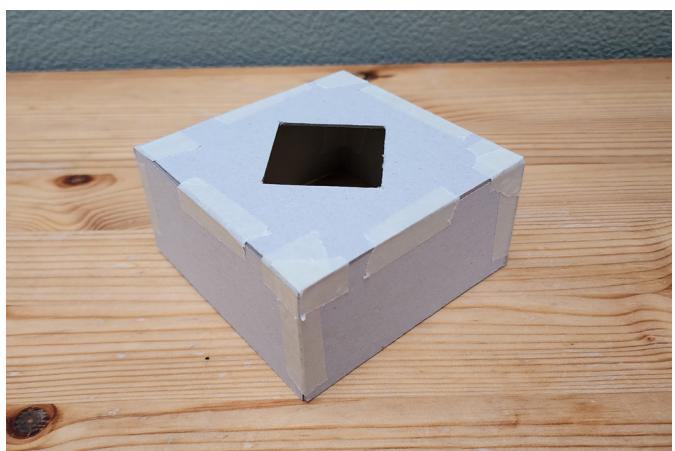


Figure 91. Prototype 3D

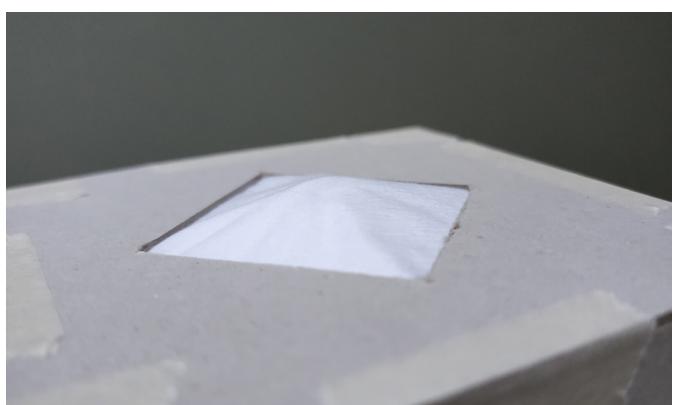


Figure 92. The top wipe tenting after the previous topmost wipe was pulled out



Figure 88. Prototype 3A



Figure 93. Side view of figure 92

As for dispensing disinfectant, with concept 3, the user has to take a wipe and hold it by the spray nozzle where disinfectant will automatically be dispensed. There is a time delay between the user's two actions. Figures 94-96 show a new iteration of this. The disinfectant would dispense into a "bowl" (see figure 94) when the user pulls out a wipe, with no time delay. After taking a wipe, the user can swipe the wipe in the bowl to moisten it.

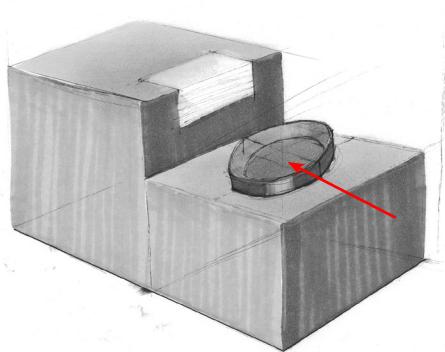


Figure 94. Sketch of new iteration of concept 3. "Bowl" indicated by the red arrow

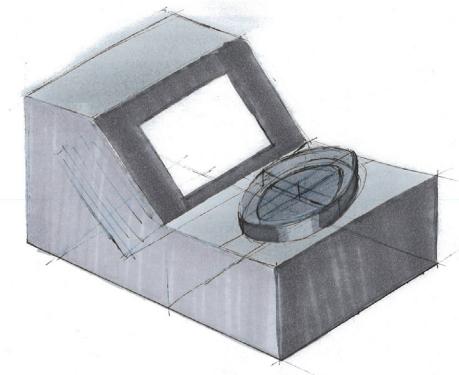


Figure 95. Sketch of new iteration of concept 3

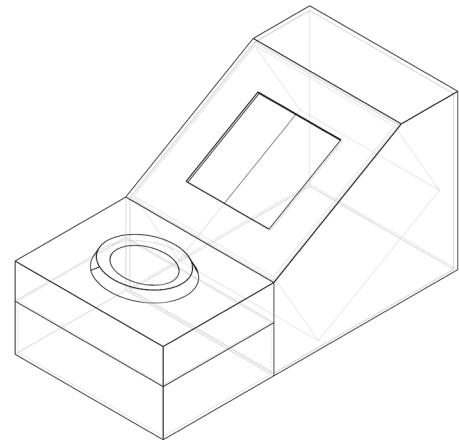


Figure 96. CAD model of figure 95, for visualisation purposes

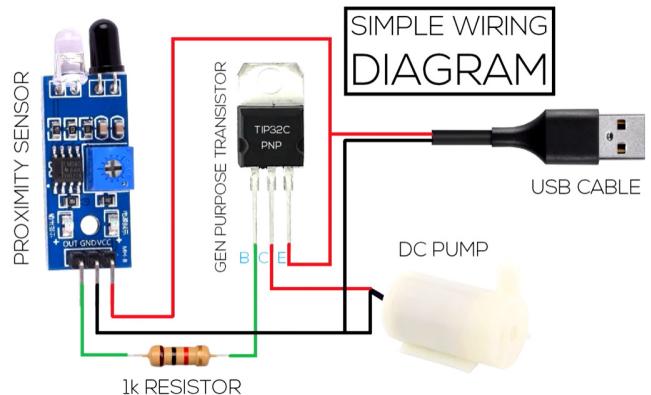


Figure 97. A diagram showing the setup of how disinfectant could be dispensed automatically (TechBuilder, 2020)

Takeaways

From prototyping for concept 1, a new idea to pick up a wipe with pins emerged. This was explored in the next cycle, which is detailed in the next subsection (5.1.2 Cycle 2). Moreover, the masking tape worked best due to its tack (stickiness). A more durable alternative could be natural rubber.

With concept 2, it was found that when pushing a wipe out of the dispenser, friction between them may damage the wipes. The shape of the dispenser should be explored to find the optimal one so that the wipes can pass through smoothly (see the next subsection for this). The material of the dispenser could be another factor. Apart from that, the wipes should also be in the "horizontal orientation".

While the prototypes for concept 3 have potential to be the final design, the user is still required to manually pick up a wipe which is the case in the current scenario. It is desirable to pursue a more novel (or innovative) idea as there would be more possibilities with future applications. Hence, instead of designing for all 3 concepts, it was determined that the focus should be on how a single wipe could be dispensed at a time as this is the main challenge for the design to be successful.

5.1.2 Cycle 2

This cycle focused on pushing/pulling a wipe out of the prototypes with two different materials/parts: pins and natural rubber.

Picking up a wipe

Two different shapes for the container/housing of the wipes were used. One was prototype 2A from cycle 1 and the second one is the same as prototype 2A except that the front 2cm of material on the top is removed (see figure 98), to reduce the amount of friction exerted on the wipes when being pushed out.

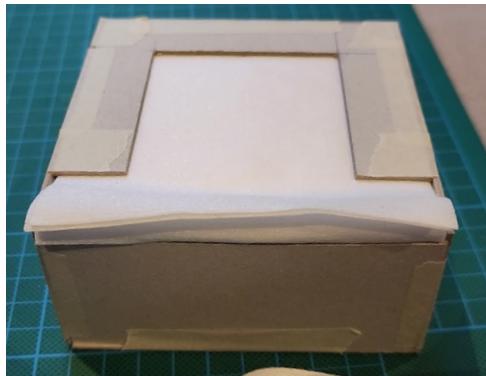


Figure 98. Second dispenser prototype used

Various materials and geometries were explored. Here are the solutions that worked:

- Piece of natural rubber: Latex means any polymer in liquid form (Wang et al., 2013). Coagulated natural rubber latex, from the rubber tree, is referred to as natural rubber. A pulling/pushing motion was used on the wipes. The wipes "stick" to the piece of latex. 2 pieces are pulled out at a time occasionally. Out of all the methods tested, this method was the "fastest".
- Natural rubber exercise resistance band: A pulling/pushing motion was used on the wipes. Multiple wipes were pulled out, or the top wipe creased, unless the right amount of force, which is yet to be determined, was applied on them during the pulling/pushing motion.
- Roller made with natural rubber resistance band (smooth surface): This did not work well if the roller was placed in the centre of the wipes. It worked better at the edge. Also, this required more force than the previous two methods.
- Roller made with natural rubber resistance band (grooved surface): This worked better than the smooth resistance band roller as there is more friction.
- Roller with small screws (screw eye hooks) angled approximately 45°: The roller was able to pick up one wipe at a time. If too much force was used,

multiple wipes were picked up and the top wipe got firmly pinned to the roller.

- Triangular roller with small screws (screw eye hooks): This seemed to work as well as the roller with small screws. Further exploration into the part geometry should be explored.
- Bar with pins: A pulling/pushing motion was used to take a wipe. It worked angled and parallel to the wipes.



Figure 99. Roller made with natural rubber resistance band (smooth surface)



Figure 100. Roller made with natural rubber resistance band (grooved surface)



Figure 101. Roller with small screws



Figure 102. Triangular roller with small screws

To note, for all these methods, they did not work as well when the dispenser was almost out of wipes - multiple wipes were picked up instead of a single one. It also became very apparent that since there is a lower reaction force from the spring, the wipes are not as tightly compressed together. Furthermore, the second dispenser prototype used (figure 98) did not work as well as prototype 2A for containing the wipes because they did not restrain them as well - multiple wipes slid forward when pulling a wipe out.

Solutions with pins

Pins are a shape-dependent solution and they work more reliably than friction-dependent solutions because they are not affected by environmental factors such as temperature. During the exploratory studies, the prototypes with pins did not work as well as the prototypes with natural rubber:

- It was more difficult to pick up a single wipe.
- The pins may deform the wipe or create holes in the wipe.
- The pins can stick to the wipe and thus required a bit more force to pull them off when compared to natural rubber.



Figure 103. Wipe sticking to the roller with small screws

Solutions with natural rubber

It is possible to quickly pull/push out one wipe at a time and with zero damage to the wipes. This makes natural rubber a good contender for the final design. However, there are pros and cons to it. Natural rubber is a low cost material - the price is approximately 1.31-1.55EUR/kg. It has excellent durability to sodium hydroxide (10%) and water so it can be cleaned with the disinfectant.

Here are the downsides to natural rubber:

- The solutions rely on friction to push out a wipe and as mentioned earlier, friction can change due to

environmental factors such as temperature, dirt and moisture. Another aspect of natural rubber that is affected by environmental conditions is a change in its dimensions. They may expand if they absorb moisture (due to humidity) or if the temperature increases, and vice versa (Timco rubber, n.d.). Laboratory technicians work in a laboratory where the environment is constant but the CSIs work in the field where it is the opposite. Hence, natural rubber, as it is, is not a suitable material for the dispenser for CSIs.

- Natural rubber deforms in the autoclave as it can generally only tolerate temperatures up to 115°C before losing useful properties. Common temperatures for autoclaves are 121 and 132°C (Centers for Disease Control and Prevention, 2016).
- Natural rubber degrades under UV light, which is sometimes used for cleaning in the laboratory, although its durability to UV radiation can be improved with antioxidant additives.

The material information above is from Granta Edupack 2020.

Solutions with silicone

An alternative to natural rubber could be silicone. It is more costly than natural rubber (around 3.33-3.67EUR/kg) but it can withstand a larger range of temperatures (-100°C to 300°C) which means that it can be autoclaved. It also has good durability to UV radiation. Finally, like natural rubber, it has excellent durability to sodium hydroxide (10%) and water so it can be cleaned with the disinfectant as well. The material information is from Granta Edupack.

Takeaways

The main takeaway from this is to continue exploring pins and to try silicone. Natural rubber has many downsides but additives can be added to improve their properties. It may be advantageous to continue exploring them.

The prototypes made in cycle 2 are low fidelity so for the next cycle, higher fidelity prototypes were made to have more consistent part placement (i.e. roller).

5.1.3 Cycle 3

Laser cut dispenser with rollers

Multiple prototypes were created out of laser cut 3.3mm plywood. Different shapes for the top of the dispenser were tried (figure 105). The ones that worked best were the second and third from the top, because less effort was required to pull out a wipe with them.

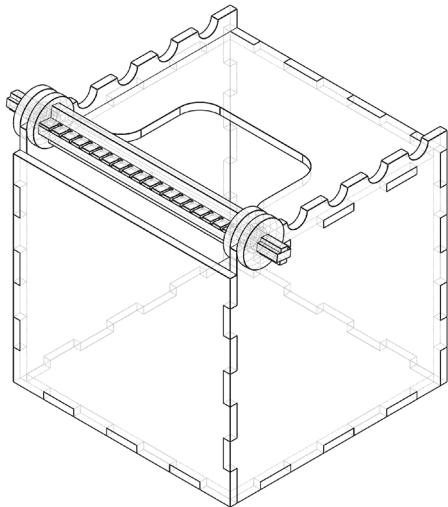


Figure 104. CAD model of the prototype

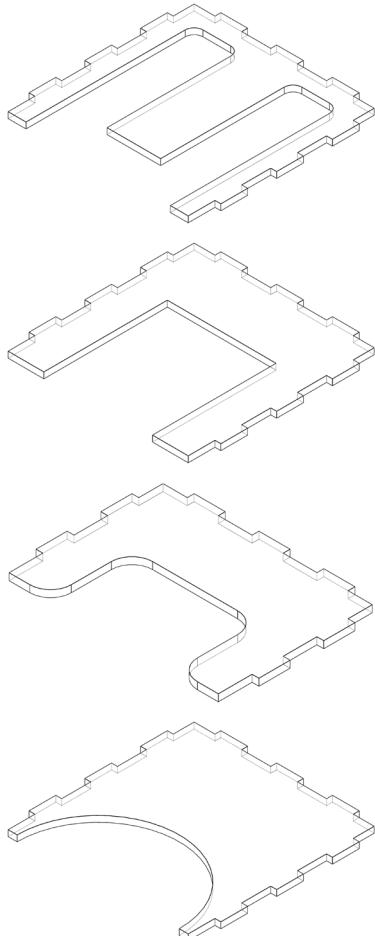


Figure 105. Different geometries for the top of the wipe dispenser

Parts to hold the screws were 3D printed from PLA (see figure 106). These were glued onto the rollers. Natural rubber latex was casted into 3D printed molds and the outcome was taped onto the rollers.



Figure 106. Roller with screw eye hooks



Figure 107. 3D printed molds for natural rubber



Figure 108. Natural rubber

The rollers with screws could pick a wipe up but the wipes stuck to the screws and wrapped around the rollers (figure 109). The wipes may be stuck to the roller because the screws are not angled. However, in the previous cycle, with the roller with angled screws, the wipes stuck to it as well.

The natural rubber rollers did not work well because the fibres from the wipes stuck to the surface of the rubber. This made the material less effective over multiple attempts until the prototype stopped working altogether.

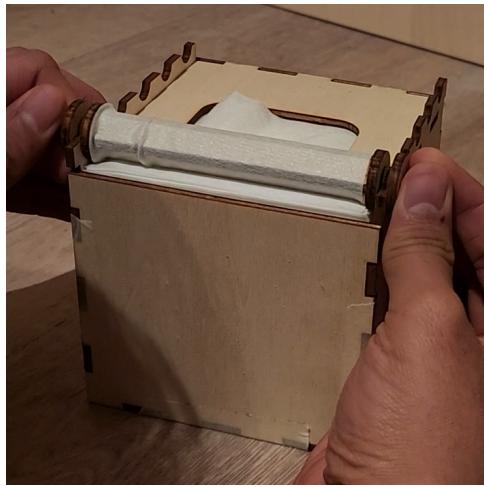


Figure 109. Wipe stuck to the roller

3D printed pins

So far, metal pins and screw eye hooks have been used in the prototypes. In this cycle, 3D printed pins were explored as there is more freedom in designing with them. Multiple Ultimaker 2+ 3D printers with 0.4mm nozzles were used to print different array of pins (see table 11) out of PLA. The layer height was 0.15mm and the infill was 80%.

To test the pins, they were used multiple times (3-5 times) to pull wipes out of the laser cut dispenser. The results are in table 12. Print quality affected the performance because bad prints were more fragile and parts broke.

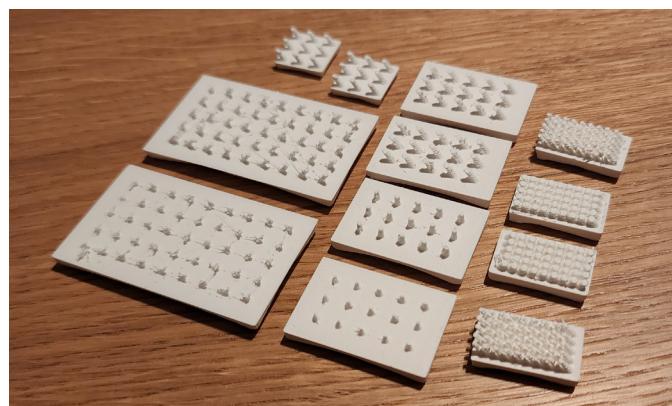


Figure 110. 3D printed pins

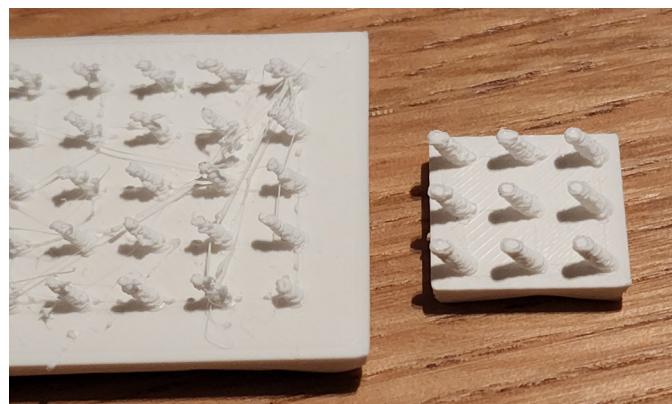


Figure 111. Different 3D prints of the same type of pins. The difference in print quality can be seen.

Table 11. Information on geometry of the 3D printed pins

	Base diameter (mm)	Top diameter (mm)	Height (mm)	Orientation	Distance between pins (mm)
1	1.5	1	2.5	Angled 51.34°	5
2	1.5	1	2.5	Angled 51.34°	2
3	1.5	1	2.5	Straight	5
4	1.5	Point	2.5	Angled 51.34°	5
5	1.5	Point	2.5	Straight	5
6	2	1.5	2.5	Angled 51.34°	5
7	2	1.5	1.5	Angled 68.2°	2

Table 12

	Performance
1	This worked but deformed the wipes a bit if too much force was used - they did not fray but their shape became a misshapen square instead of a normal square with straight sides. One pin broke in the front area (the area closest to the front of the dispenser) and this could be due to print quality.
2	This worked but not well. The pins frayed the wipes and it was difficult to get them to grip/hook into the wipes.
3	This worked occasionally. The pins were unable to "grip" the wipes.
4	This worked but some pins broke, in the front area.
5	This worked, with minimal fraying to the wipes.
6	This worked well, with minimal fraying to wipes.
7	This did not work at all. They "slid" over the surface of the wipes.



Figure 112. A frayed wipe

Finally, these 3D printed pins, unlike the metal screws and pins, do not hurt to touch. They are not sharp enough to cause finger injuries, with general handling.

Silicone

A few types of silicone were tested to push out a wipe:

1. Dragon Skin™ 10 ("Dragon Skin™ 10 medium product information", n.d.)
2. Dragon Skin™ 20 ("Dragon Skin™ 20 product information", n.d.)
3. Dragon Skin™ 30 ("Dragon Skin™ 30 product information", n.d.)
4. Ecoflex™ 00-10 ("Ecoflex™ 00-10 product information", n.d.)
5. Ecoflex™ 00-30 ("Ecoflex™ 00-30 product information", n.d.)
6. Ecoflex™ 00-50 ("Ecoflex™ 00-50 product information", n.d.)
7. PlatSil ® Gel-00 (C.Kiel, n.d.)



Figure 113. Samples of Dragon Skin 10 silicone. All the silicones tested were in this form.

They did not work well. Although some were sticky to the touch, there was not enough friction to push a wipe out of the dispenser prototype.

Takeaways

The rollers and silicones tested did not work. Therefore, these ideas were discarded and another method was designed. As natural rubber was unreliable, this was discarded as well.

Whilst the 3D printed pins require more testing and development, they are the most promising.

5.1.4 Cycle 4

This is the final cycle. A prototype for the wipes dispenser was made from 4mm laser cut acrylic and 3D printed PLA parts.

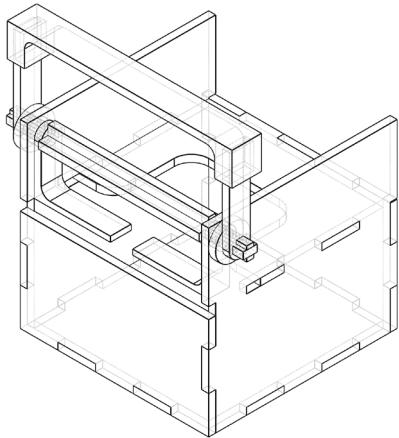


Figure 114. CAD model of the final prototype

Figure 115 shows the pins used (the first type in table 11). It was found that if the pins were not aligned the same, the wipes would only stick to the pins that comes into contact with them first. Due to this initial test, the pins on the sides were removed as they were unnecessary.

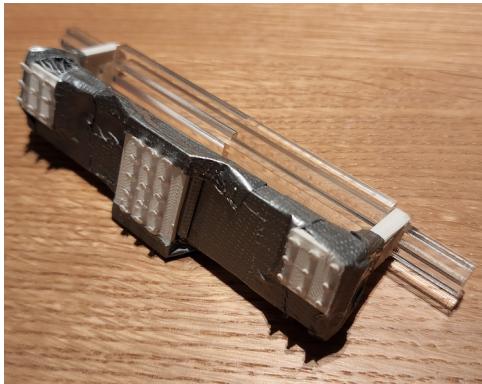


Figure 115. Prototype of the pins

This prototype was successful in picking up a single wipe at a time, with minimal damage to the wipes (figure 116). This could be improved by increasing the surface area of the contact between the pins and the wipes. There are also other points to consider. When the pins go backwards to pick up another wipe, they push against the wipes and causes them to bunch up. The pins would have to move upwards a bit so that they do not come in contact with the wipes like this, or the wipes have to move downwards.

Moreover, after a wipe has been picked up (figure 117), it is better if it is removed from the pins with an upwards motion due to the angle of the pins. Lastly, the pins pick up the wipes better if they start in the position shown in figure 119 as opposed to being 90° to the wipes.

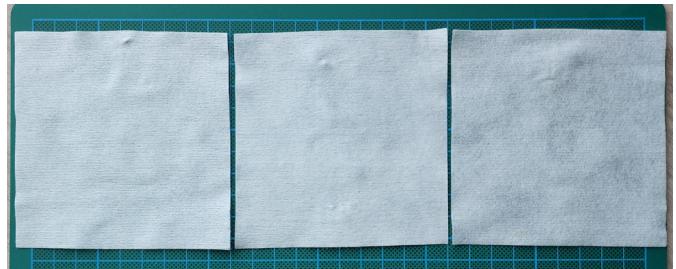


Figure 116. The condition of the wipes after being dispensed



Figure 117. How the wipe looks picked up



Figure 118. Another view of figure 117



Figure 119. The pins' start position should be approximately like this

There was an unsuccessful attempt to incorporate sprayers. This would require further development.

Takeaways

- There should be more pins so that damage to the wipes can be prevented, as there would be less force exerted over a small area of the wipes.
- When the pins go back to the start position, they should move upwards so that they do not push onto the wipes and cause them to bunch up.
- The start position of the pins should be angled around 30-40° backwards so that they pick up the wipes more reliably.
- After a wipe has been picked up, they should be removed by pulling from the pins with an upwards motion.

5.2 Amount of disinfectant to dispense per wipe

As per the list of requirement, it would be desirable if the new design for the disinfectant dispenser dispenses the equivalent of 3 pumps of disinfectant (with the current dispenser) each time. The actual amount is unknown. A Kern EMB 600-2 weighing scale (figure X), 3 disinfectant dispensers and water were used to determine what this amount is. Water was used instead of disinfectant because it was more readily available. The RNase Away and FMD Away disinfectant are around 99% water in composition. It can be assumed that the physical properties are the same.

As the mass of water is measured in the experiment, the volume (in millilitres) can be found with this equation: $Volume = Density / Mass$. The density of water is $1g/cm^3$.

Steps

1. Weigh the dispenser with no disinfectant/water in it (empty).
2. Fill the dispenser with water and weigh it again.
3. Pump the dispenser 21 times. Then, weigh.
4. Repeat step 3 three more times.
5. Repeat steps 1-4 two more times with two other dispensers.
6. After carrying out step 5, empty the dispenser and repeat steps 1-5 one more time.



Figure 120. Weighing scale

Results

Each disinfectant dispenser can contain a volume of $\sim 170\text{ml}$. 3 pumps is equal to 1.25ml , which is the average value of all 6 attempts. Accordingly, each dispenser can wet around 136 wipes. Figures X-X below are graphs of the results and there appears to be no significant correlation between the dispensers.

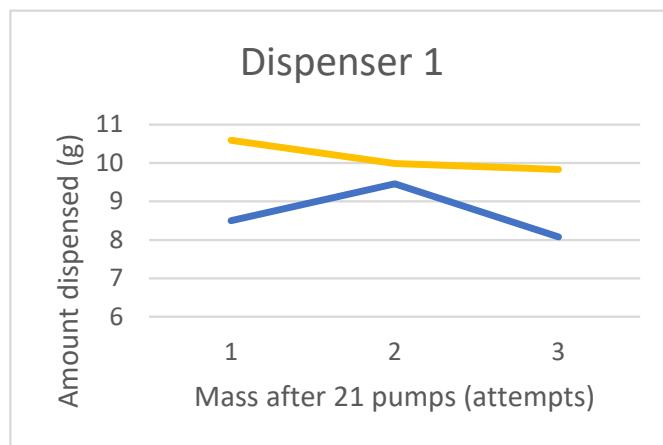


Figure 121

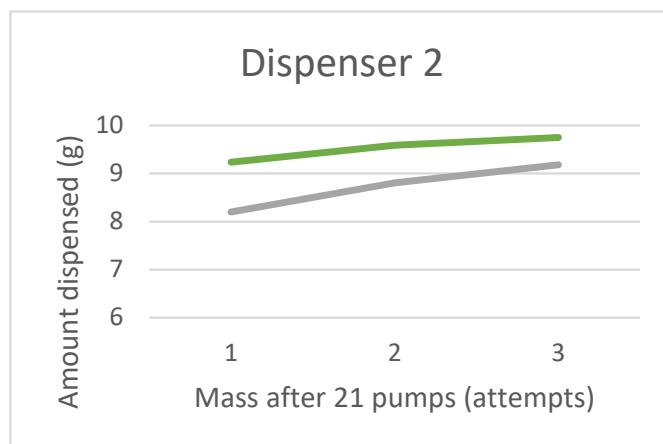


Figure 122

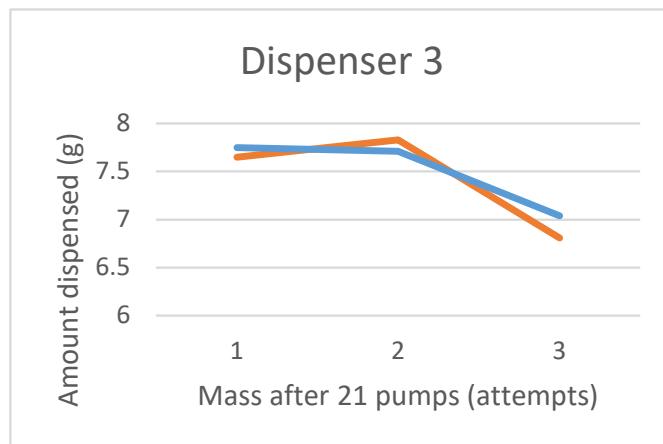


Figure 123

The data of the experiment detailed on the previous page are presented in tables 13-15 below.

To find the mass of water dispensed (columns 3, 5 and 7 in tables 14 and 15), this equation was used: Mass of dispenser full with water - Mass after 21 pumps.

In table 13, it can be seen that there is a small variation in the mass of the dispensers when empty. This may be due to some moisture from the disinfectant remaining in the dispensers after they were emptied.

Table 13

Dispenser	Mass - empty (g)	Mass - full, attempt 1 (g)	Mass of water	Mass - full, attempt 2 (g)	Mass of water (g)
1	31.1	197.18	166.08	200.43	169.33
2	31.71	200.5	168.79	200.22	168.51
3	31.24	199.17	167.93	201.12	169.88

Table 14. 1st run

Dispenser	Mass after 21 pumps - attempt 1 (g)	Mass dispensed - attempt 1 (g)	Mass after 21 pumps - attempt 2 (g)	Mass dispensed - attempt 2 (g)	Mass after 21 pumps - attempt 3 (g)	Mass dispensed - attempt 3 (g)	3 pumps - average mass dispensed (g)
1	188.68	8.5	179.22	9.46	171.14	8.08	1.24
2	192.85	7.65	185.02	7.83	178.21	6.81	1.06
3	190.97	8.2	182.16	8.81	172.98	9.18	1.25

Table 15. 2nd run

Dispenser	Mass after 21 pumps - attempt 1 (g)	Mass dispensed - attempt 1 (g)	Mass after 21 pumps - attempt 2 (g)	Mass dispensed - attempt 2 (g)	Mass after 21 pumps - attempt 3 (g)	Mass dispensed - attempt 3 (g)	3 pumps - average mass dispensed (g)
1	189.84	10.59	179.85	9.99	170.02	10.14	1.45
2	192.47	7.75	184.76	7.71	177.72	7.5	1.07
3	191.88	9.24	182.29	9.59	172.54	9.53	1.36

Design implications

Commercially available sprayers generally come in set dosages (the amount of product dispensed with a single spray). The dosages range from 0.22-1.5ml ("Guide to Mist & Trigger Sprayers", n.d.). The right dosage sprayer can be easily selected and implemented into the design.

6. FINAL DESIGN

6.1 Details

This subsection presents the final concept, which was developed from the outcome of the last cycle of prototyping and testing.



Figure 124. Render of how the actual product might look

Features

- Plastic pins to push a single wipe forward
- Wipes dispensing mechanism: The mechanism it has is the same as the prototype in cycle 4, with a few exceptions. The user must press down on the handle and then turn it to dispense a wipe. When they release the handle, it goes back up to the original position due to springs (see figure 128). This solves the clearance issue between the pins and wipes when the pins are returning to their start position.
- Disinfectant dispensing mechanism: to be incorporated
- Material: plastic, to be determined
- Top opens so that the user can reload the wipes
- Magnetic closure to ensure that the top stays closed

- Clear window to check the level of the wipes inside
- Dimensions:
 - ◊ Length: 132mm
 - ◊ Width: 107mm
 - ◊ Height: 147mm, without the handle
- Anti-skid feet for stability
- Weighted base for stability
 - ◊ Stacked metal sheets, cut into the right size, with pins through the stack to avoid rattling
 - ◊ Sand which can be mixed with glue or epoxy to hold them together so that they do not move around
 - ◊ Salt, instead of sand

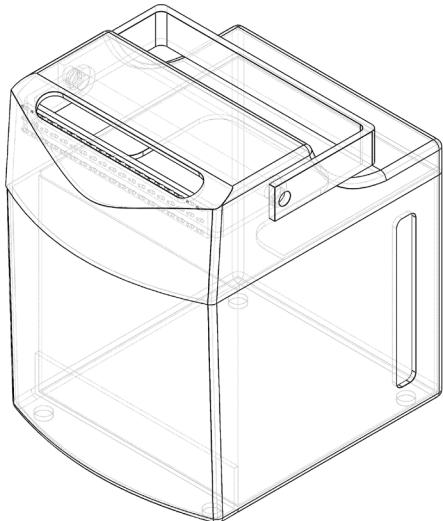


Figure 125. With top closed

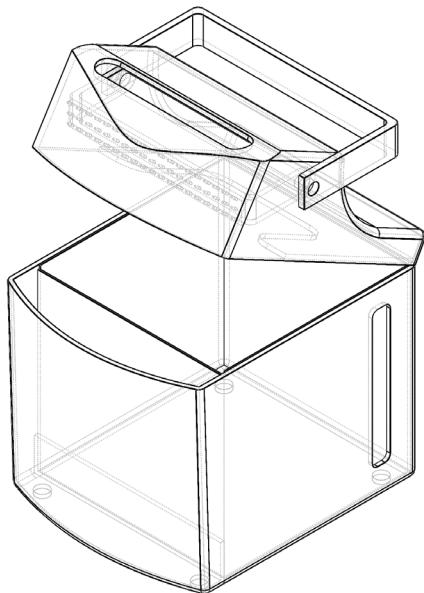


Figure 126. With top open

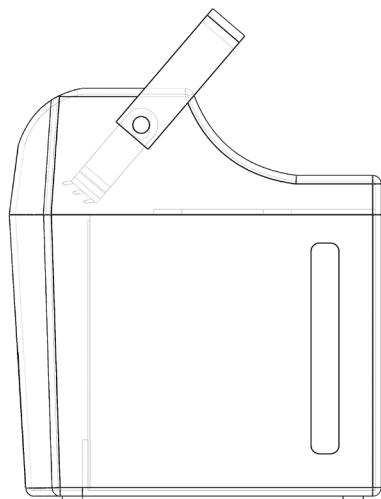


Figure 127. Side view

6.1.1 Recommendations

As mentioned on the previous page, a concept sketch of wipes dispensing mechanism with the handle and springs can be seen in figure 128 below (indicated by red arrow).

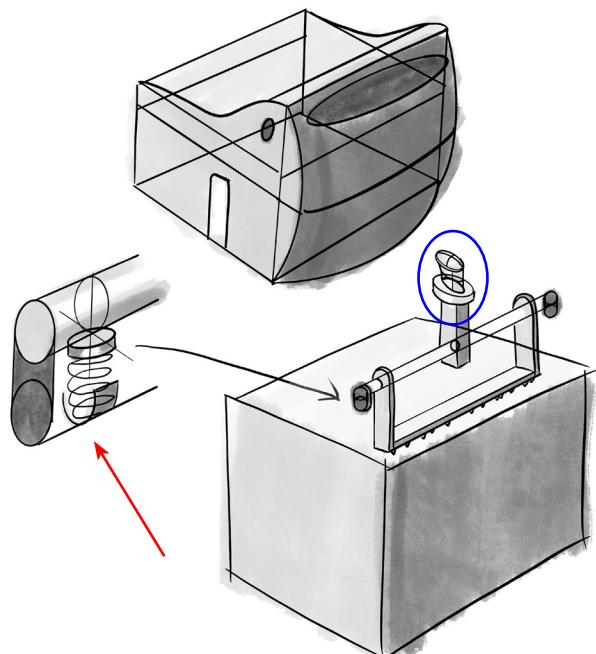


Figure 125. Concept sketches

Figure 125 also includes a sketch for how the handle could be improved (circled in blue). With the current handle design, the user is encouraged to grab it with their whole hand. A recommendation to improve this is to design something that makes the user use as little contact as possible to operate the dispenser.

Additionally, the disinfectant dispensing mechanism should be incorporated. The motion to dispense disinfectant can be combined with the motion to dispense a wipe.

Material(s) selection should be made, as well as designing for the relevant manufacturing methods.

Finally, the design should be tested with their intended users. The user testing detailed in Chapter 2 - Context can be used as a guide. The outcome of the new user tests can be compared with the previous tests to see what improvements have been made.

To note, there is space in front of the dispenser for the possibility of incorporating a disinfectant dispensing mechanism.

7. DISCUSSION AND CONCLUSION

7.1 Discussion and conclusion

7.1.1 Discussion

The objective of this project was to:

"Create a new dispenser(s) for disinfectant and dry wipes that is contamination-safe with a streamlined use process, to be used by both laboratory technicians and CSIs from the police/the NFI in the laboratory or at crime scenes."

The design process started with an in-depth user study to find out about the user experience with the current wipes and disinfectant dispensers. It was discovered that the experience was unique to each user. Both groups of users (laboratory technicians at the NFI and CSIs with the police) each had similar use processes but they all varied person-to-person. Despite this, the issues they faced were the same across the board (e.g. dispenser falling, difficult to pick up a wipe, disinfectant splashing on to the surface, etc). These identified issues were used to create a user journey and list of requirements to aid in designing the final product.

From that point, an ideation session was carried and the conceptualisation phase started. The target users were not involved in this as the focus was on the physical design. After a few rounds of prototyping and validation, there is a viable and feasible solution for dispensing wipes. It worked fairly reliably during testing but it still requires further development, especially with regards to user-product interaction. For example, the product having as little contact with the user during use, to prevent contamination. All in all, this would solve one of the main complaints the users had - difficulty in picking up a wipe. As for the disinfectant dispensing part, the same prototyping process that was undergone for the wipes dispenser should take place.

Should a fast-to-implement solution be required, one of the less novel designs created during prototyping could be used (specifically the concept 3 prototypes from cycle 1). However, as mentioned earlier in the report, the decision to pursue something more novel (how to mechanically dispense a wipe) would open more possibilities in the future.

7.1.2 Conclusion

Feasibility

As shown in the previous two chapters, there is potential to create a functional product. However, material choice and cost still needs to be taken into account. The latter is especially important as the number of dispensers needed is small (<1000)/not for mass production.

Desirability

It is desirable that the users have a better solution to the current dispensers and this has been the case since the start of this project. Despite this, the desirability of the product design (e.g. the features, user-product interaction) should be checked and validated with the target users. Although the users would like a solution, it has to be the correct one. Moreover, it should be proven that the new design will reduce the risk of contamination occurring, compared to the current dispensers, else it might not be desirable.

Viability

From this point in the project - where the context and user experience has been established, and there is a working mechanism for dispensing wipes - there is a good foundation to continue with developing a disinfectant and wipes dispenser. Once there is a fully functioning product, the implementation should be checked with the client (NFI). As the disinfectant is still in development at this moment, the product requirements and user needs may change.

7.2 Personal reflection

In this subsection, I will write in the first person and reflect on this project: regarding the process, lessons learned and overall sentiment.

I graduated with a Bachelors in mechanical engineering from my previous university and I am currently pursuing a Masters in product design. I saw an opportunity to use both my educations in this project.

I faced many challenges with this project. Firstly, project planning was the main struggle. There were external factors affecting it but disregarding them, what I would do to improve is to be stricter with time management in future projects. More specifically, knowing when to stop doing a task and continue on to the next one. In hindsight, I would have liked to have spent more time on prototyping and designing instead of processing user research data.

Another challenge for me was communication, with the clients and with my supervisors. I truly enjoyed working with them but always struggled with anxiety which sometimes prevents me from taking the initiative to reach out. This might have resulted in a lag in project progress. Even so, I am still working on improving this aspect and I find it necessary to say that I always felt encouraged and motivated after meetings.

As for the positives, I am pleased that I got the opportunity to prototype with this project. My past projects mainly focused on concept design, where visualisations were more important than how and if the product is feasible. I also enjoyed conducting the user research and feel that I learned a lot on how to plan them (i.e. user study guide, data management). With this experience, I have discovered that I would like to pursue more work like this in the future.

Overall, although I would have liked to deliver a more complete product, I am satisfied with how I am leaving this project (i.e. a comprehensive research on the context and a working wipes dispensing mechanism) and ready to conclude my masters studies.

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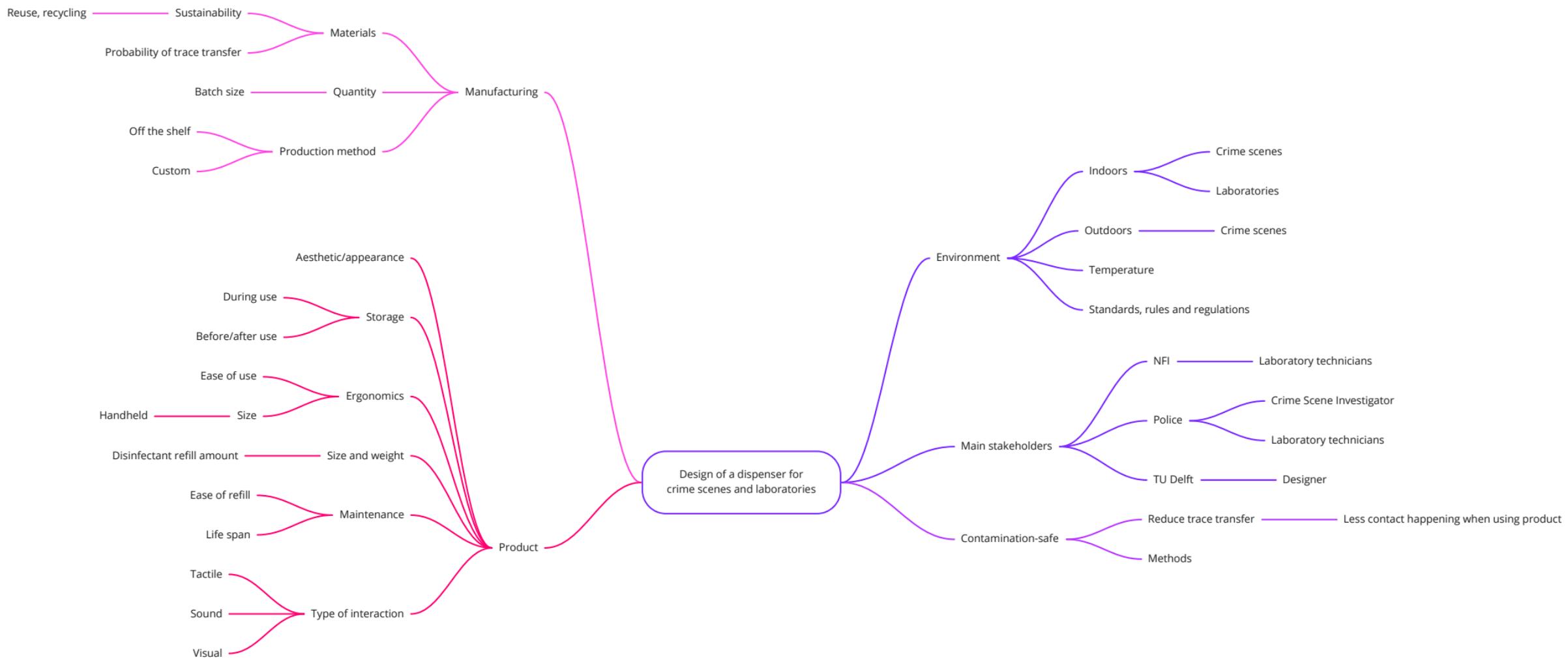
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APPENDIX A

Mind map



APPENDIX B
RNase AWAY™ data
sheet

Safety Data Sheet

(In accordance with COMMISSION REGULATION (EU) No 830/2015)

SECTION 1: Identification of the substance/mixture and of the company/undertaking

Product identifier

Product code 10328011
Product name RNASE AWAY

Chemical Name Not Applicable

REACH registration number No registration number is given yet for this substance / substances in this mixture since the annual import quantity is less than one tonnage per annum or the transition period for its registration according to Article 23 of REACH has not yet expired.

Relevant identified uses of the substance or mixture and uses advised against

Relevant identified uses For research use only
Use Description Code SU22 - Professional uses: Public domain (administration, education, entertainment, services, craftsmen), PROC15 - Use as laboratory reagent, PC21 - Laboratory chemicals, SU24 - Scientific research and development
Uses advised against Not for consumer use.

Details of the supplier of the safety data sheet

Manufacturer/Supplier

LIFE TECHNOLOGIES EUROPE BV
KWARTSWEG 2
2665 NN BLEISWIJK
NETHERLANDS
31-(0)180 392 400
Email: MSDS@lifetech.com

Life Technologies Limited
3 Fountain Drive
Inchinnan Business Park
Paisley
PA4 9RF, UK
+44 (0)141 814 6100

24 hour Emergency Response for Hazardous Materials Within the USA + Canada: 1-800-424-9300 and +1 [or Dangerous Goods] Incident. Spill, Leak, Fire, 703-527-3887
Exposure, or Accident. Call CHEMTREC Outside the USA + Canada: +1 703-741-5970

Country Specific Emergency Number (if available):

CHEMTREC Ireland (Dublin) +(353)-19014670 (Greeting Language: English and Irish)
CHEMTREC UK (London) +(44)-870-8200418 (Greeting Language: English)

SECTION 2: Hazards identification

Classification of the substance or mixture

Classification according to Regulation (EC) No 1272/2008 [CLP]

Physical hazards

Health hazards

Environmental hazards

Label elements

Labelling according to Regulation (EC) No 1272/2008 [CLP]

Hazard pictograms

Signal Word

Not Applicable

Hazard Statements

Not Applicable

Precautionary Statements

Prevention

Not Applicable

Response

Not Applicable

Storage

Not Applicable

Disposal

Not Applicable

Other hazards

Not Applicable

SECTION 3: Composition/information on ingredients

Component	CAS No	EINECS-No.	Weight-%	REACH registration number	Classification according to Regulation (EC) No 1272/2008 [CLP]
Alkali hydroxide (<0.1)	-	Not Listed	<0.1	-	-

SECTION 4: First aid measures

Description of first aid measures

Skin contact	Rinse with plenty of water. Immediate medical attention is not required.
Eye contact	Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing.
Ingestion	Not expected to present a significant ingestion hazard under anticipated conditions of normal use. If you feel unwell, seek medical advice.
Inhalation	Not expected to be an inhalation hazard under anticipated conditions of normal use of this material. Consult a physician if necessary.
Notes to Physician	Treat symptomatically.

Most important symptoms and effects, both acute and delayed

Indication of any immediate medical attention and special treatment needed

IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. IF ON SKIN (or hair): Take off immediately all contaminated clothing. Rinse skin with water/ shower.

SECTION 5: Firefighting measures

Extinguishing media

Suitable extinguishing media	Use fire extinguishing materials appropriate for surrounding materials.
Unsuitable extinguishing media	No information available.

Special hazards arising from the substance or mixture

Not known.

Advice for fire-fighters

Wear self-contained breathing apparatus and protective suit.

SECTION 6: Accidental release measures

Personal precautions, protective equipment and emergency procedures

Ensure adequate ventilation
Always wear recommended Personal Protective Equipment
Use personal protection equipment
See Section 8 for more detail.

Environmental precautions

Avoid discharge into drains and waterways whenever possible.

Methods and material for containment and cleaning up

Soak up with inert absorbent material.

Reference to other sections

See section 8 for more information.

SECTION 7: Handling and storage

Precautions for safe handling

Use personal protective equipment as required. No special handling advices are necessary.

Conditions for safe storage, including any incompatibilities

Keep in a dry, cool and well-ventilated place. Keep in properly labelled containers.

Specific end use(s)

For research use only.

SECTION 8: Exposure controls/personal protection

Control parameters

Chemical Name	EU OEL (TWA)	EU OEL (STEL)	EU Skin Notation	
Alkali hydroxide	None	None	None	
Chemical Name	Austria	Belgium (TWA)	Denmark (TWA)	Finland OEL (TWA)
Alkali hydroxide	None	None	None	None
Chemical Name	France OEL (VME)	Germany OEL (TWA)	Ireland (TWA)	Italy OEL (TWA)
Alkali hydroxide	None	None	None	None
Chemical Name	Sweden - Occupational Exposure Limits - TLVs (LLVs)	Netherlands OEL (MAC)	Spain OEL (TWA)	United Kingdom
Alkali hydroxide	None	None	None	None
Chemical Name	European Union	France OEL (VME)	Germany OEL (TWA)	
Alkali hydroxide	None	None	None	
Chemical Name	Italy OEL (TWA)	Portugal	Netherlands OEL (MAC)	Finland OEL (TWA)
Alkali hydroxide	None	None	None	None
Chemical Name	Austria	Denmark	Poland	Switzerland
Alkali hydroxide	None	None	None	None
Chemical Name	Ireland	Norway	Lithuania OEL (TWA)	Spain OEL (TWA)
Alkali hydroxide	None	None	None	None

Engineering measures Ensure adequate ventilation, especially in confined areas.

Exposure controls

Personal protection equipment

Respiratory protection In case of insufficient ventilation wear respirators and components tested and approved under appropriate government standards.

Hand protection Wear suitable gloves. Glove material: Compatible chemical-resistant gloves.

Eye protection Tight sealing safety goggles.

Skin and Body Protection Wear suitable protective clothing.

Hygiene Measures Handle in accordance with good industrial hygiene and safety practice.

Environmental exposure controls

No special environmental precautions required.

SECTION 9: Physical and chemical properties

Information on basic physical and chemical properties

Appearance	liquid	
Odour	No data	
pH	>6-8	
Melting point / melting range	°C Mixture has not been tested	°F Mixture has not been tested
Boiling point / boiling range	°C Mixture has not been tested	°F Mixture has not been tested
Flash point	°C Mixture has not been tested	°F Mixture has not been tested
Autoignition Temperature	°C Mixture has not been tested	°F Mixture has not been tested
Decomposition temperature	°C Mixture has not been tested	°F Mixture has not been tested
Evaporation rate	No data	
Flammability (solid, gas)	No data	
Upper explosion limit	Mixture has not been tested	
Lower explosion limit	Mixture has not been tested	
Vapour Pressure	Mixture has not been tested	
Relative density	Mixture has not been tested	
Specific gravity	No data	
Solubility	No data	
Partition coefficient:	No data	
n-octanol/water		
Viscosity	No data	
Explosive properties	Mixture has not been tested	
Oxidising properties	No data	

Other information

No data.

SECTION 10: Stability and reactivity

Reactivity	No information available.
Chemical stability	Stable under normal conditions.
Possibility of hazardous reactions	Hazardous reaction has not been reported.
Conditions to avoid	None known.
Incompatible materials	No dangerous reaction known under conditions of normal use.
Hazardous decomposition products	No known hazardous decomposition products.

SECTION 11: Toxicological information

Information on toxicological effects

Chemical Name	LD50 (oral, rat/mouse)	LD50 (dermal, rat/rabbit)	LC50 (inhalation, rat/mouse)
Alkali hydroxide	No data available	No data available	No data available

Principal Routes of Exposure,

Skin corrosion/irritation	Conclusive but not sufficient for classification
Serious eye damage/irritation	Conclusive but not sufficient for classification
Respiratory or skin sensitisation	Conclusive but not sufficient for classification
Specific target organ toxicity (STOT) – single exposure	Conclusive but not sufficient for classification
Specific target organ toxicity (STOT) – repeated exposure	Conclusive but not sufficient for classification
Carcinogenicity	Conclusive but not sufficient for classification
Germ cell mutagenicity	Conclusive but not sufficient for classification
Reproductive Toxicity	Conclusive but not sufficient for classification
Aspiration Hazard	Conclusive but not sufficient for classification

SECTION 12: Ecological information

Toxicity

The environmental impact of this product has not been fully investigated.

Chemical Name	Freshwater Algae Data	Water Flea Data	Freshwater Fish Species Data	Microtox Data	log Pow
Alkali hydroxide	No data available	No data available	No data available	No data available	No data available

Persistence and degradability No information available.

Bioaccumulative potential No information available.

Results of PBT and vPvB assessment

No information available.

Other adverse effects

No information available.

SECTION 13: Disposal considerations

Waste treatment methods

The generation of waste should be avoided or minimized wherever possible. Empty containers or liners may retain some product residues. This material and its container must be disposed of in according to approved disposal technique. Disposal of this product, its solutions or of any by-products, shall comply with the requirements of all applicable local, regional or national/federal regulations.

SECTION 14: Transport information

IATA / ADR / DOT-US / IMDG

Not regulated in the meaning of transport regulations

UN number	Not Applicable
UN proper shipping name	Not Applicable
Transport hazard class(es)	Not Applicable
Packing group	Not Applicable

Environmental hazards

Not Applicable

Special precautions for user

Not Applicable

Transport in bulk according to Annex II of MARPOL and the IBC Code

Not Applicable.

SECTION 15: Regulatory information

Safety, health and environmental regulations/legislation specific for the substance or mixture

Substances of Very High Concern

EU REACH (1907/2006) - Annex XIV - Substances Subject to Authorization

None

Restricted substances under EC 1907/2006, Annex XVII

Substances listed under Annex I of Regulation (EC) No 689/2008

None.

Restricted substances under Annex V of Regulation (EC) No 689/2008

None.

Substances under Regulation (EC) No 850/2004 of the European Parliament and of the Council of 29 April 2004 on persistent organic pollutants and amending Directive 79/117/EEC

None.

German Water hazard classes (Wassergefährdungsklassen)

Other International Inventories

Chemical Name	EINECS (European Union)	ELINCS (European List of Notified Chemical Substances)	ENCS (Japan)	PICCS (Philippines)
Alkali hydroxide	-	-	-	-
Chemical Name	AICS (Australia)	South Korea (KECL)	Canada (DSL)	NDSL
Alkali hydroxide	-	-	-	-

Chemical safety assessment

No Chemical safety assessment has been carried out.

SECTION 16: Other information

Reason for revision Update according to Commission Regulation (EU) No 830/2015

Revision number 3

Revision date 13-Dec-2017

References

- ECHA: <http://echa.europa.eu/>
- TOXNET: <http://toxnet.nlm.nih.gov/>
- eChemPortal: <http://www.echemportal.org/>
- LOLI database: <https://www.chemadvisor.com/loli-database>

Classification and procedure used to derive the classification for mixtures according to Regulation (EC) 1272/2008 [CLP]:

"The above information was acquired by diligent search and/or investigation and the recommendations are based on prudent application of professional judgment. The information shall not be taken as being all inclusive and is to be used only as a guide. All materials and mixtures may present unknown hazards and should be used with caution. Since the Company cannot control the actual methods, volumes, or conditions of use, the Company shall not be held liable for any damages or losses resulting from the handling or from contact with the product as described herein.

THE INFORMATION IN THIS SDS DOES NOT CONSTITUTE A WARRANTY, EXPRESSED OR IMPLIED, INCLUDING ANY IMPLIED WARRANTY OF MERCHANTABILITY OR FITNESS FOR ANY PARTICULAR PURPOSE"

APPENDIX C
Pipette tip rack data
sheet

Pipette Tips

For Purity and Convenience These Tips Deliver



Ultra Pure

BioClean Ultra tips are manufactured in Class 100,000 cleanroom conditions, rigorously tested for a broad range of contaminants and carefully wrapped to preserve and protect their purity until ready for use.



Hinged/Removable Lid

The multifunction lid offers complete flexibility. A special hinge allows the lid to open to a full 120°. Press it further and the lid releases from the box. These racks are sturdy, stackable and fully autoclavable.



Multichannel Friendly

Whether your pipette has 8 or 12 channels, the walls of the tip box are tapered to allow full or partial tip loading.



Opens with One Hand

The safety latch on the front of the rack prevents tips from accidental spills. The latch opens easily with gentle pressure from your thumb and index fingers.



BioClean Ultra Pipette Tips

Tighter Purity Standard; New Packaging

BioClean® has long been the standard for assuring customers that Rainin tips are high quality and free of biological contaminants. With BioClean Ultra, we've made these industry-leading measures more stringent and comprehensive by expanding detection levels to include protein and protease.

BioClean TM **ultra** With the introduction of the BioClean Ultra standard, we introduced a new rack and refill system that delivers exceptional ease and convenience, particularly for researchers who prefer a hinged lid.

Note: New packaging for RT racked tips, Green-Pak® and SpaceSaver®. TerraRack®, StableRak™ and StableStak™ have not changed.

METTLER **TOLEDO**

Feature-Rich Rack and Refill System

At last, a rack and refill system that works with you.



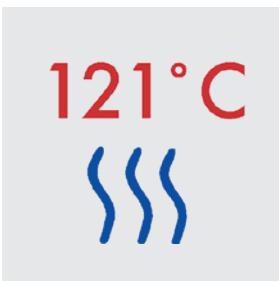
Lighter Weight

Integrating the tip deck and base adds strength and stability. The result: we've reduced the amount of plastic used in each by an average of 20%. Less plastic means less weight and less plastic waste.



Stackable

Our new rack stacks five high for orderly, space-saving storage. High-resolution labeling on the front of the racks provide product details in an easy-read format. The colored tip decks extend along the perimeter of the box, making the volume readily apparent.



Autoclavable

Our new racks are fully autoclavable and can withstand many trips through the autoclave. They're refillable with the Green-Pak single rack refill or from our SpaceSaver stacked refill system.

BioClean UltraTM

The new standard for tip purity

For accurate results, you need to be certain your pipette tips are free from biological contaminants. Rainin's stringent BioClean Ultra test regimen assures you that you're using the finest, most pure tips available.

Contaminants Tested

Contaminants Tested	Testing Detection Levels
RNase	$\leq 10^{-9}$ Kunitz units/ μ L
DNase	$\leq 10^{-7}$ Kunitz units/ μ L
Human DNA	< 0.32 pg
Bacterial DNA	< 1 pg
Endotoxin	≤ 0.001 EU/mL
ATP	$< 2 \times 10^{-12}$ mg/ μ L
Protein	< 2 ng/lane (no visible band)
Protease	≤ 500 ng/mL
PCR Inhibitors	None detected

Rainin, Pipetting 360°, BioClean, LTS, Green-Pak, SpaceSaver and TerraRack are registered trademarks, and BioClean Ultra, StableStak and StableRack are trademarks of Mettler-Toledo Rainin, LLC.



METTLER TOLEDO Group

Laboratory Division

Local contact: www.mt.com/contacts



Subject to technical changes

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For more information

APPENDIX D
Amplitude™ Delta™
wipes data sheet

Pipette Tips

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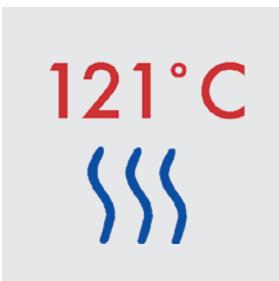
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Our new rack stacks five high for orderly, space-saving storage. High-resolution labeling on the front of the racks provide product details in an easy-read format. The colored tip decks extend along the perimeter of the box, making the volume readily apparent.



Autoclavable

Our new racks are fully autoclavable and can withstand many trips through the autoclave. They're refillable with the Green-Pak single rack refill or from our SpaceSaver stacked refill system.

BioClean UltraTM

The new standard for tip purity

For accurate results, you need to be certain your pipette tips are free from biological contaminants. Rainin's stringent BioClean Ultra test regimen assures you that you're using the finest, most pure tips available.

Contaminants Tested

Contaminants Tested	Testing Detection Levels
RNase	$\leq 10^{-9}$ Kunitz units/ μ L
DNase	$\leq 10^{-7}$ Kunitz units/ μ L
Human DNA	< 0.32 pg
Bacterial DNA	< 1 pg
Endotoxin	≤ 0.001 EU/mL
ATP	$< 2 \times 10^{-12}$ mg/ μ L
Protein	< 2 ng/lane (no visible band)
Protease	≤ 500 ng/mL
PCR Inhibitors	None detected

Rainin, Pipetting 360°, BioClean, LTS, Green-Pak, SpaceSaver and TerraRack are registered trademarks, and BioClean Ultra, StableStak and StableRack are trademarks of Mettler-Toledo Rainin, LLC.



METTLER TOLEDO Group

Laboratory Division

Local contact: www.mt.com/contacts



Subject to technical changes

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For more information

APPENDIX E
User study plan:
Questionnaire

Method 1: Questionnaire

As mentioned earlier, this questionnaire aims to find out the most common object cleaned, in order to have consistent actions to test in user observations.

Participants

Number of participants: >15 participants

Participant demographics:

- Gender: N/A
- Age: N/A
- Occupation: CSIs' and laboratory technicians

Duration: ~5 minutes

Procedure

The questionnaire will be presented on a MS Teams form.

Questionnaire

Hello. I am a Masters product design student at TU Delft looking to develop a new disinfectant and wipes dispenser that will reduce the chances of trace transfer/contamination. This questionnaire will take approximately 5 mintues. Your data will be used only for the project and will be completely confidential. Thank you!

Question 1: What is your job title?

- Laboratory technician
- Crime Scene Investigator
- Other: _____

Question 2: Do you use or have you used the dispensers in the image (image of the newest dispenser)?

- Yes
- No

If no: section A

Question A-3: Do you have to clean tools/equipment at work?

- Yes
- No

If yes:

Question A-4: Please describe the dispenser(s) you use to clean tools. Short text.

Question A- 5: What tools do you normally clean? Please select all that apply.

- Tweezers (pincet)
- Scissors
- Wire cutters (kniptang)
- Ruler (liniaal)
- Gloves
- Cups
- Table
- Pen/marker
- Other: _____

If no: end questionnaire.

If yes: section B

Question B-3: How many times have you used this dispenser?

- Once
- Once every few months
- Once a month, on average
- Once a week, on average
- Once a day, on average
- Many times per day

Question B-4: How often do you have to clean tools/equipment?

- Once every few months
- Once a month, on average
- Once a week, on average
- Once a day, on average
- Many times per day
- Less than the above stated

Question B-5: Where do you use the dispensers? Please select all that apply.

- Laboratory
- Crime scene
- Other: _____

Question B-6: What tools do you normally clean? Please select all that apply.

- Tweezers (pincet)
- Scissors
- Wire cutters (kniptang)
- Ruler (liniaal)
- Gloves
- Cups
- Table
- Pen/marker
- Other: _____

Results

Qualitative results will be presented in tables and quantitative as graphs/pie charts.

Table 3. Example results table for questionnaire responses

Question/parameter: ?	
Positives	
Similarities between participants	
Differences between participants	
Negatives	
Similarities between participants	
Differences between participants	

APPENDIX F
User study plan: User
observation study

Method 2: User observations

Participants

Number of participants: 7

Participant demographics:

- Gender: Irrelevant
- Age: Irrelevant
- Occupation: Laboratory technicians at the NFI

Duration: ~30 minutes

Tools and equipment

- Fluorescent powders
- Baby oil
- Camera for filming
- Camera with UV light
- A3 paper
- Dispensers (3 per participant)
- Gloves
- 3 objects to be cleaned by the participant, which will be known after the questionnaire is conducted (9 total per participant)

Procedure

The user observations will be conducted in a laboratory at the NFI. Firstly, the camera is to be set up on a tripod in front of the participant's workspace and at a height where the participant's head is not in frame. The study will thus begin with an introduction to the participant and they will be asked to sign the informed consent form on a tablet. Then, the user observation will be carried out as detailed in "User observation steps". The researcher will stand or sit at the side, out of the way of the participant.

Introduction to the participants

Hello, I'm Josephine and together with the NFI, I am working on a project to redesign a disinfectant dispenser that is used to clean tools. In this study today, you will be asked to clean 3 different objects and with 3 repeats each, there will be a total of 9 objects for you to clean. Please work as you normally do. Fluorescent powder will be dusted on your gloves, a different colour for each hand, and we will be able to see the areas where you come in contact with under a UV light later. The purpose of this study is to observe your process and also to help inform design decisions so that we can create a new product that is easy to use and contamination-safe. If you consent to participating in this study and allowing me to record your responses, please read and sign this informed consent form.

User observation steps

1. Lay down a sheet of paper on the surface where the participant is to work. Place the dispenser and object on it.
2. The participant will already have their gloves on because they are already in the lab. Apply a layer of oil on the gloves so that the fluorescent powders can stick on them.
3. Two fluorescent powders will be dusted on their gloves, with colour X on the right hand and colour Y on the left hand.*
4. The camera shall now begin filming. Ask the participant to clean Object 1.
5. The participant cleans another two of Object 1.
6. Stop recording. Slide the sheet of paper away with the dispenser.
7. Then, give them a new dispenser and gloves. They will remove their current gloves and put on the new ones, as they normally do. Repeat steps 1-5 but with Object 2.
8. Repeat step 6 and 7 but with Object 3.
9. Conduct a short interview with them to ask about their process (see post-observation interview short guide).**
10. When the participant has left, take pictures of the 3 dispensers used with the camera with UV light. For the wipe

1. dispenser, take pictures of the: front, left, right, back, top and bottom (6 sides). For the disinfectant dispenser, take pictures of the: top with the cap on, top with the cap off and bottom. Rotate the bottle in 45deg increments (approximately), taking a photo each angle.

* Although the source of contamination will be from the object to be cleaned in the real life scenario, the amount of fluorescent powder that would transfer from them to the dispenser will be negligible. Thus, it was decided that the fluorescent powders will go on the gloves instead to show the contact between the participant and dispenser. This keeps in line with the assumption that contact transfers traces (Locard's Principle).

** During the user observation, the observer shall not interact with the participant in any way. This is so that the participant's actions are not influenced by having to talk, think aloud, etc. Therefore, the participants will be asked about their thoughts regarding the cleaning process after.

Post-observation interview short guide

- Talk me through your process. Tell me about the before, during and after of cleaning your tools. Go through notes written during the observation, if there are any.
- Is any part of the process inconvenient, or that you dislike?
- Which hand is dominant, left or right?
- How long have you worked this job?

Results

The researcher will go over the videos of the participants cleaning the objects and the pictures of the UV-lit dispensers, and record the required results (see Tables 1 and 2). These results will be put into the tables shown on the following page. Furthermore, timelines with points marked out will be created for each participant to record each time contact is made with the dispenser during the cleaning process so that there is a visual overview of their process.

To find the surface area covered in fluorescent powder (%), the UV-lit dispenser photos will first be loaded onto Adobe Photoshop. For the photos of the (cylindrical) disinfectant dispenser, they will be stitched together to make a continuous image in a way that it looks like the cylinder is unrolled and flat (panorama). Then, the areas with fluorescent powder will be isolated. The number of pixels for these areas will be counted and compared against the total number of pixels for the whole dispenser to find the surface area covered in fluorescent powder in terms of percentage.

Table 1. Example results table

Parameter	Participant/ Attempt	Object 1			Object 2			Object 3		
		1	2	3	1	2	3	1	2	3
Frequency of contact (number of times)	A									
	B									
	C									
	D									
	E									
	F									
	G									
Total duration of contact (s)	A									
	B									
	C									
	D									
	E									
	F									
	G									
Average frequency of contact (times)										
Average duration of contact (s)										

Table 2. Example results table

Surface area of dispenser covered in fluorescent powder (%)	Participant	Object 1	Object 2	Object 3
From left hand	A			
	B			
	C			
	D			
	E			
	F			
	G			
From right hand	A			
	B			
	C			
	D			
	E			
	F			
	G			
Total (both hands)	A			
	B			
	C			
	D			
	E			
	F			
	G			
Overall average	All			

APPENDIX G
User study plan:
Interviews

Method 3: Interviews

Participants

Number of participants: The aim will be between 5 - 7 participants

Participant demographics:

- Gender: Irrelevant
- Age: All ages
- Occupation: CSIs with the police

Duration: ~20 minutes

Tools and equipment

Laptop/phone and interview guide.

Procedure

The interview may take place online, over a Zoom meeting, or the researcher (Josephine) may travel and meet with the interviewee. If the case is the former, the interview will be recorded (audio and visual) on the laptop with the OBS software. The participant will also be asked to sign the informed consent form on a tablet instead of via e-mail. If the latter, a phone will be used to voice-record. During the interview, the interview guide will be referred to on a tablet. The interview guide serves, as the name suggests, as a guide and additional questions may be asked if necessary. Certain questions may also be skipped depending on the participant's responses.

Interview guide

Introduction to the participant:

Hello, I'm Josephine and together with the NFI, I am working on a project to redesign a disinfectant dispenser that is used to clean tools. Thank you for agreeing to have an interview with me. It will take approximately 15 minutes. Your answers will help to create a new product that is easy to use and contamination-safe. If you consent to participating in this interview and allowing me to record your responses, please read and sign the informed consent form which you can find in your e-mail and send it back to me later.

Firstly, I would like to ask some basic questions about your job.

Who is the participant?

- Job description: Can you briefly describe to me what you do?
- Experience: How long have you worked at this job?

Context:

- Where do you generally work? Assumption: crime scenes would be one of the places.
- How similar would you say crime scenes/laboratories are? Can you elaborate?

Process/workflow:

- Now, I would like to talk to you about the tool cleaning part of your job. Is there a specific procedure you follow when cleaning your tools?
 - ◊ If they don't mention the items they use: Can you describe to me what items you use to clean your tools?
 - ◊ If more detail is needed on the dispenser: Could you describe to me what dispenser you use?
 - ◊ How do you differentiate between the items you use when working? Assumption: the dispenser needs labelling.
- Do you think it is a quick and easy process to use the dispenser?
 - ◊ For a quantitative answer: How much time would you say it takes?
- How often do you have to clean tools with the dispenser?
- Before you start using the dispenser, do you check how much disinfectant is in the bottle?
 - ◊ Do you refill the dispenser? How?

- ◊ How long does one refill of a dispenser last with regular use?
- How do you store the dispenser?
- Where is the dispenser placed at the crime scene/laboratory while you are working?
- Do you share the dispenser with colleagues?
 - ◊ If yes: How many colleagues do you have to share with?
- Can you tell me what steps you take to prevent transferring any traces from the items you are cleaning?

Personal opinion:

- Do you have anything you dislike about the dispenser? What about good things?
- Do you have improvements you can suggest?
- Now, I will show you a new dispenser. What do you think about it?
- Would you be interested in staying up to date with this project?

Results

Answers from the participants will be tabled to show a clear overview of the insights gained.

Table 3. Example results table

Question/parameter: ?	
Positives	
Similarities between participants	
Differences between participants	
Negatives	
Similarities between participants	
Differences between participants	

APPENDIX H
Consent forms

Design of a dispenser for crime scenes and laboratories

This research is conducted as part of the MSc study Industrial Design Engineering at TU Delft.

Contact: Josephine Leong, josephineleongzhennian@student.tudelft.nl

Informed Consent Form

Participant information

Hello! You are being invited to participate in a research study for a master's thesis project titled "design of a dispenser for crime scenes and laboratories". The purpose of this study is to observe your process and also to help inform design decisions so that we can create a new product that is easy to use and contamination-safe.

You will be taking part in the following activities:

1. User observation

You will be asked to clean 3 different objects and with 3 repeats each. There will be a total of 9 objects for you to clean. Fluorescent powder will be dusted on your gloves, a different colour for each hand, and we will be able to see the areas where you come in contact with under a UV light later. This observation will be recorded.

2. Post-user observation interview

After the user observation, you will be asked a few questions about your process during the user observation. This interview will be recorded and transcribed.

Pseudonymised (meaning that, instead of using your name, your data will be assigned a unique participant number) data and findings will be used for the master's thesis and may be shared with other researchers through publications and presentations. Your participation in this study is entirely voluntary and you can withdraw at any time. There will be no negative consequences for withdrawing.

Explicit Consent Points

1. I have read, or someone has read, the study information and I understand the content. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
2. I consent voluntarily to be a participant in this study.
3. I understand that taking part in the study involves: user observation and post-user observation interview.
4. I understand that I can refuse to answer questions and can ask for activities to be stopped at any point during the study with no negative consequences. Data collection software will be turned off and devices will be removed immediately.
5. I understand that taking part in the study involves collecting specific personally identifiable information (name, email, phone number, photos, videos) with the potential risk of my identity being revealed.
6. I understand that taking part in the study involves collecting video footage (that is anonymised) of myself.
7. I understand that collected data will be pseudonymised and stored on secure platforms provided by TU Delft after the completion of the master's thesis project for a period of 10 years.
8. I understand that I can ask to remove all my data until the end date of the master's thesis and that it is not possible after said end date.
9. I understand that personal information collected about me that can identify me, such as my name, e-mail address and phone number, will not be shared beyond the study team and will be destroyed as soon as the master thesis project is completed.
10. I understand that after the research study the de-identified information I provide will be used for the master's thesis and may be shared with other researchers through publications and presentations.
11. I give permission that my responses, views, or other input can be quoted pseudonymously in research outputs.
12. I give permission that unrecognisable photos can be used in research outputs.

Please express your consent to the above-mentioned points by sending a reply to this email that states "I give consent." OR by signing the below.

Last name

First name

____ / ____ / 2022

Date (dd/mm/yyyy)

Signature

Design of a dispenser for crime scenes and laboratories

This research is conducted as part of the MSc study Industrial Design Engineering at TU Delft.

Contact: Josephine Leong, josephineleongzhennian@student.tudelft.nl

Informed Consent Form

Participant information

Hello! You are being invited to participate in a research study for a master's thesis project titled "design of a dispenser for crime scenes and laboratories". The purpose of this study is to observe your process and also to help inform design decisions so that we can create a new product that is easy to use and contamination-safe.

You will be taking part in the following activity:

1. User interview

The interview may take place online, over a Zoom meeting, or in person. You will be asked questions about the work that you do, your use of the dispenser to clean tools and how you find the experience when interacting with the dispenser. This interview will be recorded and transcribed.

Pseudonymised (meaning that, instead of using your name, your data will be assigned a unique participant number) data and findings will be used for the master's thesis and may be shared with other researchers through publications and presentations. Your participation in this study is entirely voluntary and you can withdraw at any time. There will be no negative consequences for withdrawing.

Explicit Consent Points

1. I have read, or someone has read, the study information and I understand the content. I have been able to ask questions about the study and my questions have been answered to my satisfaction.
2. I consent voluntarily to be a participant in this study.
3. I understand that taking part in the study involves: user interview.
4. I understand that I can refuse to answer questions and can ask for activities to be stopped at any point during the study with no negative consequences. Data collection software will be turned off and devices will be removed immediately.
5. I understand that taking part in the study involves collecting specific personally identifiable information (name, email, phone number, photos, videos) with the potential risk of my identity being revealed.
6. I understand that taking part in the study involves collecting video footage (that is anonymised) of myself.
7. I understand that collected data will be pseudonymised and stored on secure platforms provided by TU Delft after the completion of the master's thesis project for a period of 10 years.
8. I understand that I can ask to remove all my data until the end date of the master's thesis and that it is not possible after said end date.
9. I understand that personal information collected about me that can identify me, such as my name, e-mail address and phone number, will not be shared beyond the study team and will be destroyed as soon as the master thesis project is completed.
10. I understand that after the research study the de-identified information I provide will be used for the master's thesis and may be shared with other researchers through publications and presentations.
11. I give permission that my responses, views, or other input can be quoted pseudonymously in research outputs.
12. I give permission that unrecognisable photos can be used in research outputs.

Please express your consent to the above-mentioned points by sending a reply to this email that states "I give consent." OR by signing the below.

Last name

First name

____ / ____ / 2022
Date (dd/mm/yyyy)

Signature

APPENDIX I

Processed images

Participant D - Disinfectant dispenser (Attempt 1)

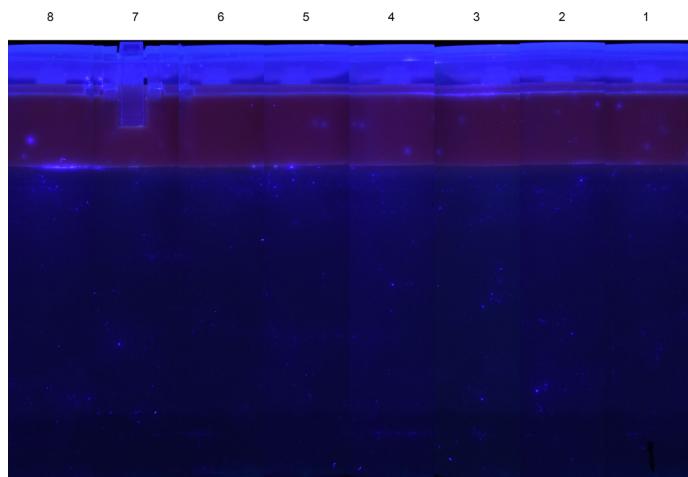


Figure 1. Cropped images of the clean dispenser. Total pixel count: 188566px

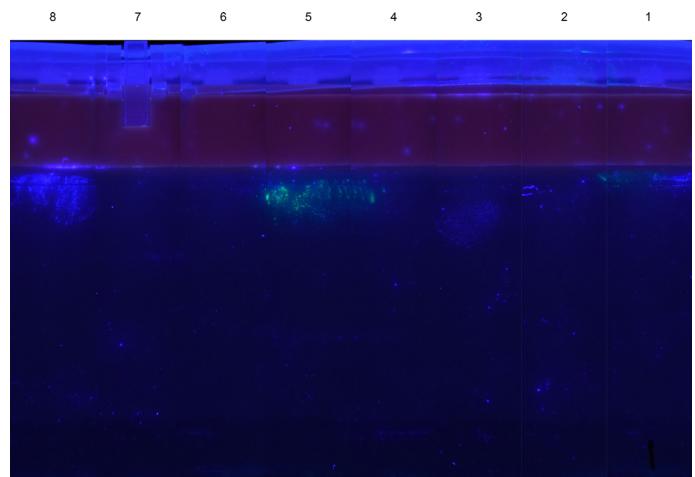


Figure 2. Cropped images of the used dispenser

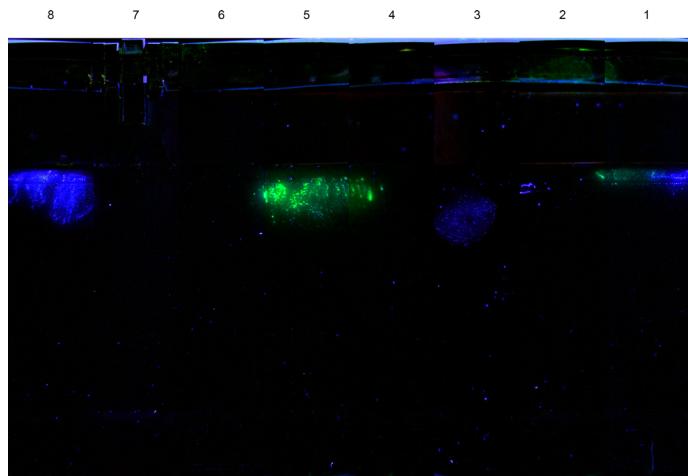


Figure 3. Figure 2 subtracted from figure 1. Isolated areas pixel count: 55921px

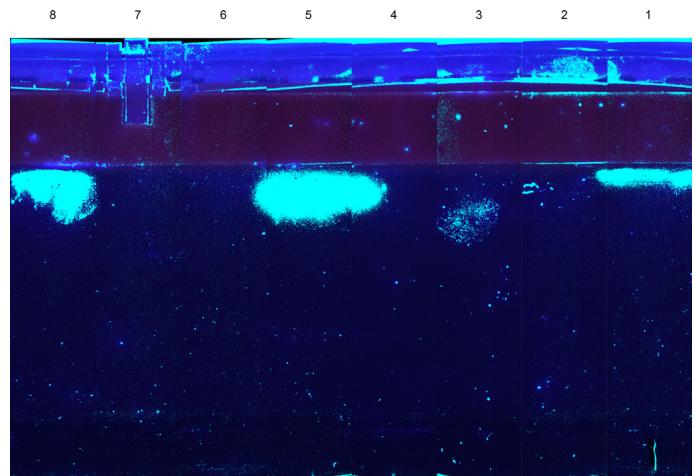


Figure 4. Final image of finger/handprints overlaid on figure 1

Table 1

Actions	Observation notes
Opening disinfectant dispenser	Used their right hand to hold the bottom part and their left hand to open the lid (without using their fingertips)
Closing disinfectant dispenser	Uses their right hand to close the lid and their left hand to hold the bottom part.

Participant D - Disinfectant dispenser (Attempt 2)

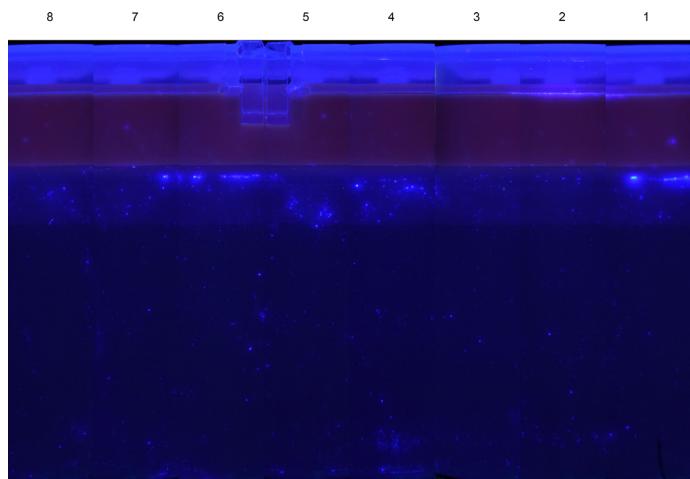


Figure 5. Cropped images of the clean dispenser. Total pixel count: 187782px

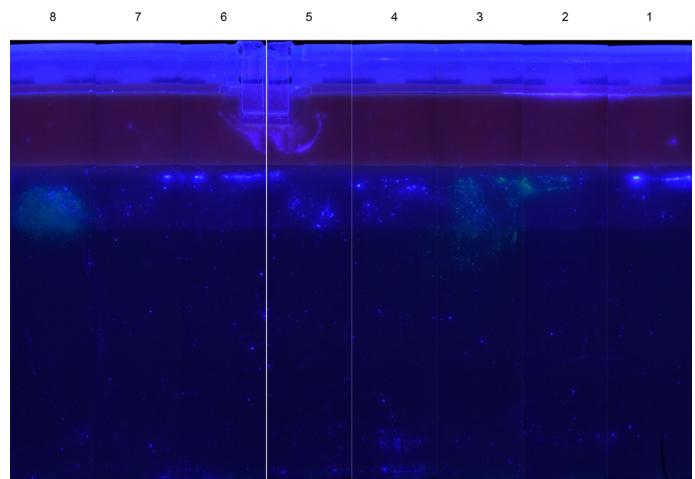


Figure 6. Cropped images of the used dispenser

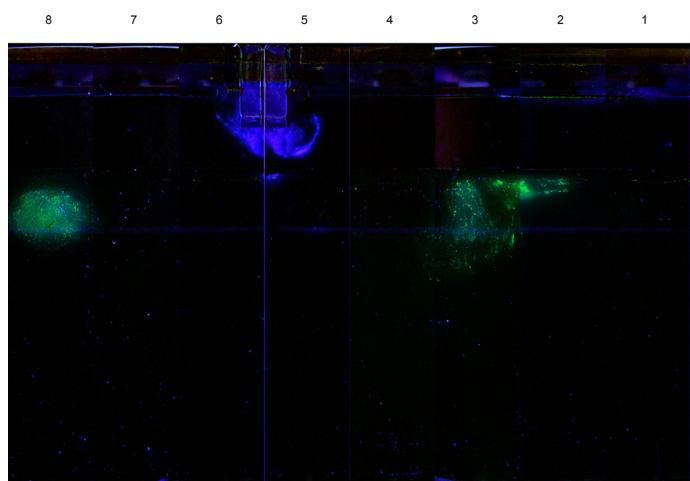


Figure 7. Figure 6 subtracted from figure 5. Isolated areas pixel count: 39058px

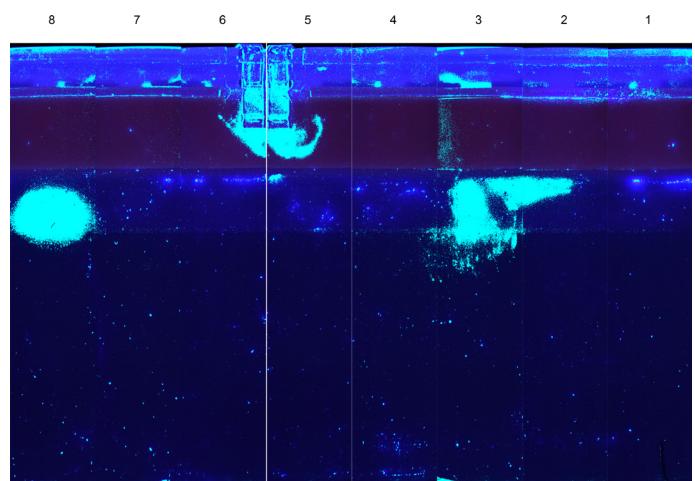


Figure 8. Final image of finger/handprints overlaid on figure 5

Table 2

Actions	Observation notes
Opening disinfectant dispenser	Uses their right hand to open the lid and their left hand to hold the bottom part.
Closing disinfectant dispenser	Uses their right hand to close the lid and their left hand (palm area) to hold the bottom part.

Participant D - Disinfectant dispenser (Attempt 3)

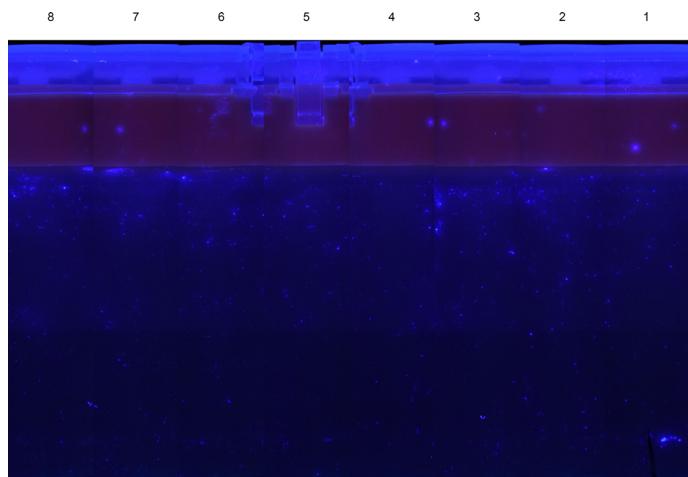


Figure 9. Cropped images of the clean dispenser. Total pixel count: 188139px

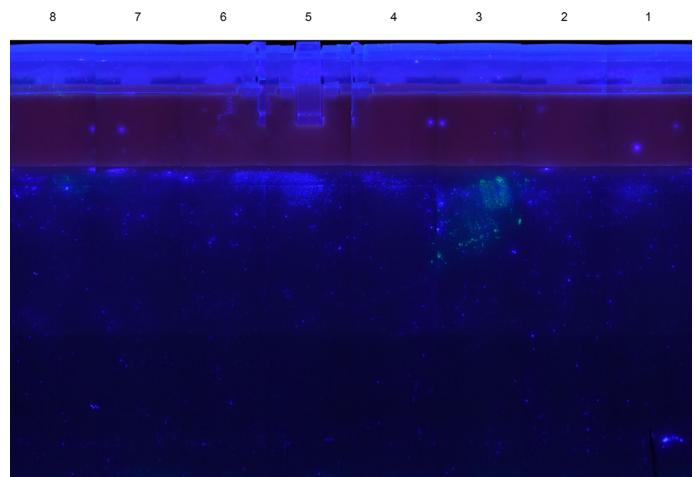


Figure 10. Cropped images of the used dispenser

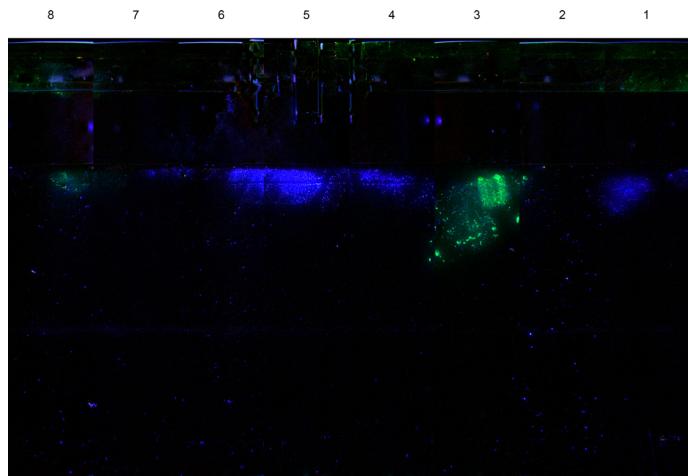


Figure 11. Figure 10 subtracted from figure 9. Isolated areas pixel count: 41868px

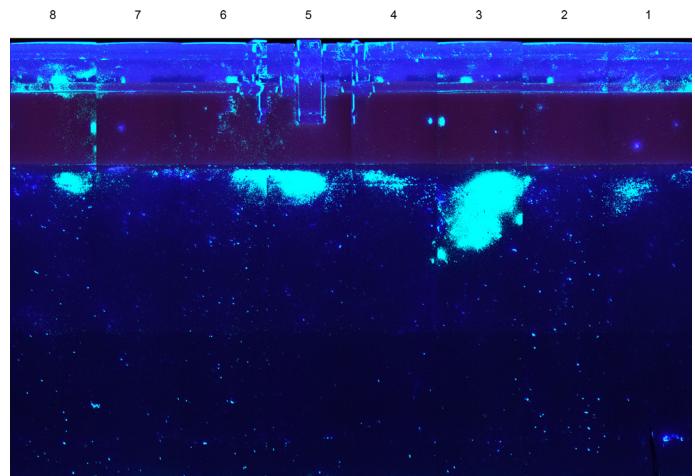


Figure 12. Final image of finger/handprints overlaid on figure 9

Table 3

Actions	Observation notes
Opening disinfectant dispenser	Right hand holds the bottom part and left hand opens the lid
Closing disinfectant dispenser	Uses their right hand to close the lid and their left hand to hold the bottom part.

Participant D - Wipes dispenser (Attempt 1)

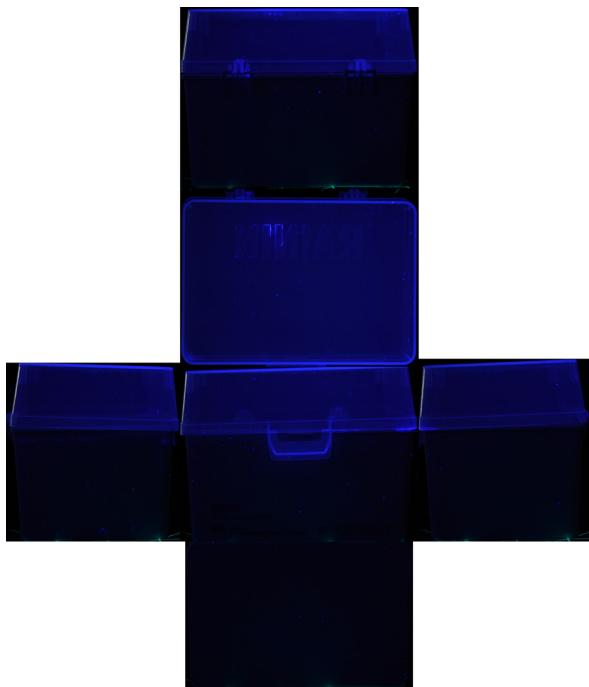


Figure 13. Cropped images of the clean dispenser. Total pixel count: 463793px

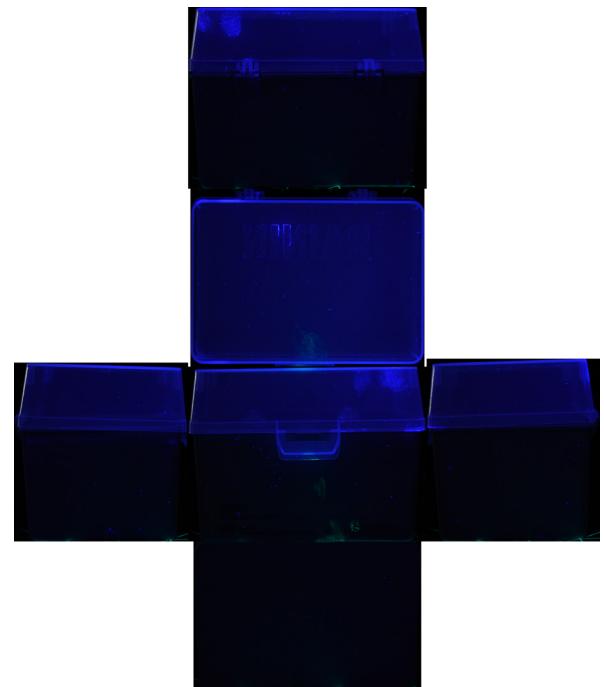


Figure 14. Cropped images of the used dispenser

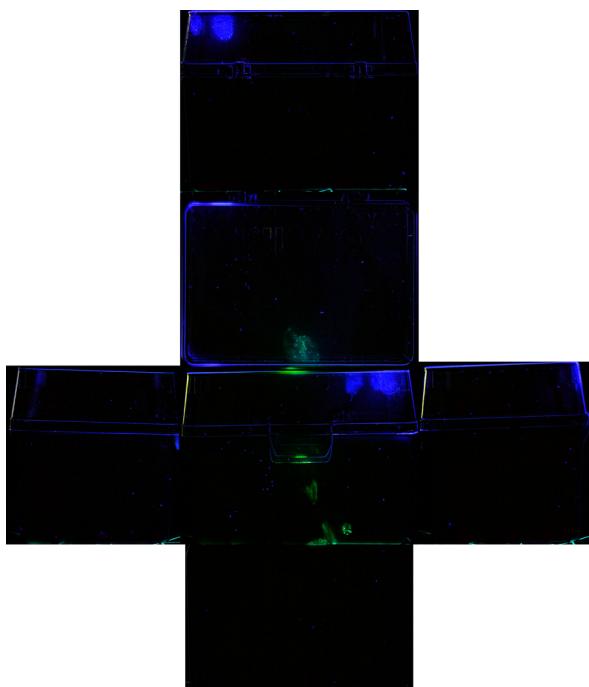


Figure 15. Figure 14 subtracted from figure 13. Isolated areas pixel count: 337770px

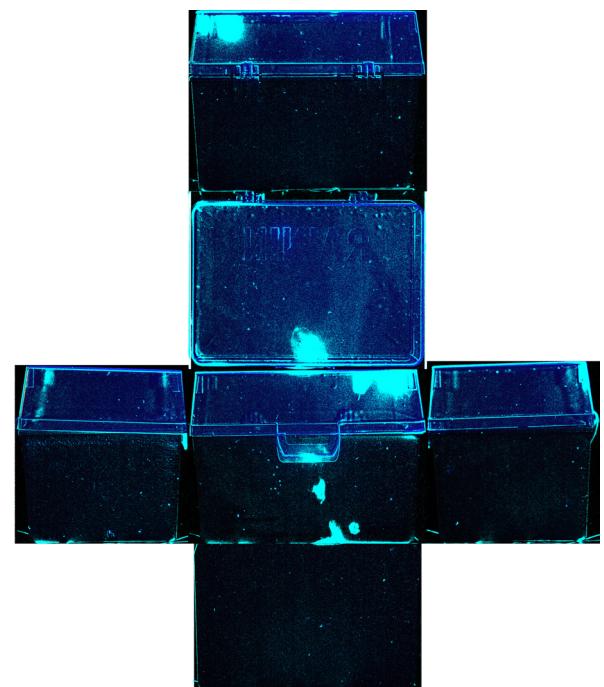


Figure 16. Final image of finger/handprints overlaid on figure 13

Table 4

Actions	Observation notes
Opening wipes dispenser	Uses their right hand to open the lid and their left hand to hold the bottom part. The dispenser tilted and moved backwards a bit
Closing wipes dispenser	Uses their right hand to close the lid and their left hand to hold the bottom part.

Participant D - Wipes dispenser (Attempt 2)

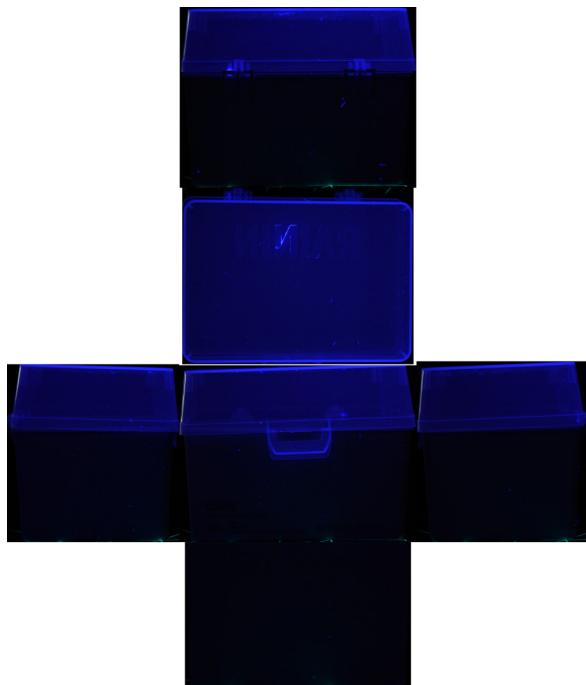


Figure 17. Cropped images of the clean dispenser. Total pixel count: 468332px

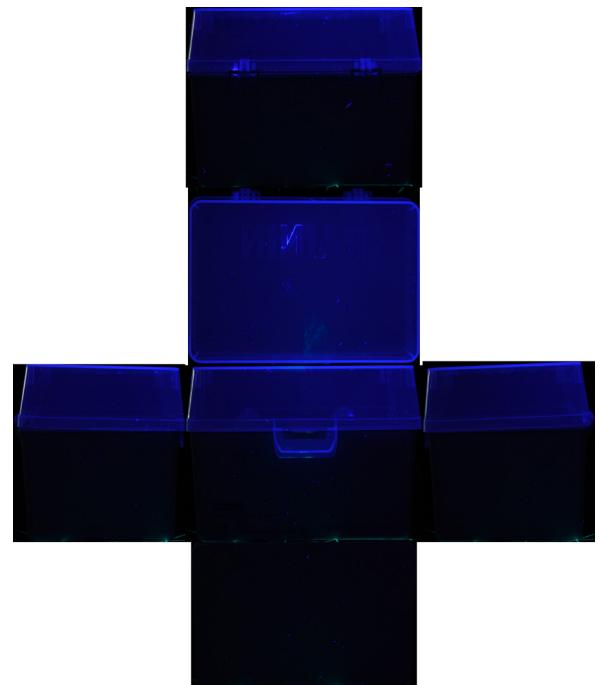


Figure 18. Cropped images of the used dispenser

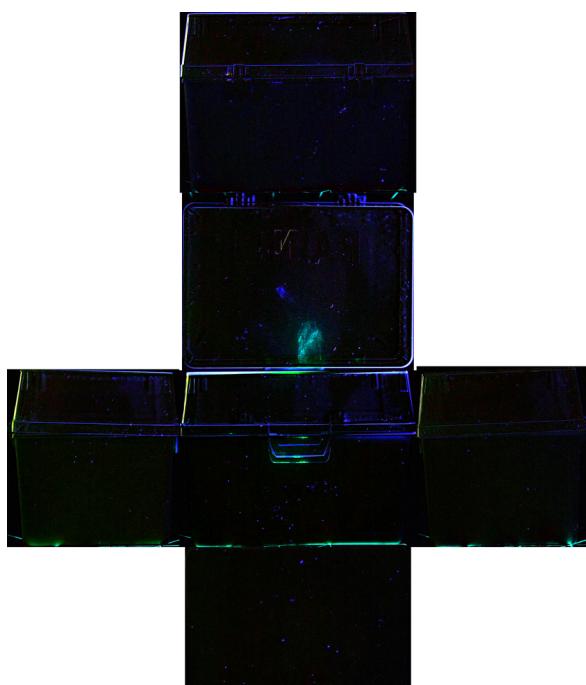


Figure 19. Figure 18 subtracted from figure 17. Isolated areas pixel count: 437034px

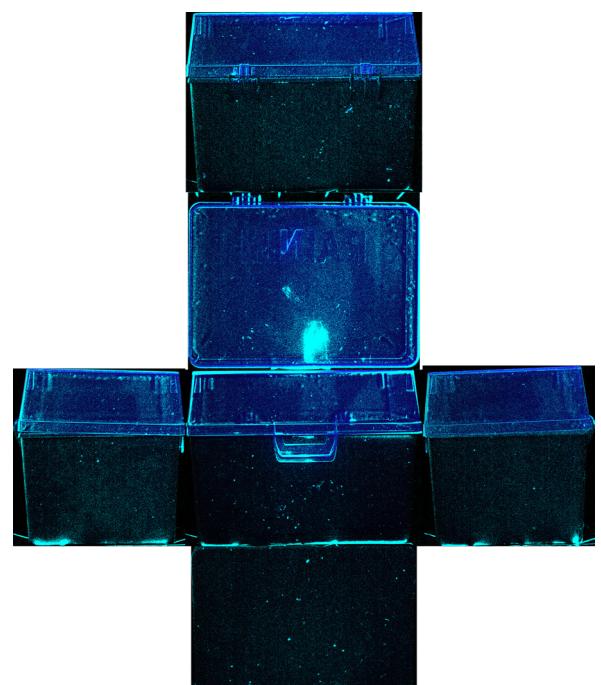


Figure 20. Final image of finger/handprints overlaid on figure 17

Table 5

Actions	Observation notes
Opening wipes dispenser	Uses left hand. Grips tops and bottom of lid with hand. The dispenser falls backwards and they used their left hand to tip it upright again.
Closing wipes dispenser	Uses their right hand to close the lid and their left hand to hold the bottom part. Taps the top of the lid with their right hand after.

Participant D - Wipes dispenser (Attempt 3)



Figure 21. Cropped images of the clean dispenser. Total pixel count: 456921px



Figure 22. Cropped images of the used dispenser

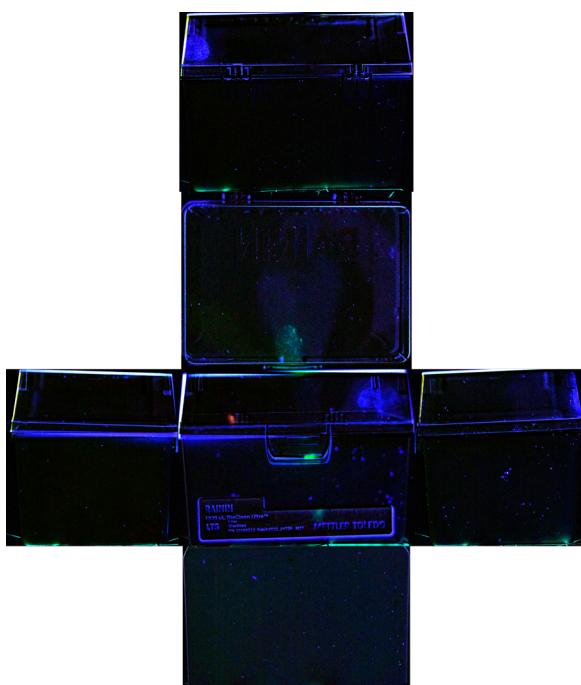


Figure 23. Figure 22 subtracted from figure 21. Isolated areas pixel count: 306282px

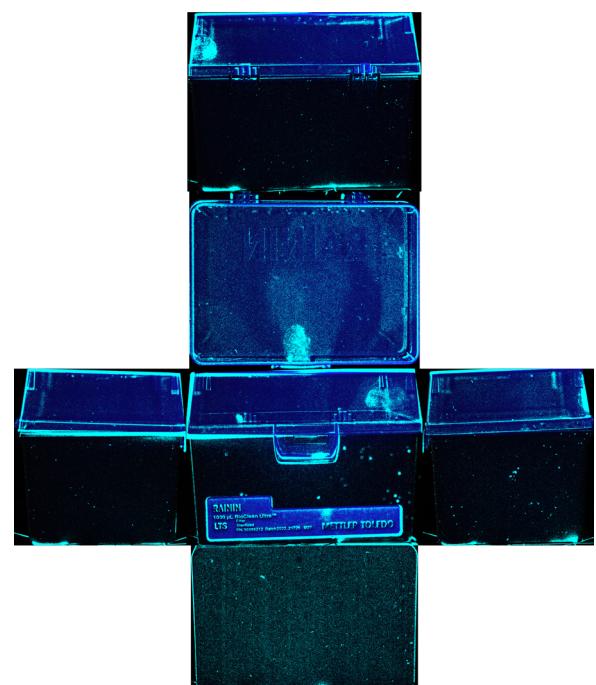


Figure 24. Final image of finger/handprints overlaid on figure 21

Table 6

Actions	Observation notes
Opening wipes dispenser	Uses both hand to open the lid of the dispenser. The dispenser falls backwards. They used the side of their left hand to tilt it upright after opening the disinfectant dispenser.
Closing wipes dispenser	Used right hand

Participant E - Disinfectant dispenser (Attempt 1)

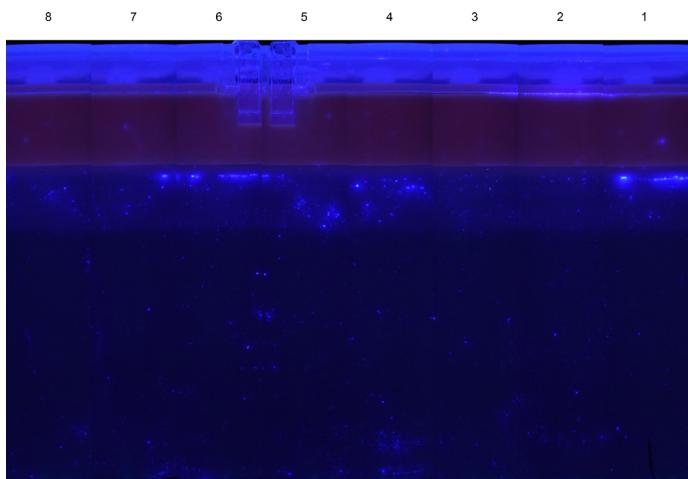


Figure 25. Cropped images of the clean dispenser. Total pixel count: 188155px

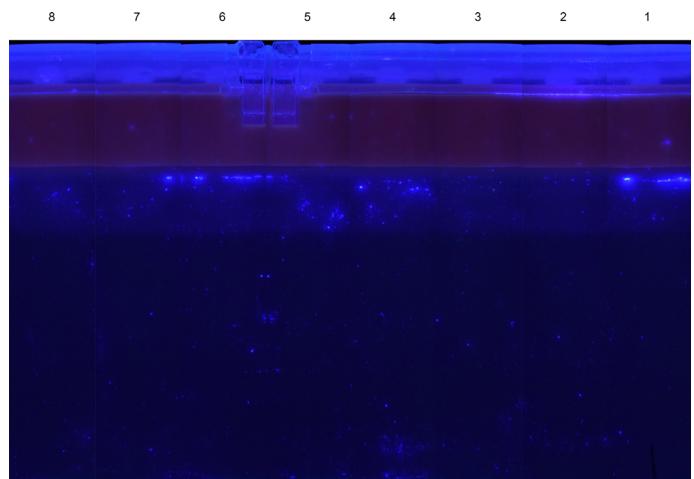


Figure 26. Cropped images of the used dispenser

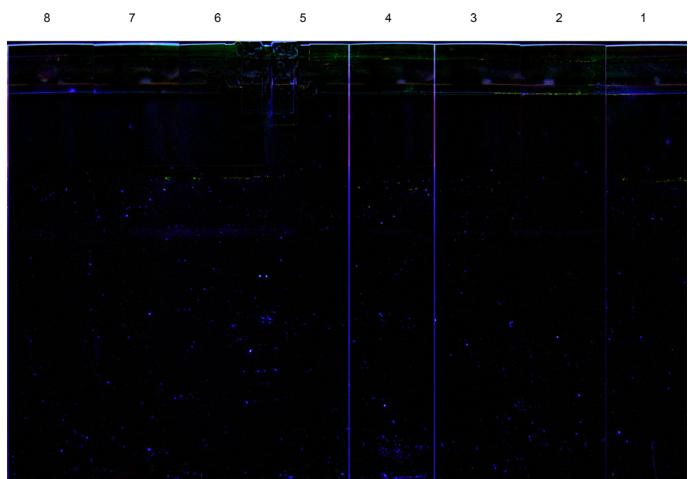


Figure 27. Figure 26 subtracted from figure 25. Isolated areas pixel count: 74314px

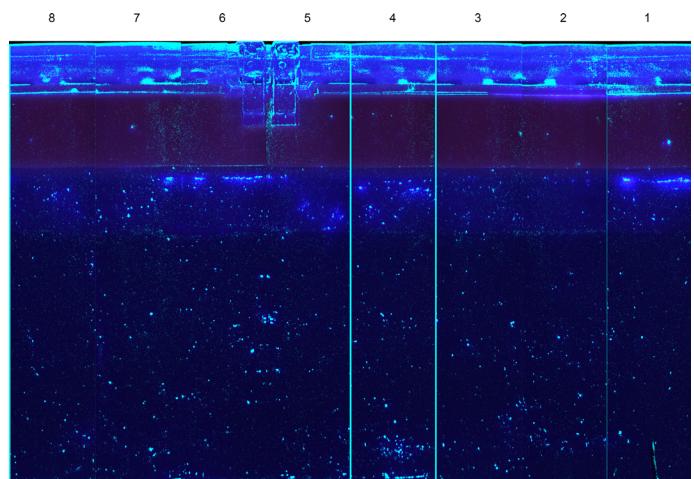


Figure 28. Final image of finger/handprints overlaid on figure 25

Table 7

Actions	Observation notes
Opening disinfectant dispenser	Opens with their left hand
Closing disinfectant dispenser	Closed with their right hand

Participant E - Disinfectant dispenser (Attempt 2)

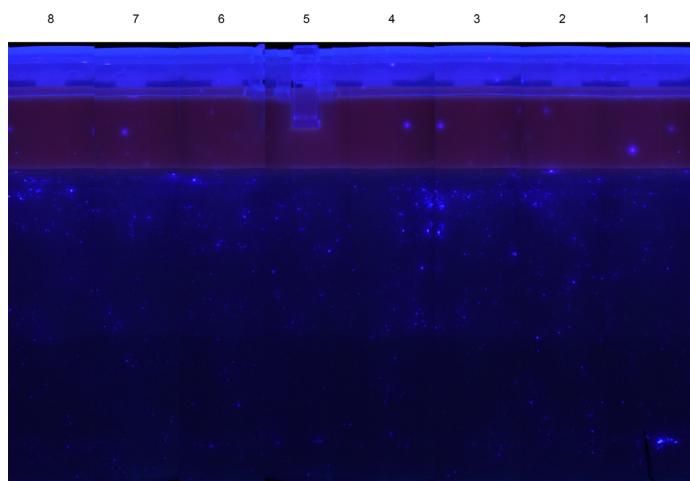


Figure 29. Cropped images of the clean dispenser. Total pixel count: 188155px

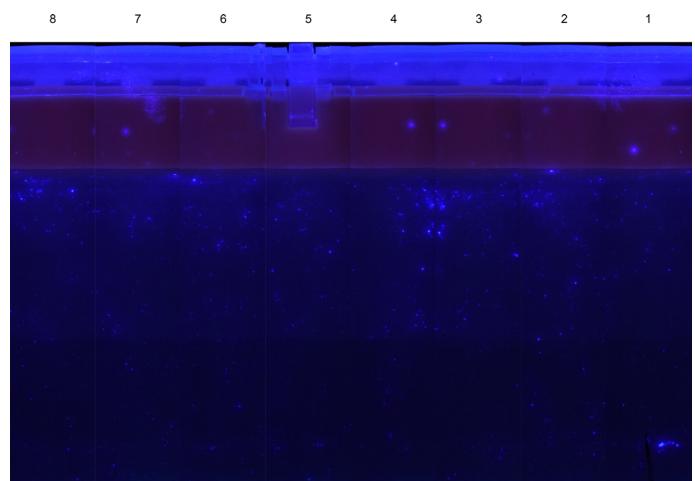


Figure 30. Cropped images of the used dispenser

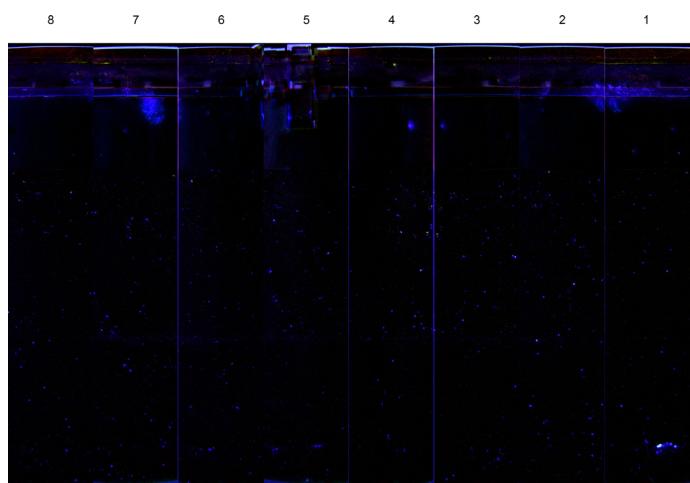


Figure 31. Figure 30 subtracted from figure 29. Isolated areas pixel count: 123886px

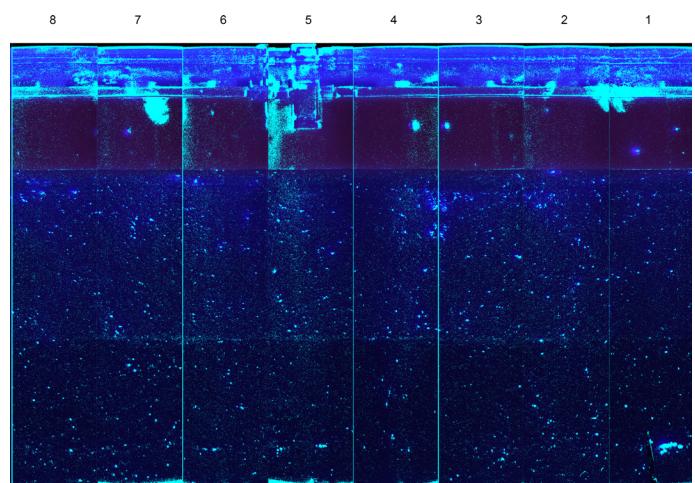


Figure 32. Final image of finger/handprints overlaid on figure 29

Table 8

Actions	Observation notes
Opening disinfectant dispenser	Rotates the dispenser until the right way was facing towards them, then opened the lid with one hand (right).
Closing disinfectant dispenser	Used their right hand to hold the lid and close it. The dispenser tilted and moved but did not close until after a few attempts.

Participant E - Disinfectant dispenser (Attempt 3)

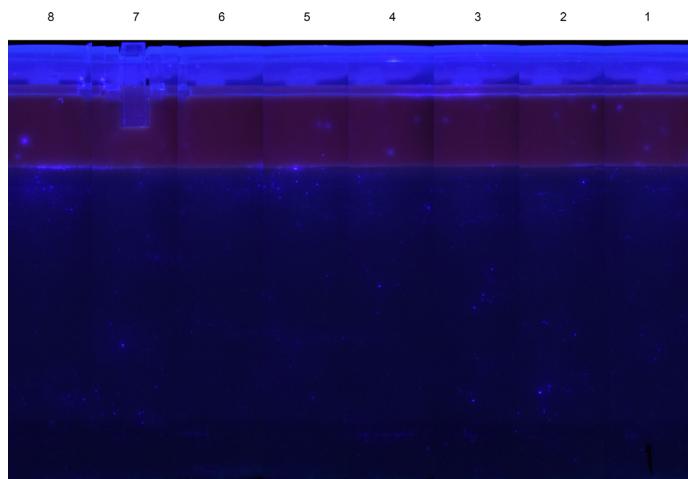


Figure 33. Cropped images of the clean dispenser. Total pixel count: 188139px

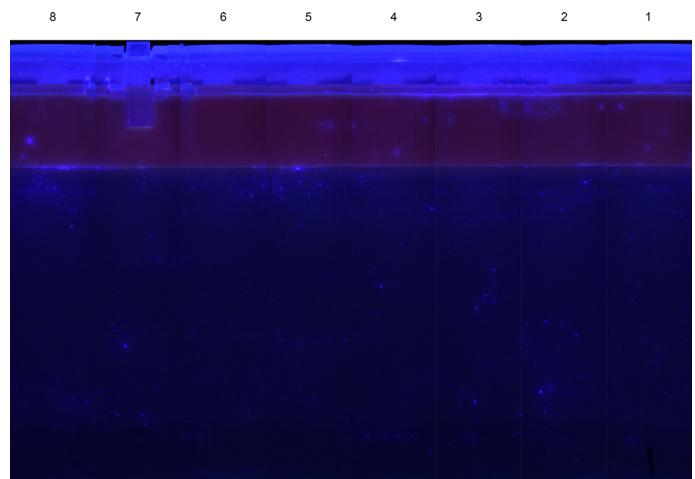


Figure 34. Cropped images of the used dispenser

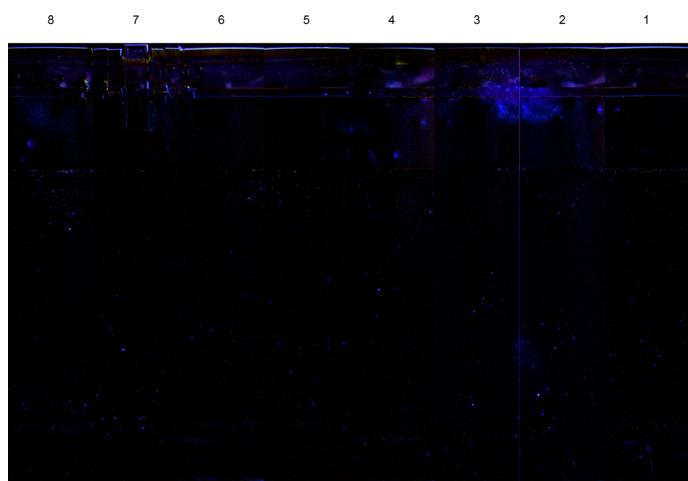


Figure 35. Figure 34 subtracted from figure 33. Isolated areas pixel count: 157289px

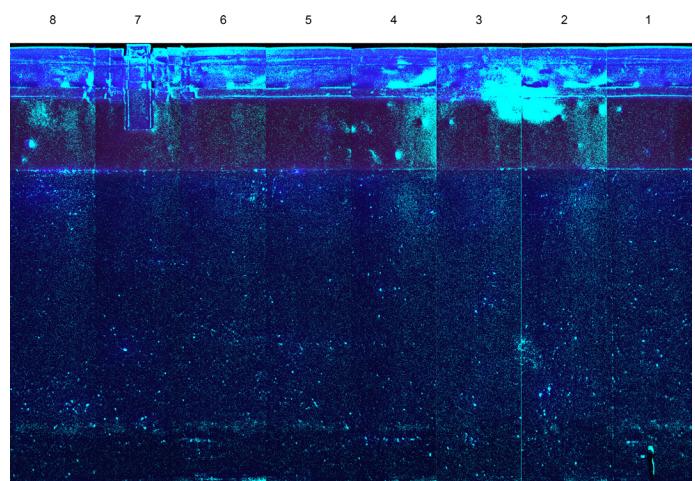


Figure 36. Final image of finger/handprints overlaid on figure 33

Table 9

Actions	Observation notes
Opening disinfectant dispenser	Opens with right hand.
Closing disinfectant dispenser	Closed with left hand. The dispenser tips and rotates and falls over. They catch the dispenser mid-roll and place it upright.

Participant E - Wipes dispenser (Attempt 1)



Figure 37. Cropped images of the clean dispenser. Total pixel count: 456124px



Figure 38. Cropped images of the used dispenser

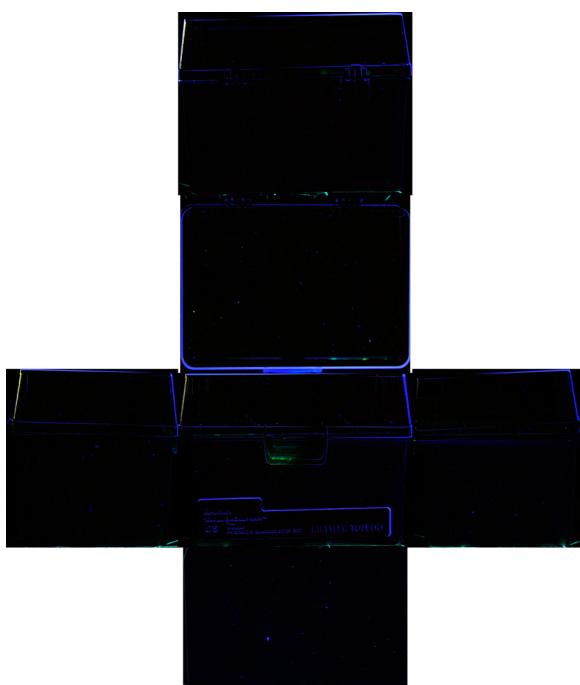


Figure 39. Figure 38 subtracted from figure 37. Isolated areas pixel count: 343354px

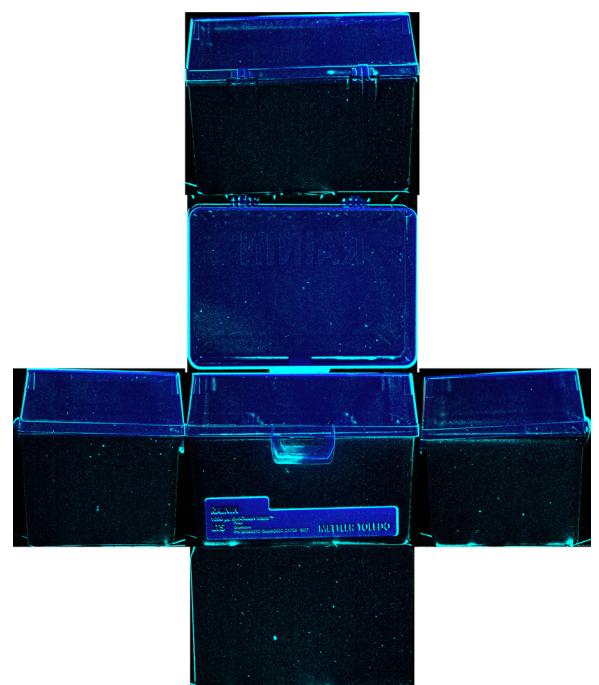


Figure 40. Final image of finger/handprints overlaid on figure 37

Table 10

Actions	Observation notes
Opening wipes dispenser	Opens the lid with their left hand. The dispenser falls backwards but they tip it upright again with the same hand.
Closing wipes dispenser	Closed the lid with their left hand

Participant E - Wipes dispenser (Attempt 2)

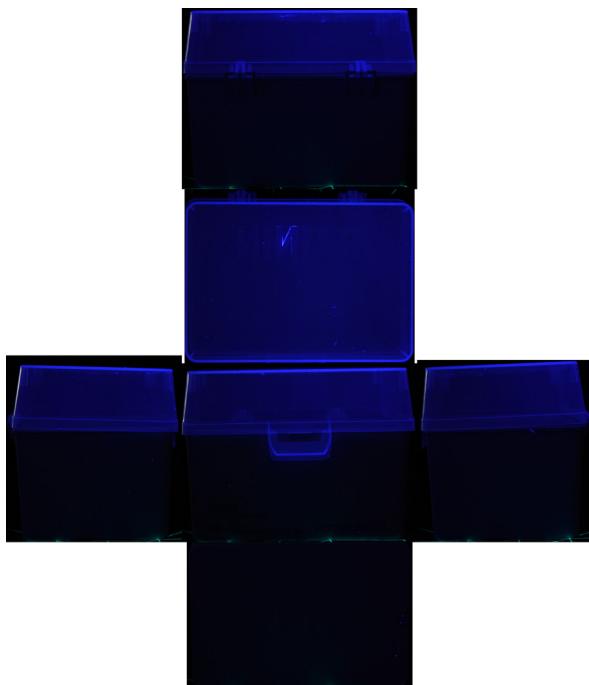


Figure 41. Cropped images of the clean dispenser. Total pixel count: 456506px

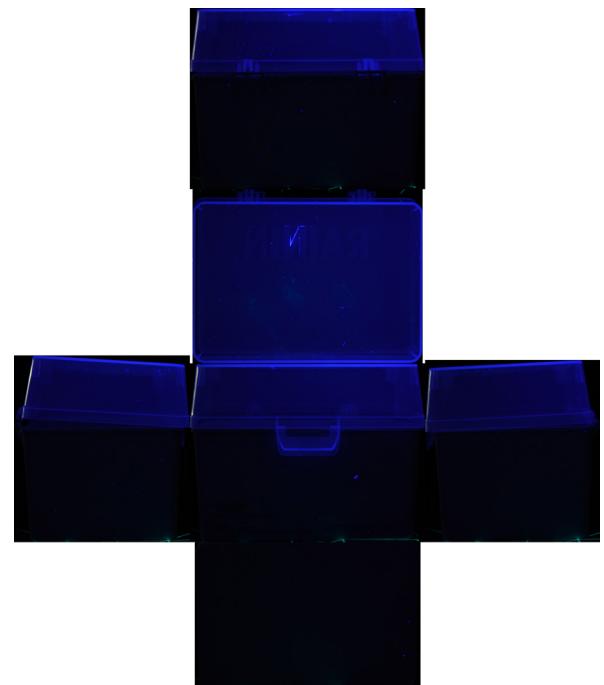


Figure 42. Cropped images of the used dispenser

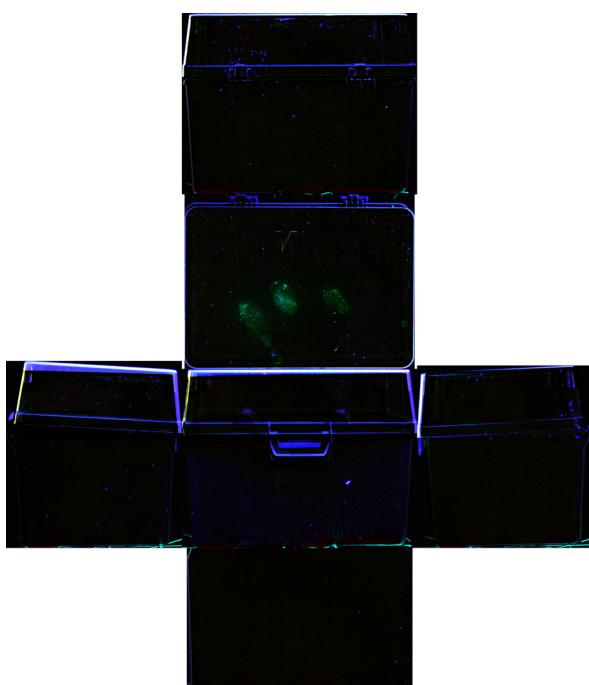


Figure 43. Figure 42 subtracted from figure 41. Isolated areas pixel count: 382394px

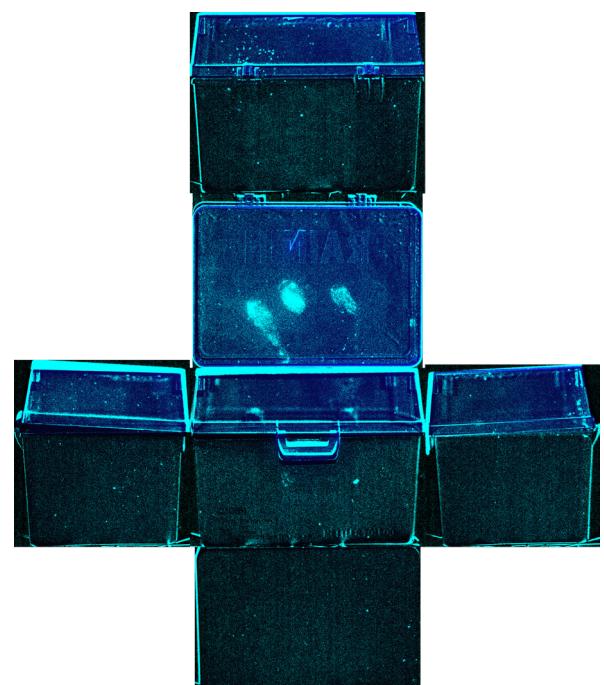


Figure 44. Final image of finger/handprints overlaid on figure 41

Table 11

Actions	Observation notes
Opening wipes dispenser	Opened with their left hand. The dispenser tipped backward a little.
Closing wipes dispenser	Closed the lid with their left hand

Participant E - Wipes dispenser (Attempt 3)

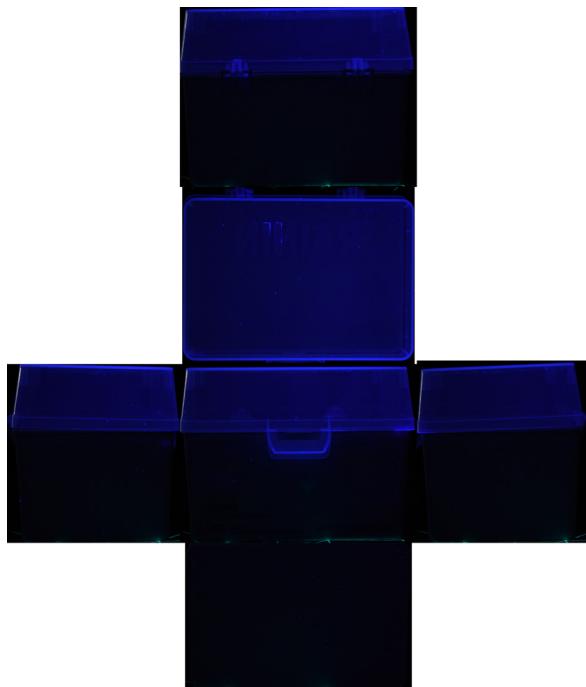


Figure 45. Cropped images of the clean dispenser. Total pixel count: 459925px

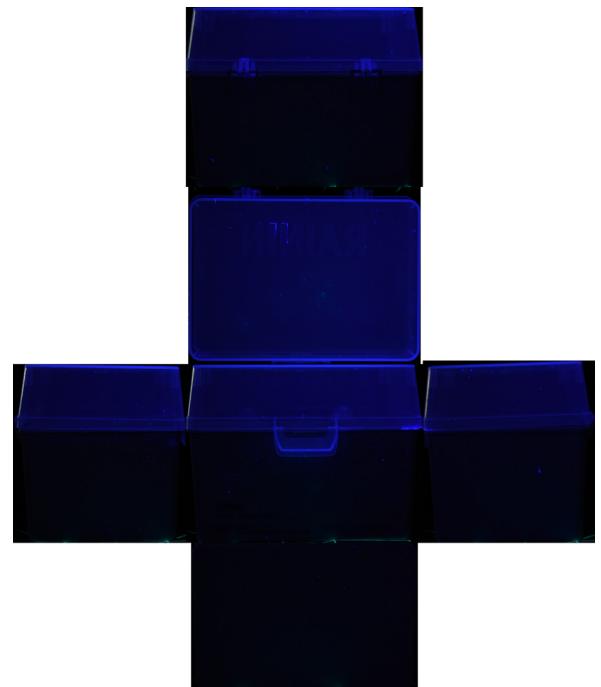


Figure 46. Cropped images of the used dispenser

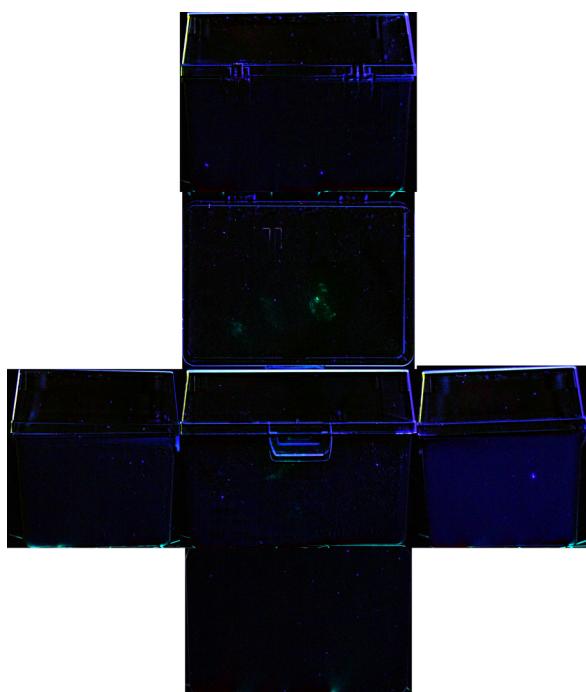


Figure 47. Figure 46 subtracted from figure 45. Isolated areas pixel count: 439883px

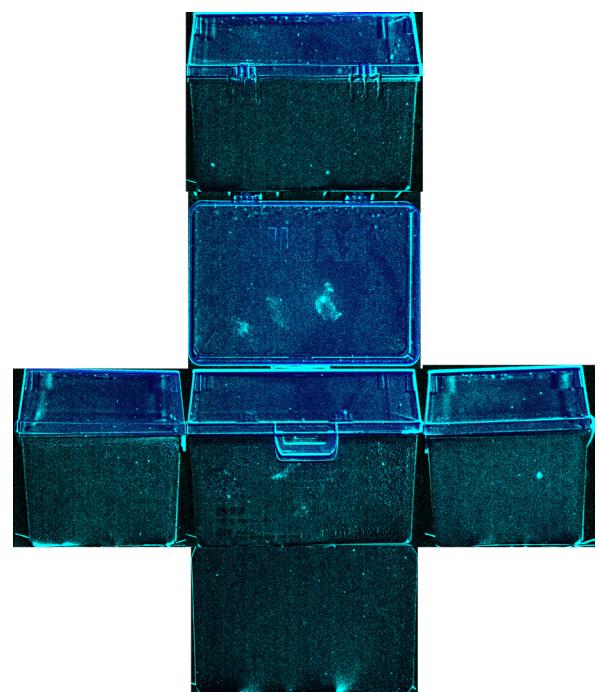


Figure 48. Final image of finger/handprints overlaid on figure 45

Table 12

Actions	Observation notes
Opening wipes dispenser	Opens with left hand
Closing wipes dispenser	Closed with right hand

Participant F - Disinfectant dispenser (Attempt 1)

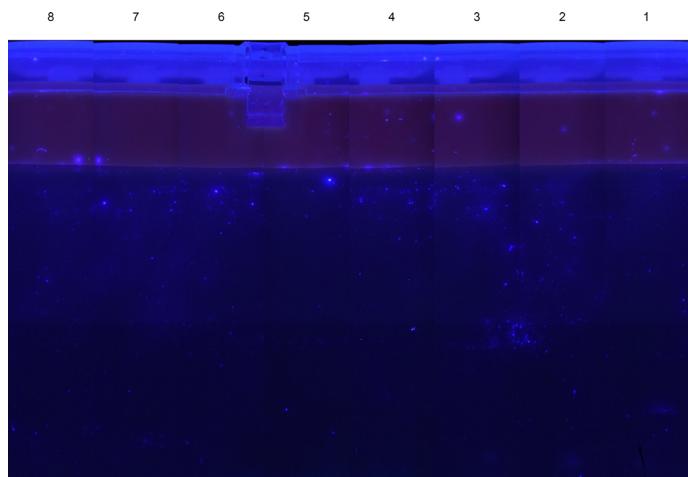


Figure 49. Cropped images of the clean dispenser. Total pixel count: 188139px

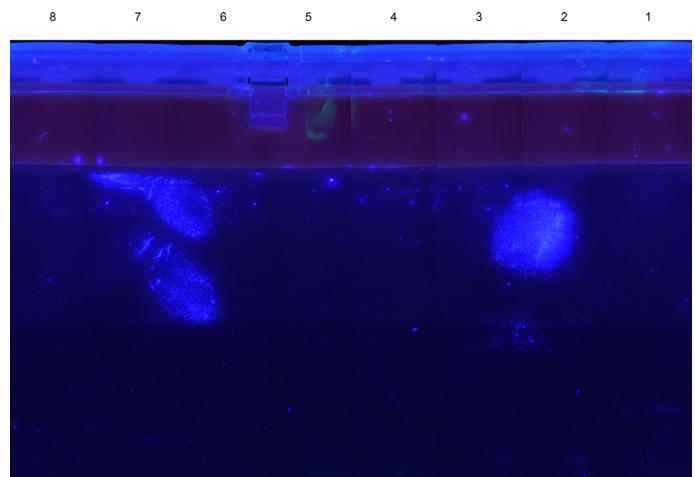


Figure 50. Cropped images of the used dispenser

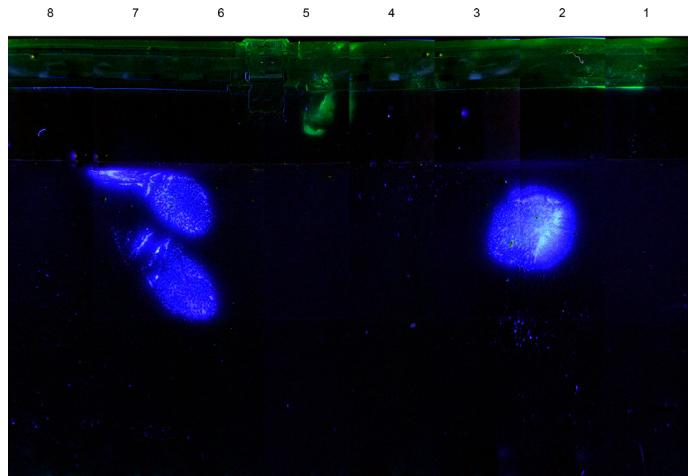


Figure 51. Figure 50 subtracted from figure 49. Isolated areas pixel count: 85133px

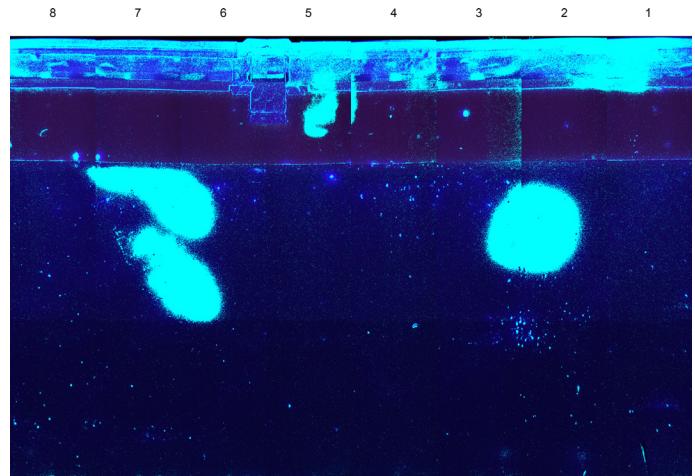


Figure 52. Final image of finger/handprints overlaid on figure 49



Figure X. Top (reference subtracted from used)

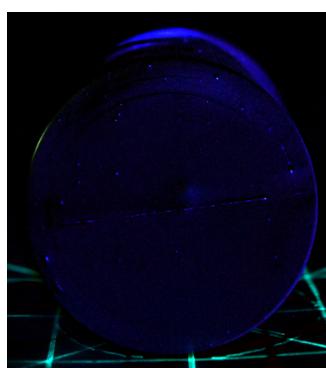


Figure X. Bottom (reference subtracted from used)

Table 13

Actions	Observation notes
Opening disinfectant dispenser	They attempted to open the dispenser with their left hand only but the dispenser did not open. They then used their other hand to hold the bottom part and open the dispenser.
Closing disinfectant dispenser	Closed with their left hand. They pressed down on the lid with some force. Note: their preferred hand may be due to the location of the dispenser.

Participant F - Disinfectant dispenser (Attempt 2)

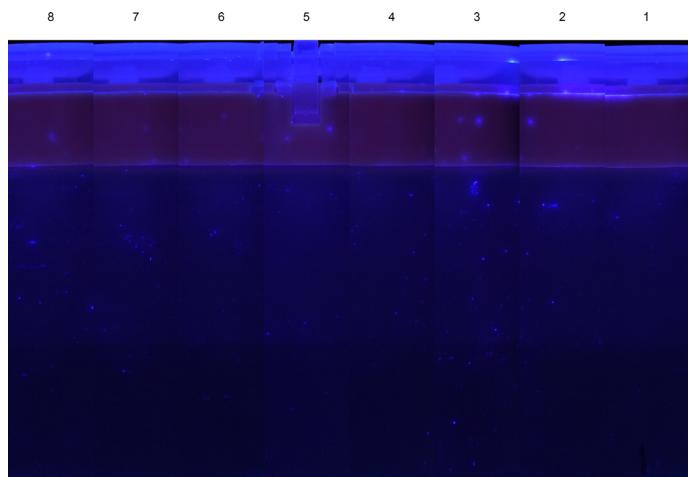


Figure 53. Cropped images of the clean dispenser. Total pixel count: 188139px

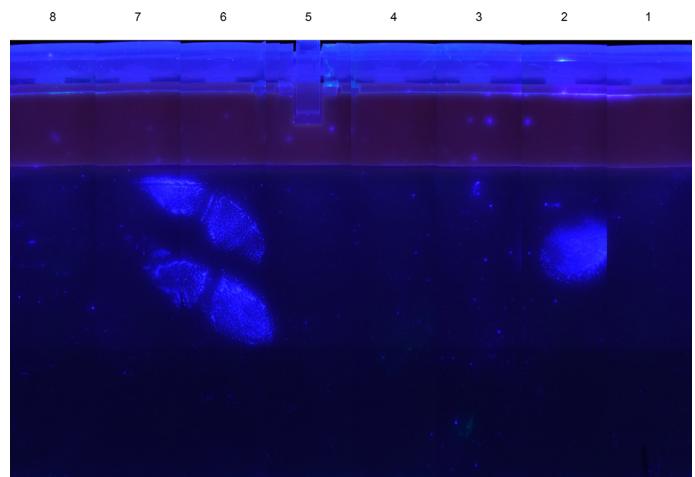


Figure 54. Cropped images of the used dispenser

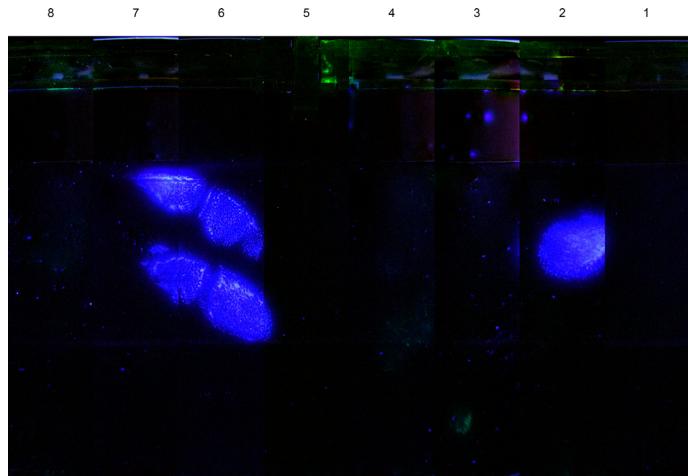


Figure 55. Figure 54 subtracted from figure 53. Isolated areas pixel count: 78669px

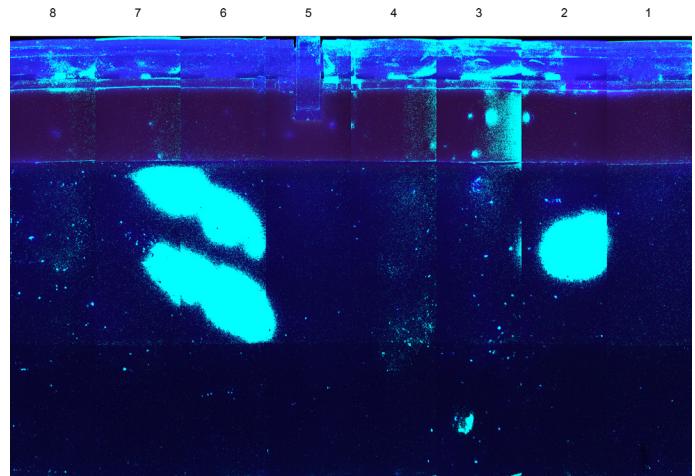


Figure 56. Final image of finger/handprints overlaid on figure 53



Figure X. Top (reference subtracted from used)



Figure X. Bottom (reference subtracted from used)

Table 14

Actions	Observation notes
Opening disinfectant dispenser	Used left hand to rotate the dispenser to face the right way. Used right hand to hold the bottom part and left hand to pull the lid open
Closing disinfectant dispenser	Held the bottom part with their left hand and closed the lid with their right.

Participant F - Disinfectant dispenser (Attempt 3)

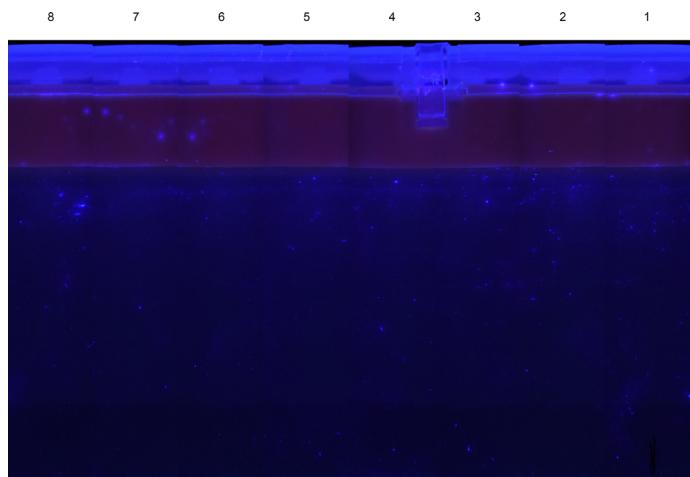


Figure 57. Cropped images of the clean dispenser. Total pixel count: 188139px

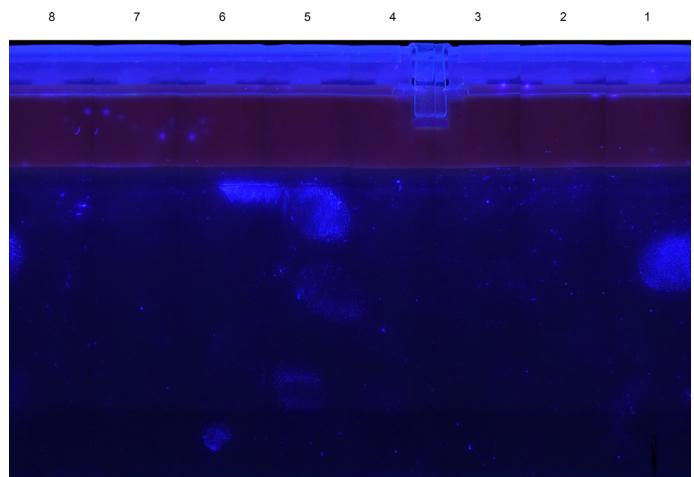


Figure 58. Cropped images of the used dispenser

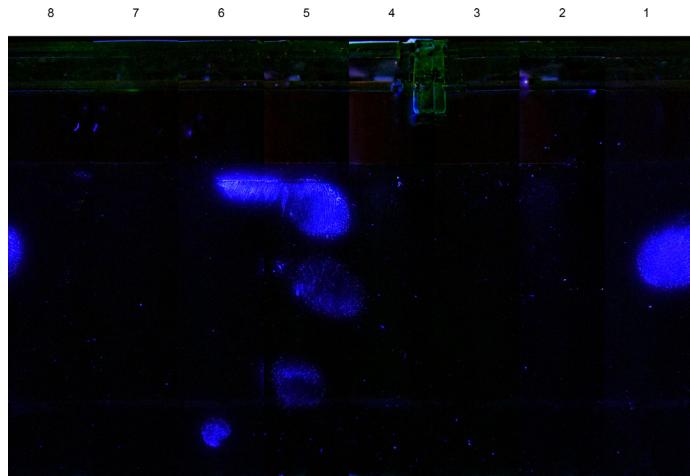


Figure 59. Figure 58 subtracted from figure 57. Isolated areas pixel count: 84695px

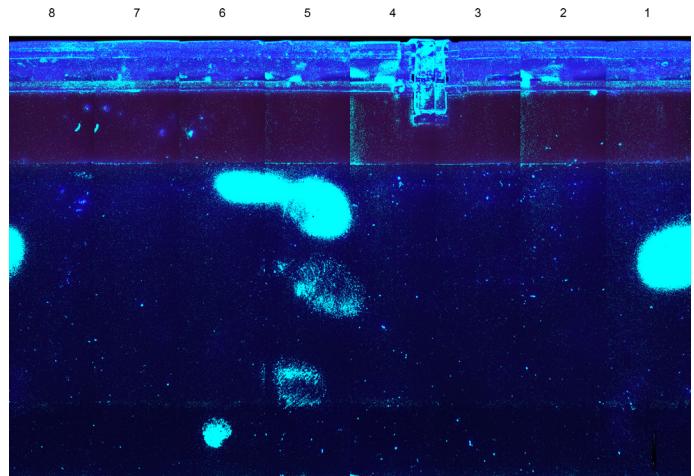


Figure 60. Final image of finger/handprints overlaid on figure 57



Figure X. Top (reference subtracted from used)

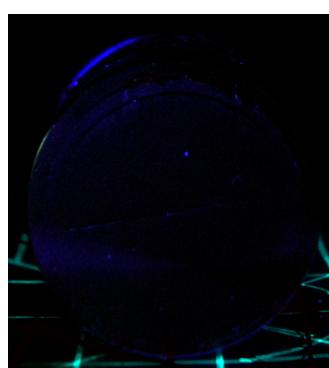


Figure X. Bottom (reference subtracted from used)

Table 15

Actions	Observation notes
Opening disinfectant dispenser	Used right hand to hold the bottom part and left hand to pull the lid open
Closing disinfectant dispenser	Closed with left hand

Participant F - Wipes dispenser (Attempt 1)



Figure 61. Cropped images of the clean dispenser. Total pixel count: 461049px



Figure 62. Cropped images of the used dispenser

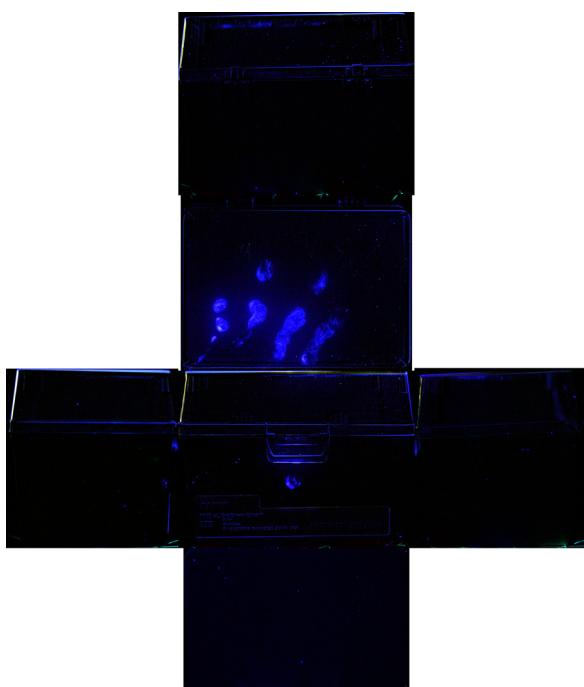


Figure 63. Figure 62 subtracted from figure 61. Isolated areas pixel count: 282131px

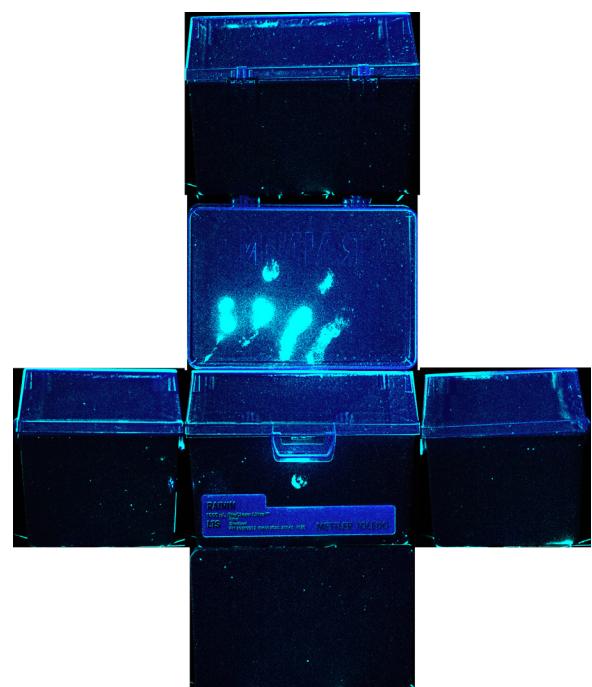


Figure 64. Final image of finger/handprints overlaid on figure 61

Table 16

Actions	Observation notes
Opening wipes dispenser	Opens with right hand. The dispenser falls backwards. After opening the disinfectant dispenser, they used the heels of both hands to right the dispenser.
Closing wipes dispenser	Closed with their right hand.

Participant F - Wipes dispenser (Attempt 2)

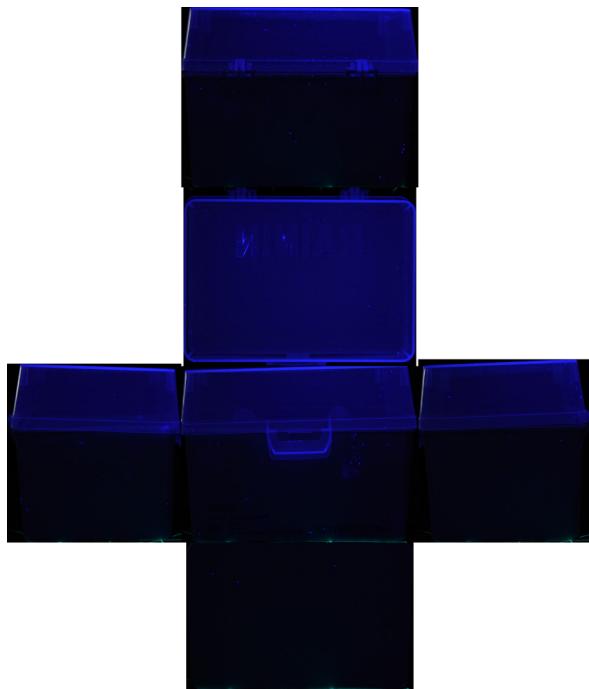


Figure 65. Cropped images of the clean dispenser. Total pixel count: 460929px

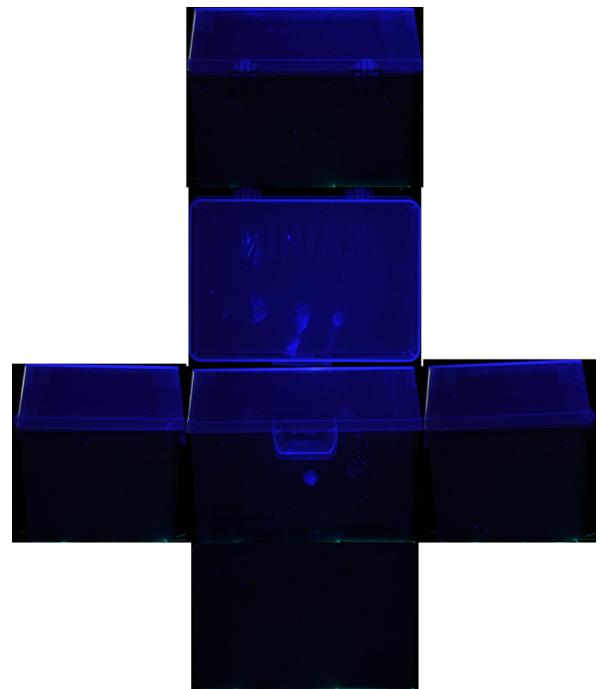


Figure 66. Cropped images of the used dispenser

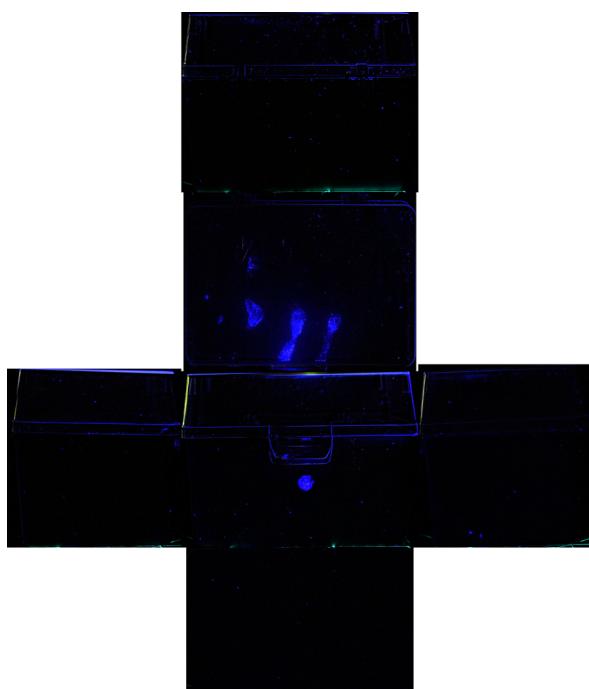


Figure 67. Figure 66 subtracted from figure 65. Isolated areas pixel count: 383742px

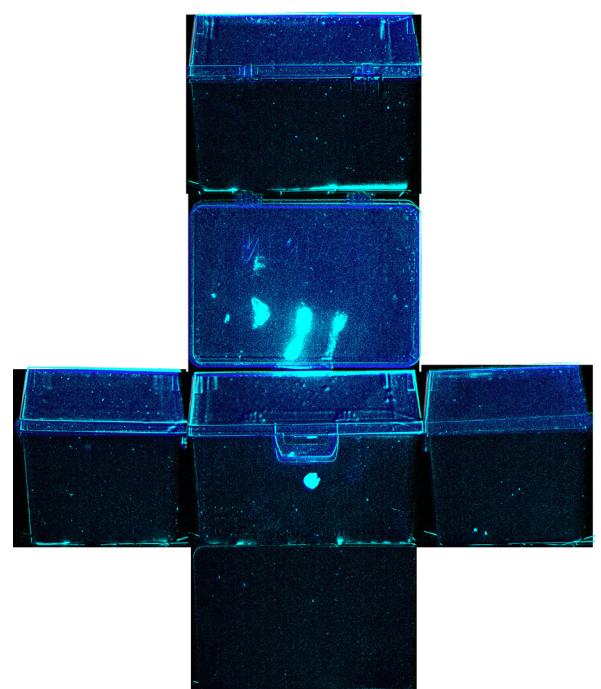


Figure 68. Final image of finger/handprints overlaid on figure 65

Table 17

Actions	Observation notes
Opening wipes dispenser	Opened the lid with right hand
Closing wipes dispenser	Closed with their right hand.

Participant F - Wipes dispenser (Attempt 3)

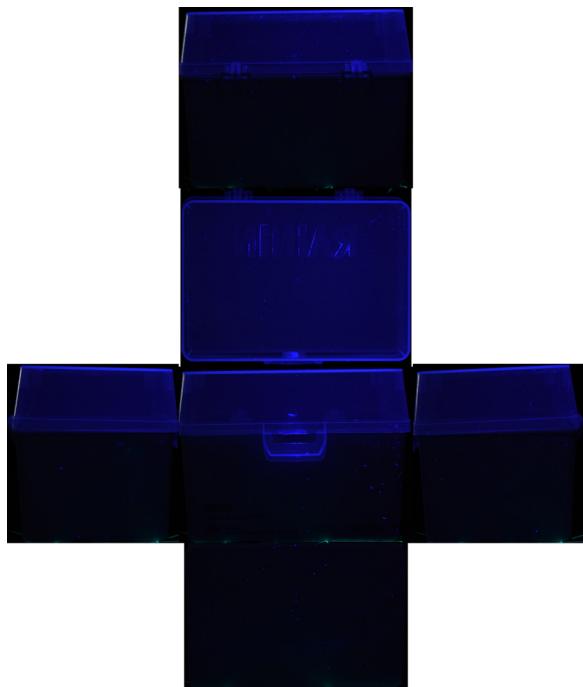


Figure 69. Cropped images of the clean dispenser. Total pixel count: 464882px

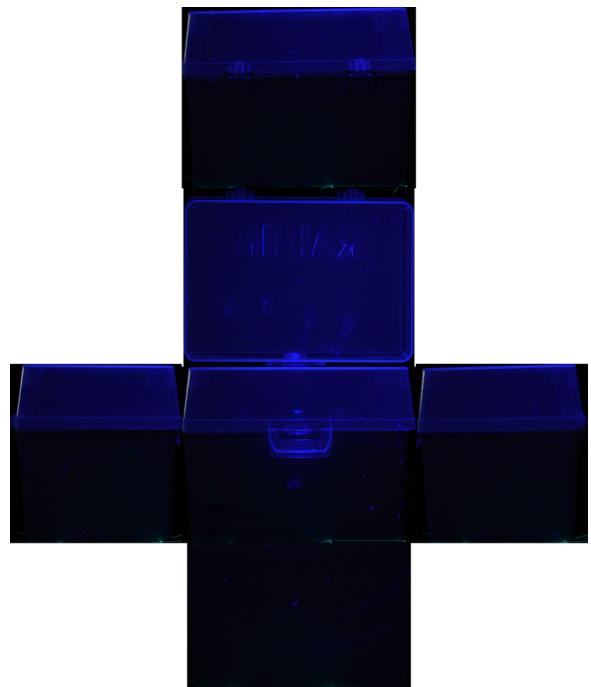


Figure 70. Cropped images of the used dispenser

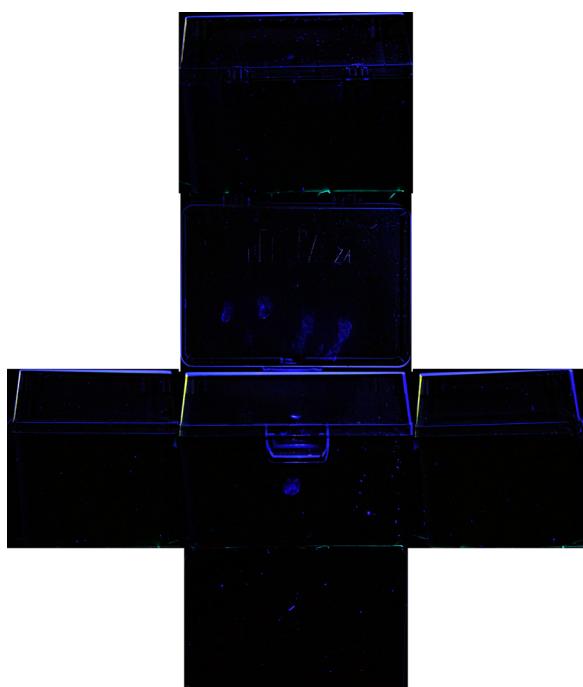


Figure 71. Figure 70 subtracted from figure 69. Isolated areas pixel count: 382157px

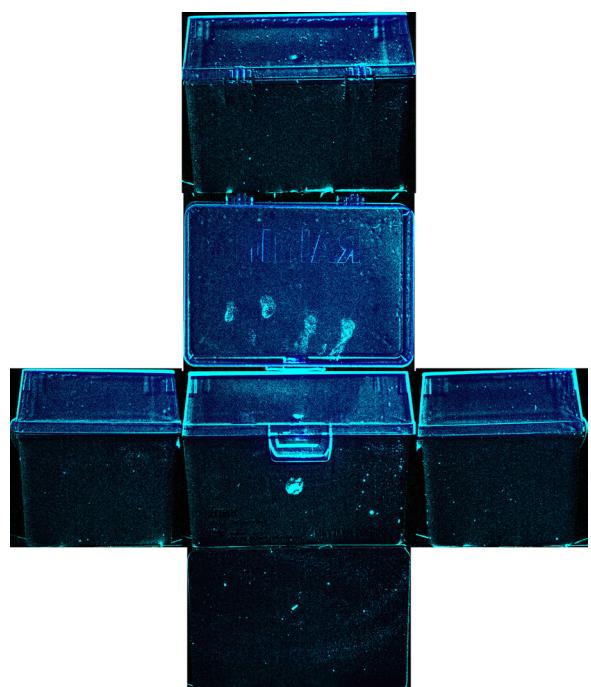


Figure 72. Final image of finger/handprints overlaid on figure 69

Table 18

Actions	Observation notes
Opening wipes dispenser	Opened the lid with right hand. The dispenser tilted backward.
Closing wipes dispenser	Closed with right hand

Participant G - Disinfectant dispenser (Attempt 1)

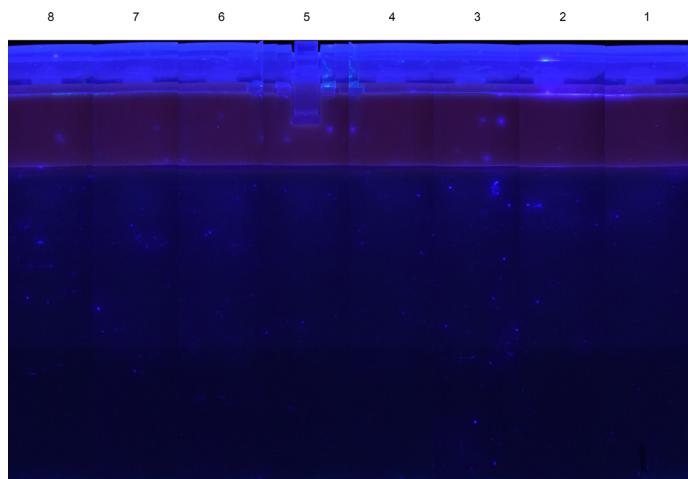


Figure 73. Cropped images of the clean dispenser. Total pixel count: 188139px

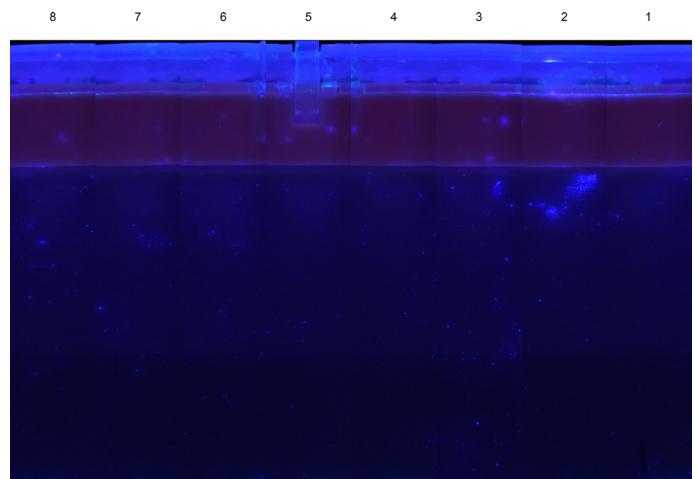


Figure 74. Cropped images of the used dispenser

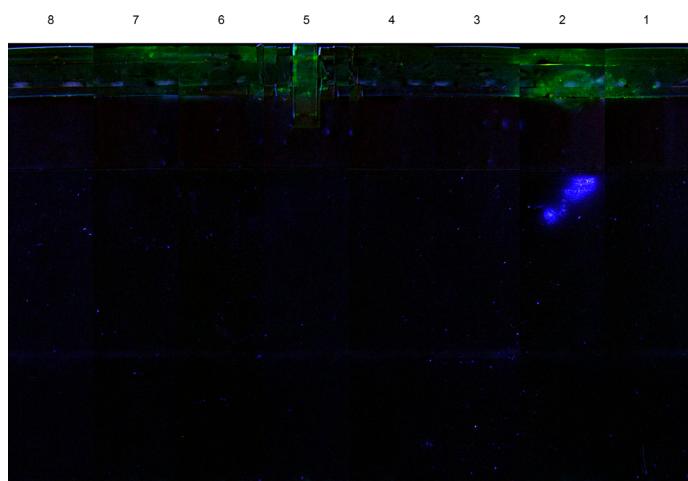


Figure 75. Figure 74 subtracted from figure 73. Isolated areas pixel count: 135853px

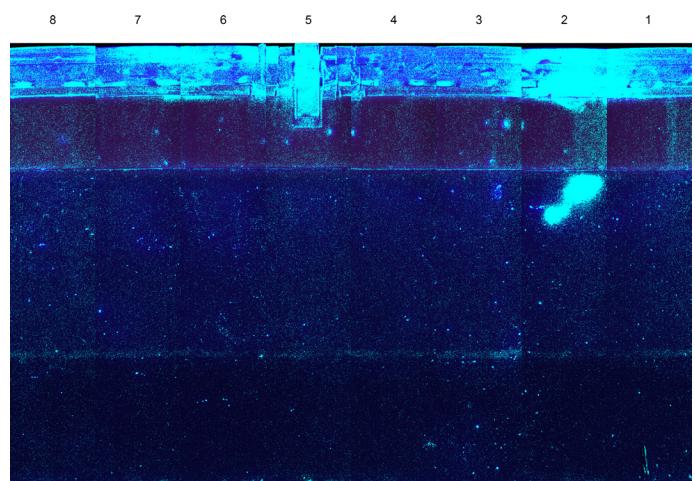


Figure 76. Final image of finger/handprints overlaid on figure 73

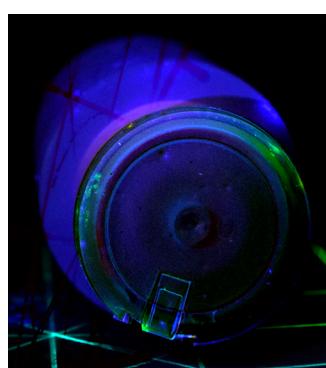


Figure X. Top (reference subtracted from used)

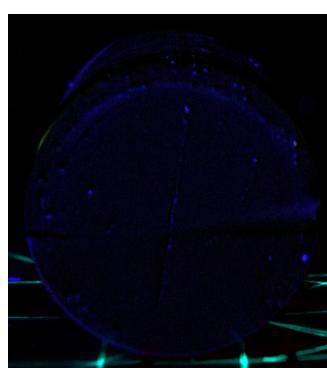


Figure X. Bottom (reference subtracted from used)

Table 19

Actions	Observation notes
Opening disinfectant dispenser	Lifted the dispenser with their left hand to reposition it and used the same hand to open the lid.
Closing disinfectant dispenser	Closed with left hand. They used their thumb to press on the bottom part of the dispenser and their other fingers on the lid.

Participant G - Disinfectant dispenser (Attempt 2)

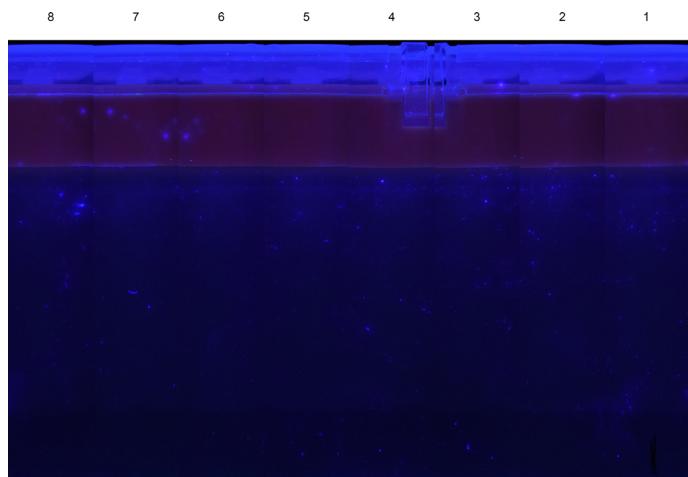


Figure 77. Cropped images of the clean dispenser. Total pixel count: 188139px

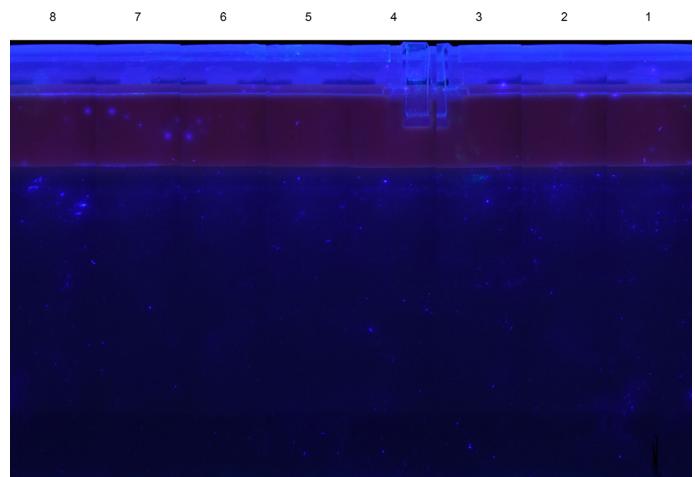


Figure 78. Cropped images of the used dispenser

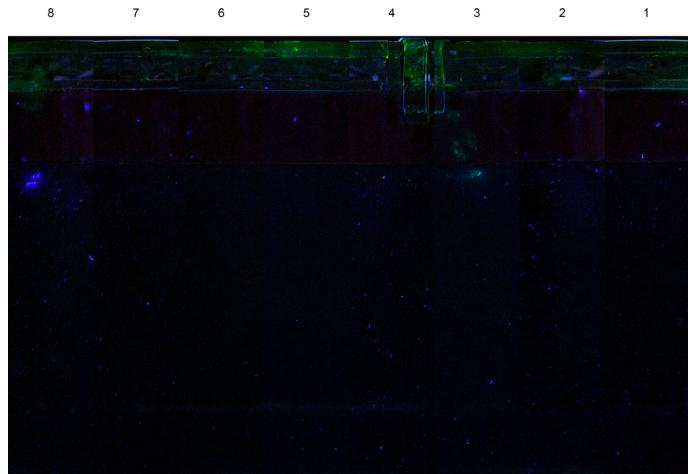


Figure 79. Figure 78 subtracted from figure 77. Isolated areas pixel count: 156854px

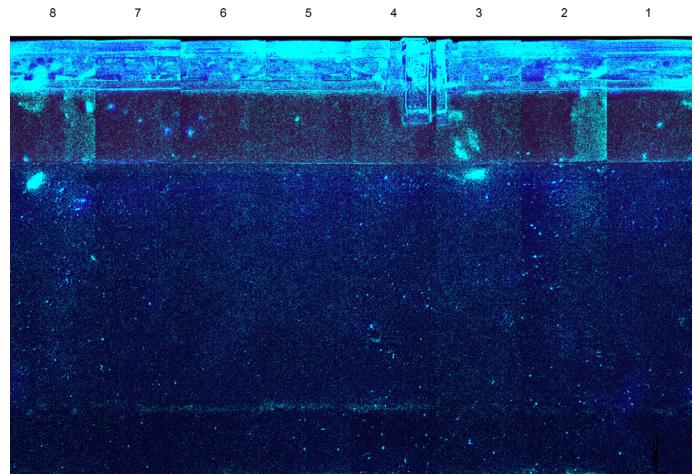


Figure 80. Final image of finger/handprints overlaid on figure 77



Figure X. Top (reference subtracted from used)

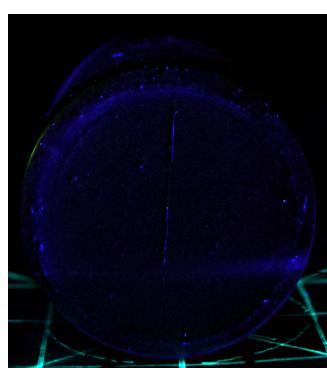


Figure X. Bottom (reference subtracted from used)

Table 20

Actions	Observation notes
Opening disinfectant dispenser	Rotated the dispenser with their left hand, used their right to nudge the bottom part down (it lifted up) while opening the lid with the other hand.
Closing disinfectant dispenser	Closed with left hand

Participant G - Disinfectant dispenser (Attempt 3)

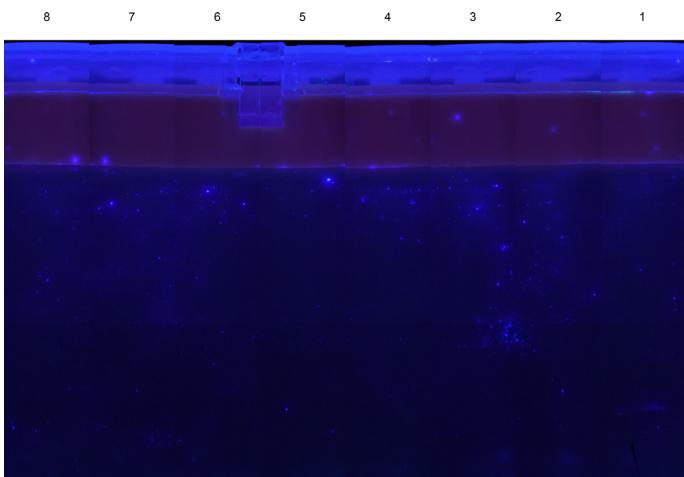


Figure 81. Cropped images of the clean dispenser. Total pixel count: 187798px

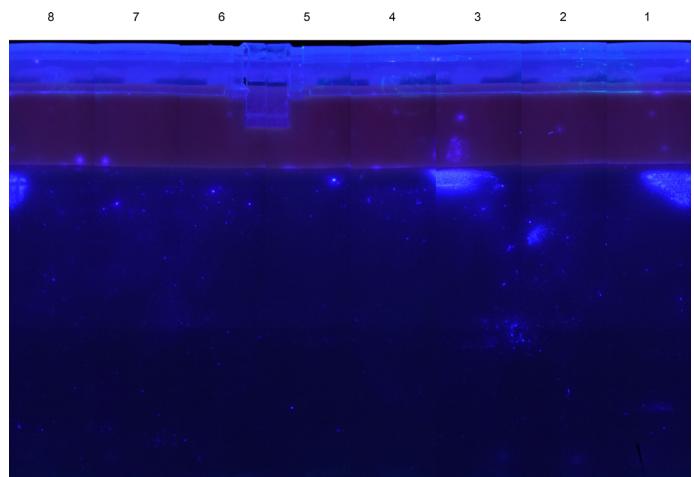


Figure 82. Cropped images of the used dispenser

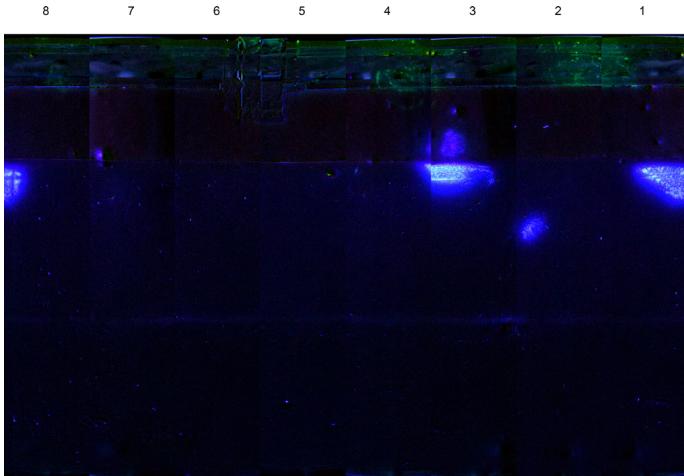


Figure 83. Figure 82 subtracted from figure 81. Isolated areas pixel count: 114765px

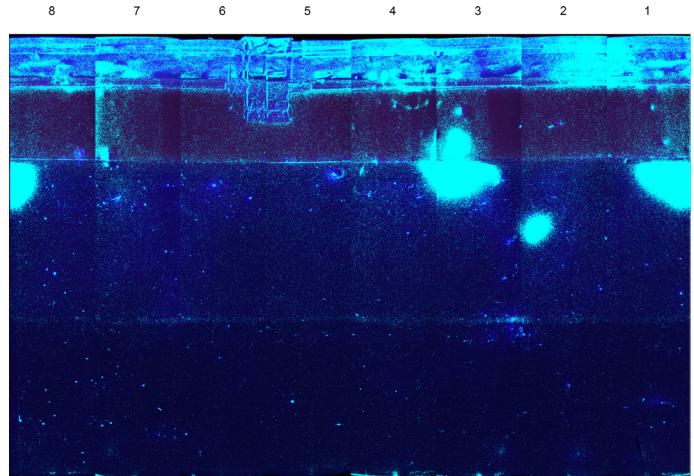


Figure 84. Final image of finger/handprints overlaid on figure 81



Figure X. Top (reference subtracted from used)

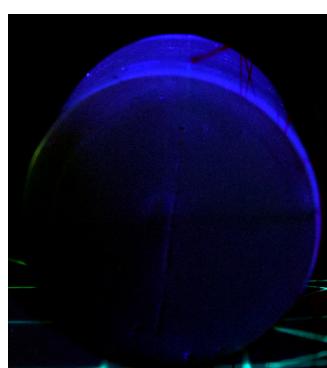


Figure X. Bottom (reference subtracted from used)

Table 21

Actions	Observation notes
Opening disinfectant dispenser	Rotated the dispenser with their left hand, used their right to hold the bottom part while opening the lid with the other hand.
Closing disinfectant dispenser	Closed with left hand

Participant G - Wipes dispenser (Attempt 1)

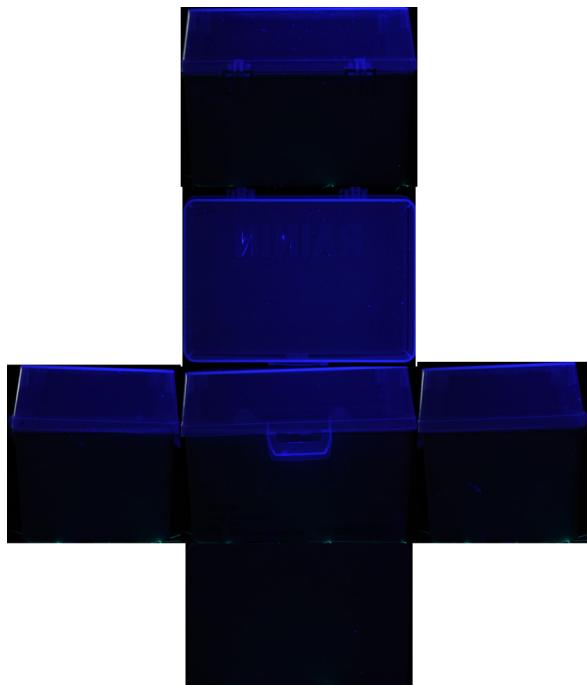


Figure 85. Cropped images of the clean dispenser. Total pixel count: 461180px

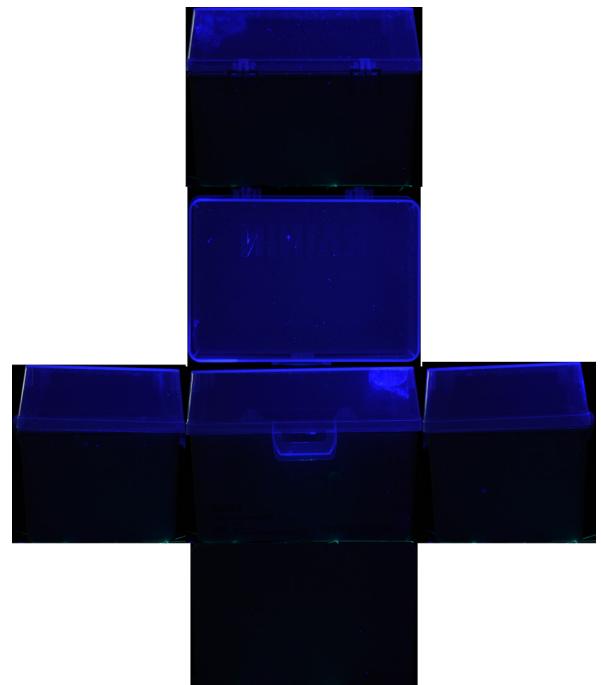


Figure 86. Cropped images of the used dispenser

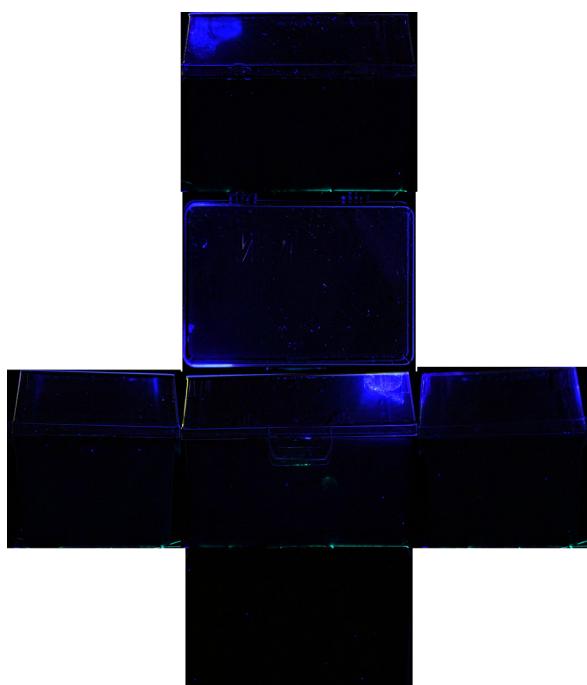


Figure 87. Figure 86 subtracted from figure 85. Isolated areas pixel count: 413158px

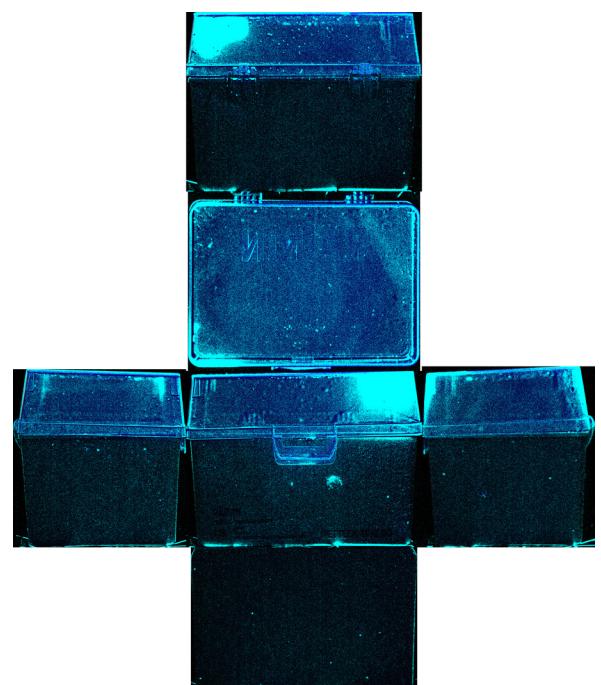


Figure 88. Final image of finger/handprints overlaid on figure 85

Table 22

Actions	Observation notes
Opening wipes dispenser	Opened the lid with their right hand and used their other hand to hold the bottom part
Closing wipes dispenser	Closed with right hand

Participant G - Wipes dispenser (Attempt 2)



Figure 89. Cropped images of the clean dispenser. Total pixel count: 461392px



Figure 90. Cropped images of the used dispenser

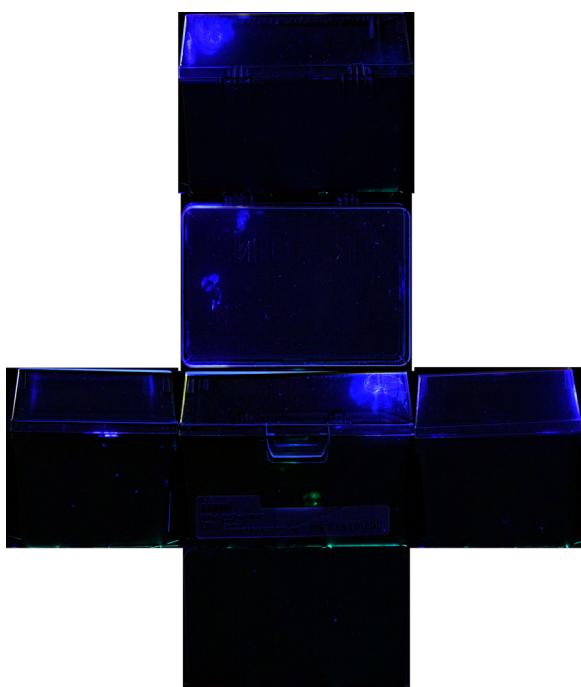


Figure 91. Figure 90 subtracted from figure 89. Isolated areas pixel count: 265328px

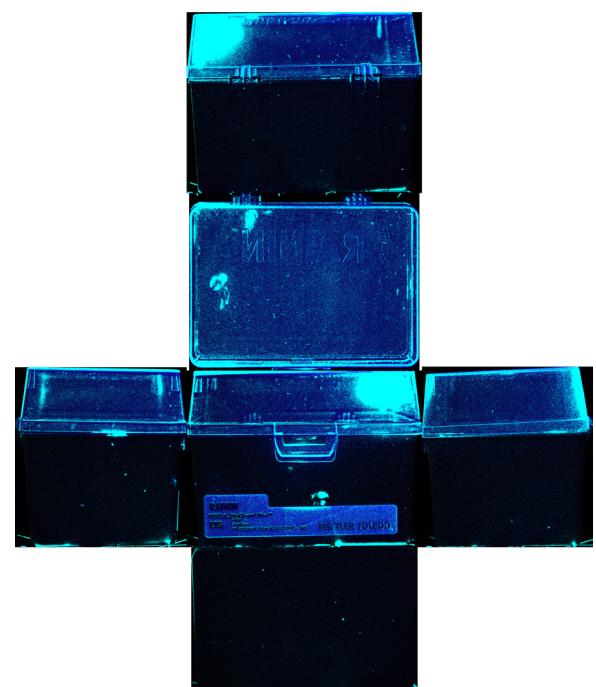


Figure 92. Final image of finger/handprints overlaid on figure 89

Table 23

Actions	Observation notes
Opening wipes dispenser	Opens with their right hand. The dispenser moves backwards and they stop it with their other hand.
Closing wipes dispenser	Closed with right hand

Participant G - Wipes dispenser (Attempt 3)

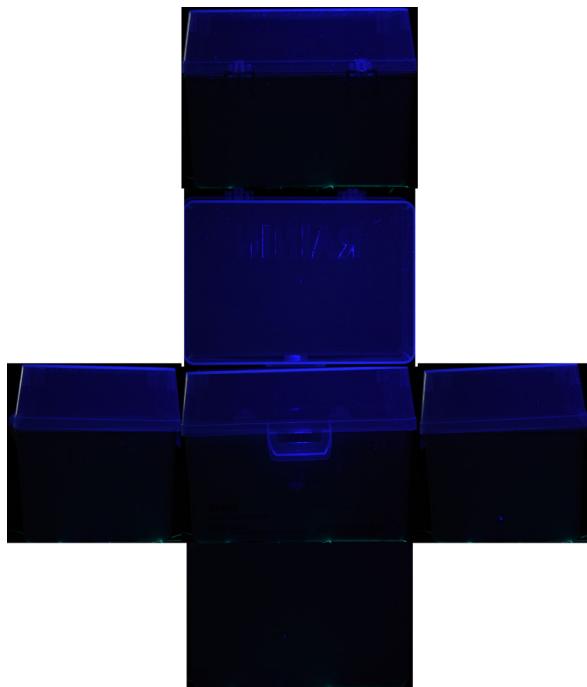


Figure 93. Cropped images of the clean dispenser. Total pixel count: 461395px

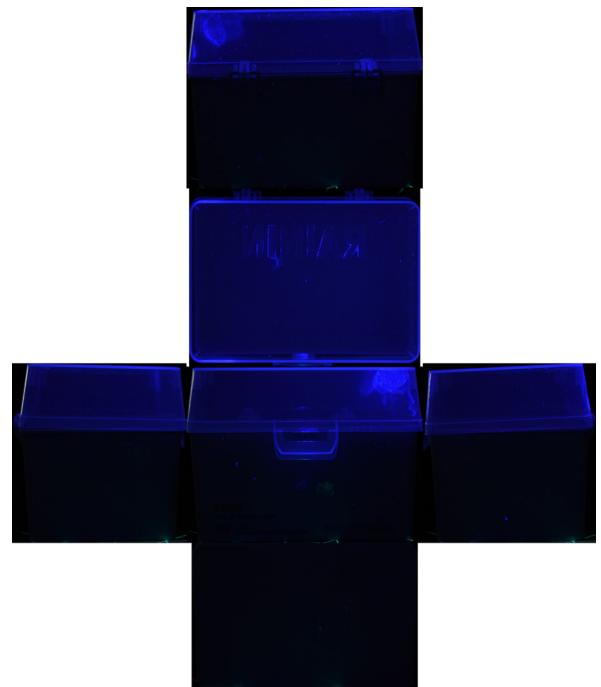


Figure 94. Cropped images of the used dispenser

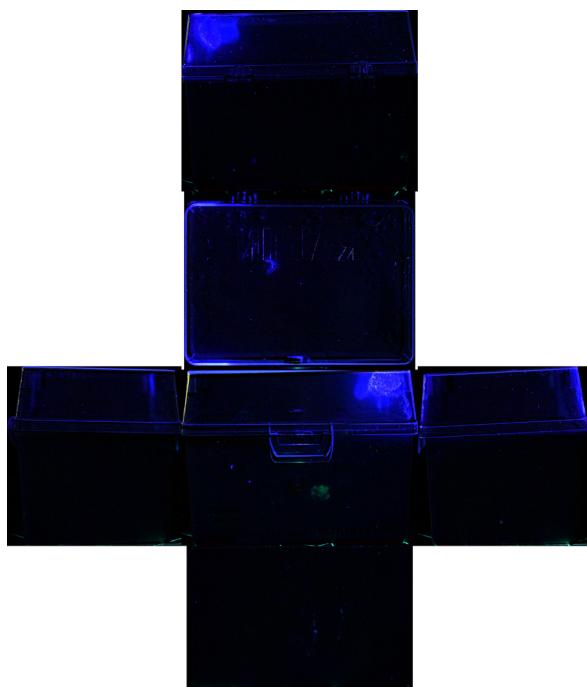


Figure 95. Figure 94 subtracted from figure 93. Isolated areas pixel count: 461395px

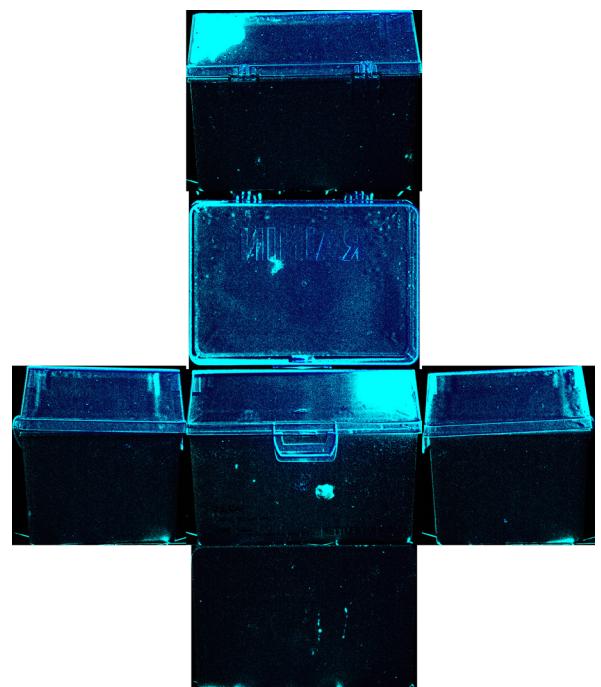


Figure 96. Final image of finger/handprints overlaid on figure 93

Table 24

Actions	Observation notes
Opening wipes dispenser	Grips the side of the lid with their right hand (same as the other 2 objects). Uses left hand to hold the bottom part.
Closing wipes dispenser	Closed with right hand

APPENDIX J
Number of pixels

IMAGE PROCESSING: NUMBER OF PIXELS

Disinfectant	Isolated	Reference	Isolated/reference percentage
D1	55921	188566	29.65592949
D2	39058	187782	20.79965066
D3	41868	188139	22.25375919
E1	74314	188155	39.49616008
E2	123886	188155	65.84252345
E3	157289	188139	83.60254918
F1	85133	188139	45.25005448
F2	78669	188139	41.81429688
F3	84695	188139	45.01724789
G1	135853	188139	72.20884559
G2	156854	188139	83.37133715
G3	114765	187798	61.11087445

Wipes	Isolated	Reference	Isolated/reference percentage
D1	343354	456124	75.27645991
D2	382394	456506	83.76538315
D3	306282	456921	67.03171883
E1	337770	463793	72.82774859
E2	437034	468332	93.317134
E3	439883	459925	95.64233299
F1	282131	461049	61.19327881
F2	383742	460929	83.25403696
F3	382157	464882	82.20516174
G1	413158	461180	89.58714602
G2	265328	461392	57.5059819
G3	318905	461395	69.11756738

Averages	Isolated	Reference	Isolated - std dev	Percentages
D	45615.6667	188162.333	9034.597187	24.2364464
E	118496.333	188149.667	41749.23995	62.9804109
F	82832.3333	188139	3612.1973	44.0271997
G	135824	188025.333	21044.51499	72.2303524
Total		188119.083		
Std dev (total)	41529.793	195.822488		

Averages	Isolated	Reference	Isolated - std dev	Percentages
D	344010	456517	38060.24025	75.357854
E	404895.667	464016.667	58149.98318	87.2624052
F	349343.333	462286.667	58212.98283	75.5508258
G	332463.667	461322.333	74841.86867	72.0702318
Total	357678.167	461035.667		
Std dev (total)	58000.6057	3551.2935		

APPENDIX K
User observation study:
Photos taken

IMAGES TAKEN OF THE DISINFECTANT DISPENSER DURING THE USER OBSERVATION STUDY

Disinfectant dispenser

2nd session

*Each row: same dispenser used

A1	D3	E2	
A2	F1	G3	
A3	C3	D2	E1
B1	F3	G2	
B2	F2	G1	
B3	C2	D1	E3
C1	D3		

A1	D3	E2	
A2	F1	G3	
A3	C3	D2	E1
B1	F3	G2	
B2	F2	G1	
B3	C2	D1	E3
C1	D3		

With top and bottom imaged

A1	D3	E2	
A2	F1	G3	
A3	C3	D2	E1
B1	F3	G2	
B2	F2	G1	
B3	C2	D1	E3
C1	D3		

With references for top and bottom

APPENDIX L
User observation study:
Participant times

USER OBSERVATIONS: TIMES

Participant A - Object 1			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	00:06.23	00:09.14	00:02.91
Open disinfectant dispenser			
Take wipe(s)	00:12.18	00:13.00	00:00.80
	00:10.04	00:11.23	00:01.19
	00:32.27	00:34.04	00:01.77
	00:53.14	00:54.20	00:01.06
Pump disinfectant	00:14.06	00:15.22	00:01.16
	00:35.03	00:36.19	00:01.16
	00:55.10	00:56.08	00:00.98
Clean 1st tool	00:19.02	00:30.29	00:11.27
Clean 2nd tool	00:38.20	00:47.27	00:09.07
Clean 3rd tool	00:56.23	01:09.18	00:12.95
Close disinfectant dispenser	01:12.00	01:12.27	00:00.27
Close wipes dispenser	01:13.09	01:14.03	00:00.93
Throw wipe(s) away	00:31.26	00:45.10	00:13.99
	01:10.29		
Total duration	01:07.79		

Participant A - Object 2			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	02:20.05	02:21.08	00:01.03
Open disinfectant dispenser			
Take wipe(s)	02:21.13	02:22.21	00:01.08
	02:23.01	02:23.13	00:00.12
	02:38.11	02:38.18	00:00.07
	02:55.12	02:56.09	00:00.97
Pump disinfectant	02:24.06	02:26.09	00:02.03
	02:43.01	02:44.14	00:01.13
	02:57.03	02:58.23	00:01.20
Clean 1st tool	02:28.09	02:36.04	00:07.95
Clean 2nd tool	02:43.05	02:51.28	00:08.23
Clean 3rd tool	03:03.16	03:12.10	00:08.94
Close disinfectant dispenser	03:15.25	03:17.01	00:01.76
Close wipes dispenser	03:14.73	03:15.11	00:00.86
Throw wipe(s) away	2:36:28, 2:53:03, 3:13:23		
Total duration	00:56.96		

Participant A - Object 3			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	04:28.25	04:29.25	00:01.00
Open disinfectant dispenser			
Take wipe(s)	04:29.09	04:31.01	00:00.94
	04:31.16	04:33.73	00:02.07
	04:46.06	04:47.00	00:00.94
	05:00.16	05:01.18	00:01.02
Pump disinfectant	04:34.12	04:36.00	00:01.88
	04:51.01	04:52.14	00:01.13
	05:03.09	05:03.15	00:00.06
Clean 1st tool	04:37.13	04:43.18	00:06.05
Clean 2nd tool	04:51.06	04:57.23	00:06.17
Clean 3rd tool	05:04.20	05:10.24	00:06.04
Close disinfectant dispenser	05:15.11	05:16.24	00:01.13
Close wipes dispenser	05:14.07	05:14.25	00:00.18
Throw wipe(s) away	00:45:45, 05:09.08, 5:13:00		
Total duration	00:47.99		

Participant A - Averages			
Action	Average duration (mins.ms)		
Open wipes dispenser	00:01.03		
Open disinfectant dispenser	00:00.95		
Close disinfectant dispenser	00:01.05		
Close wipes dispenser	00:00.66		
Clean object 1	00:11.10		
Clean object 2	00:08.37		
Clean object 3	00:08.37		
Take wipe(s) - Object 1	00:01.34		
Take wipe(s) - Object 2	00:00.39		
Take wipe(s) - Object 3	00:01.34		
Pump disinfectant - Object 1	00:01.33		
Pump disinfectant - Object 2	00:01.75		
Pump disinfectant - Object 3	00:01.62		
Total	00:57.58		

Participant B - Object 1			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	00:08.11	00:11.08	00:02.97
Open disinfectant dispenser	00:11.28	00:12.15	00:00.87
Take wipe(s)	00:13.03	00:14.07	00:01.04
	00:37.15	00:38.25	00:01.10
	01:00.20	01:01.00	00:00.80
Pump disinfectant	00:16.10	00:17.08	00:00.98
	00:39.11	00:41.13	00:00.99
	01:02.04	01:03.06	00:00.99
Clean 1st tool	00:18.25	00:33.21	00:14.96
Clean 2nd tool	00:42.24	00:50.00	00:15.76
Clean 3rd tool	01:04.21	01:15.17	00:10.96
Close disinfectant dispenser	01:18.07	01:18.20	00:00.13
Close wipes dispenser	01:18.29	01:19.13	00:00.84
Throw wipe(s) away	00:36:36, 00:50:08, 00:51:10, 1:10:09		
Total duration	01:11.02		

Participant B - Object 2			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	03:20.37	03:24.37	00:04:00
Open disinfectant dispenser	03:25.10	03:26.04	00:00:94
Take wipe(s)	03:28.11	03:29.37	00:01:16
	03:22.07	03:25.24	00:03:17
Pump disinfectant	04:20.09	04:21.44	00:01:05
	04:51.22	04:52.45	00:00:33
	05:05.03	05:06.00	00:00:56
	05:10.10	05:17.14	00:07:04
Clean 1st tool	04:23.26	04:25.19	00:01:53
Clean 2nd tool	05:08.21	05:19.22	00:11:03
Clean 3rd tool	05:28.20	05:36.33	00:07:53
Close disinfectant dispenser	03:41.01	03:41.29	00:00:28
Close wipes dispenser	03:42.11	03:43.20	00:01:09
Throw wipe(s) away	05:00:46, 05:19:13, 5:21:00, 3:21:00, 3:27:27		
Total duration	01:12.93		

Participant B - Object 3			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	04:44.27	04:46.15	00:01:08
Open disinfectant dispenser	04:43.09	04:44.16	00:01:07
Take wipe(s)	04:46.28	04:49.28	00:03:00
	05:07.15	05:07.05	00:01:04
	05:20.23	05:21.27	00:01:04
Pump disinfectant	04:50.17	04:53.10	00:02:03
	05:27.21	05:08.18	00:00:97
	05:22.10	05:23.13	00:01:03
Clean 1st tool	04:55.19	05:01.21	00:06:02
Clean 2nd tool	05:09.14	05:18.07	00:08:93
Clean 3rd tool	05:24.15	05:29.09	00:04:04
Close disinfectant dispenser	05:32.08	05:33.23	00:01:15
Close wipes dispenser	05:34.06	05:35.08	00:01:02
Throw wipe(s) away	05:00:46, 05:19:13, 5:21:00, 3:21:00, 3:27:27		
Total duration	05:00:51		

Participant B - Averages			
Action	Average duration (mins.ms)		
Open wipes dispenser	00:02:95		
Open disinfectant dispenser	00:00:86		
Close disinfectant dispenser	00:00:52		
Close wipes dispenser	00:00:68		
Clean object 1	00:06:70		
Clean object 2	00:06:63		
Clean object 3	00:06:63		
Take wipe(s) - Object 1	00:00:98		
Take wipe(s) - Object 2	00:01:77		
Take wipe(s) - Object 3	00:01:75		
Pump disinfectant - Object 1	00:01:33		
Pump disinfectant - Object 2	00:01:44		
Pump disinfectant - Object 3	00:01:64		
Total	01:04:02		

Participant C - Object 1			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	00:03.23	00:05.14	00:01:51
Open disinfectant dispenser			
Take wipe(s)	00:09.14	00:11.07	00:01:53
	00:37.19	00:39.08	00:01:59
	01:00.20	01:01.00	00:00:59
Pump disinfectant	00:24.05	00:24.27	00:00:22
	01:04.21	01:05.00	00:00:59
	01:26.27	01:23.15	00:00:89
Close disinfectant dispenser	02:18.17	02:19.06	00:00:89
Close wipes dispenser	02:19.24	02:20.12	00:00:88
Throw wipe(s) away	01:39:06, 1:57:20, 2:15:08		
Total duration	01:36.04		

Participant C - Object 2			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	01:59.25	02:01.04	00:01:19
Open disinfectant dispenser			
Take wipe(s)	03:33.15	03:35.21	00:02:06
	03:51.28	03:53.02	00:01:14
Pump disinfectant	04:04.04	04:05.00	00:00:56
	04:21.05	04:22.09	00:00:56
	04:53.04	04:54.07	00:00:53
Clean 1st tool	04:08.12	04:09.23	00:01:11
Clean 2nd tool	04:30.05	04:31.96	00:01:51
Clean 3rd tool	04:51.05	04:52.14	00:01:09
Close disinfectant dispenser	04:07.07	04:08.08	00:01:01
Close wipes dispenser	04:09.01	04:10.00	00:00:59
Throw wipe(s) away	2:36:28, 2:53:03, 3:13:23		
Total duration	00:55.11		

Participant C - Object 3			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	04:26.20	04:28.14	00:01:54
Open disinfectant dispenser			
Take wipe(s)	04:28.23	04:29.24	00:01:01
	04:38.11	04:39.27	00:01:16
	04:58.18	04:59.09	00:00:51
Pump disinfectant	04:47.09	04:48.74	00:01:05
	04:58.26	05:01.03	00:02:07
	05:12.25	05:13.30	00:00:98
Clean 1st tool	04:45.07	04:50.13	00:05:06
Clean 2nd tool	04:59.06	05:01.20	00:06:10
Clean 3rd tool	05:14.06	05:20.21	00:06:16
Close disinfectant dispenser	06:23.21	06:24.05	00:00:84
Close wipes dispenser	06:25.16	06:25.00	00:00:84
Throw wipe(s) away	5:51:33, 6:06:16, 6:22.10		
Total duration	00:52.88		

Participant C - Averages			
Action	Average duration (mins.ms)		
<tbl_info

Participant G - Object 1			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	00:15.05	00:16.23	00:01.18
Open disinfectant dispenser	00:19.12	00:20.20	00:01.08
Take wipe(s)	00:20.20	00:20.30	00:00.10
	00:40.20	00:43.18	00:03.98
	01:04.23	01:07.05	00:02.82
Pump disinfectant	00:21.10	00:23.09	00:01.99
	00:44.07	00:45.26	00:01.19
	01:28.04	01:29.83	00:01.81
Clean 1st tool	00:25.08	00:35.05	00:10.97
Clean 2nd tool	00:49.07	01:01.14	00:12.07
Clean 3rd tool	01:13.03	01:23.23	00:10.21
Close disinfectant dispenser	01:32.03	01:33.06	00:01.04
Clove wipes dispenser	01:30.27	01:31.20	00:00.93
Throw wipe(s), away	0:39.06, 1:03.19,		
	3:28.04		
Total duration (mins.ms)	01:18.01		

Participant G - Object 2			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	02:47.16	02:49.01	00:01.85
Open disinfectant dispenser	02:52.01	02:53.24	00:01.23
Take wipe(s)	02:49.01	02:51.05	00:02.05
	03:10.71	03:13.24	00:02.53
	03:29.06	03:34.16	00:05.10
Pump disinfectant	02:54.07	02:56.21	00:02.14
	03:14.08	03:15.17	00:01.09
	03:30.08	03:31.18	00:01.10
Clean 1st tool	02:57.12	03:09.17	00:12.05
Clean 2nd tool	03:18.03	03:26.10	00:08.07
Clean 3rd tool	03:39.17	03:48.28	00:09.11
Close disinfectant dispenser	03:51.27	03:53.01	00:01.74
Clove wipes dispenser	03:51.03	03:51.20	00:00.17
Throw wipe(s), away	0:03.11.10,		
	3:28.14, 3:50.00		
Total duration (mins.ms)	01:05.85		

Participant G - Object 3			
Action	Start (mins.ms)	End (mins.ms)	Duration (mins.ms)
Open wipes dispenser	04:55.08	04:56.28	00:01.20
Open disinfectant dispenser	04:57.15	04:58.25	00:01.10
Take wipe(s)	04:56.00	04:57.00	00:01.00
	05:19.03	05:22.26	00:03.23
	05:38.19	05:42.07	00:03.88
Pump disinfectant	05:02.15	05:04.18	00:02.03
	05:23.09	05:25.08	00:01.99
	05:45.00	05:47.00	00:02.00
Clean 1st tool	05:05.26	05:14.03	00:08.77
Clean 2nd tool	05:27.27	05:35.11	00:07.84
Clean 3rd tool	05:46.16	05:54.29	00:08.13
Close disinfectant dispenser	05:59.20	06:00.19	00:00.99
Clove wipes dispenser	05:58.26	06:00.03	00:01.77
Throw wipe(s), away	0:05.17.24,		
	5:36.25, 5:57.01		
Total duration (mins.ms)	01:05.11		

Participant G - Averages	
Action	Average duration (mins.ms)
Open wipes dispenser	00:01.41
Open disinfectant dispenser	00:1.14
Close disinfectant dispenser	00:00.56
Clean object 1	00:11.42
Clean object 2	00:09.74
Clean object 3	00:08.25
Take wipe(s) - Object 1	00:02.44
Take wipe(s) - Object 2	00:02.78
Take wipe(s) - Object 3	00:03.33
Pump disinfectant - Object 1	00:01.66
Pump disinfectant - Object 2	00:01.44
Pump disinfectant - Object 3	00:01.98
Total	01:09.66

APPENDIX M
User observation study:
Notes

USER OBSERVATIONS: NOTES

 The participant had some struggles
 The dispenser fell over
 "Unnecessary" actions by the participant
 The participant used both hands

Participant A			
Action	Object 1	Object 2	Object 3
Opening wipes dispenser	Uses two hands to open. Left hand on the bottom part and right hand to pull open the lid.	Uses two hands to open. Left hand on the bottom part and right hand to pull open the lid.	Uses two hands to open. Left hand on the bottom part and right hand to pull open the lid.
Opening disinfectant dispenser	Same as the wipes dispenser.	Same as the wipes dispenser.	Same as the wipes dispenser.
Taking a wipe	Right hand to take wipe.	Right hand to take wipe.	Right hand to take wipe.
Pumping disinfectant onto wipes	Right hand to pump disinfectant. Pumps a few times (3-4).	Right hand to pump disinfectant. Pumps a few times (3-4).	Right hand to pump disinfectant. Pumps a few times (3-4).
Using the wipes	Transfer wipe to left hand, opens dispenser, transfers back to right hand to pump disinfectant. Uses left hand to hold wipe and right hand for the tool.	Uses left hand to hold wipe and right hand for the tool.	Right hand to hold wipe and left hand for the tool.
Closing wipes dispenser	Right hand to close lid, left hand to hold the dispenser in place.	Only one hand (right) to close.	Only one hand (right) to close.
Closing disinfectant dispenser	Same as the wipes dispenser.	Only one hand (right) to close. Taps/presses the lid after closing.	Uses only one hand (right) at first to close but the dispenser wobbles. Then they used the other hand to hold the dispenser and then they closed the lid. Taps the top of the lid at the end.

Participant B			
Action	Object 1	Object 2	Object 3
Opening wipes dispenser		Tries to open using their right hand only but the dispenser falls backwards. They then used both hands to open the dispenser (they only used the thumb on their second hand to push the bottom of the dispenser down whilst pulling up the lid)	
Opening disinfectant dispenser	Opens with right hand	Used both hands in the same fashion as for wipes dispenser	
Taking a wipe	Takes with right hand, wrist turns so that the wipe is vertical, then turns to horizontal to press the pump	Used right hand only. Struggled to take one wipe alone. Shakes the wipes to get rid of the wipe stuck below the top one but that was unsuccessful. They pinched the top wipe off instead. For the 3rd item, they struggled to take only one wipe and in the end, used multiple pieces.	Struggles to pinch a single wipe during the first attempt.
Pumping disinfectant onto wipes	Pumps 2-3 times	For the first item, they pumped 2 times. Then they started cleaning the item but throws the wipe away halfway. They took a 2nd wipe, which they struggled to do (see above), then pumps 7 times. For the 2nd item, they pumped twice and looked at the wipe and then started using it.	Pumps 2 times
Using the wipes	Wipe stays in right hand	Wipe stays in right hand	Wipe stays in right hand
Closing wipes dispenser	Closes with right hand	Closes with right hand. Used the knuckle of their pinky finger to tap the top of the lid after closing.	Closes with right hand. Uses their thumb to tap the top of the lid after.
Closing disinfectant dispenser	Closes with right hand	Closes with right hand. Pressed the top of the lid after with their index finger.	Closes with right hand

Participant C			
Action	Object 1	Object 2	Object 3
Opening wipes dispenser	Uses their right hand to open the lid and their left hand to hold the bottom part.	Uses their right hand to open the lid and their left hand to hold the bottom part.	Uses their right hand to open the lid and their left hand to hold the bottom part.
Opening disinfectant dispenser	Uses their right hand to open the lid and their left hand to hold the bottom part.	Uses their right hand to open the lid and their left hand to hold the bottom part.	Uses their right hand to open the lid and their left hand to hold the bottom part.
Taking a wipe	Uses their right hand. Took some time to take a wipe during their 2nd attempt.	Uses their right hand. Took some time to take a wipe for all attempts (they repeated the pinching motion multiple times). For the final attempt, they used multiple wipes.	Uses their right hand. Struggled to take a wipe on their 2nd attempt
Pumping disinfectant onto wipes	Pumps 2 times	Pumps 2 times	Pumps 2 times
Using the wipes	Wipe stays in right hand	Wipe stays in right hand	Wipe stays in right hand
Closing wipes dispenser	Closes with right hand. The dispenser tilts backwards.	Closed the dispenser with their right hand. Then they tapped the top of the lid with their left hand.	Closed the dispenser with their right hand. After closing, pressed the top of the lid with their right hand.
Closing disinfectant dispenser	Closes with right hand	Closed the dispenser with their right hand. Then they pressed the top of the lid with their left hand.	Closed with their left hand.

Participant D			
Action	Object 1	Object 2	Object 3

Opening wipes dispenser	Uses their right hand to open the lid and their left hand to hold the bottom part. The dispenser tilted and moved backwards a bit	Uses left hand. Grips tops and bottom of lid with hand. The dispenser falls backwards and they used their left hand to tip it upright again.	Uses both hand to open the lid of the dispenser. The dispenser falls backwards. They used the side of their left hand to tilt it upright after opening the disinfectant dispenser.
Opening disinfectant dispenser	Used their right hand to hold the bottom part and their left hand to open the lid (without using their fingertips)	Uses their right hand to open the lid and their left hand to hold the bottom part.	Right hand holds the bottom part and left hand opens the lid
Taking a wipe	Took a wipe with their right hand, passed it to their left and then right again	Took some time to take one piece and moves the dispenser in the process. Took a wipe with their right hand, passed it to their left and then right again. For the 3rd attempt, they tried to separate "multiple" wipes but there was only one in their hand. They then proceeded with their task.	Took a wipe with their right hand, passed it to their left and then right again. It took some time for them to take a piece. For their final attempt, they used both hands to separate a wipe from other pieces in the dispenser.
Pumping disinfectant onto wipes	Pumps 2-4 times. For the 3rd attempt, they look at the wipe after pumping and then pumped again.	Pumps 2-3 times.	Pumps 2-3 times
Using the wipes	Wipe stays in right hand	Wipe stays in right hand	Wipe stays in right hand
Closing wipes dispenser	Uses their right hand to close the lid and their left hand to hold the bottom part.	Uses their right hand to close the lid and their left hand to hold the bottom part. Taps the top of the lid with their right hand after.	Used right hand
Closing disinfectant dispenser	Uses their right hand to close the lid and their left hand to hold the bottom part.	Uses their right hand to close the lid and their left hand (palm area) to hold the bottom part.	Uses their right hand to close the lid and their left hand to hold the bottom part.

Participant E			
Action	Object 1	Object 2	Object 3
Opening wipes dispenser	Opens the lid with their left hand. The dispenser falls backwards but they tip it upright again with the same hand.	Opened with their left hand. The dispenser tipped backward a little.	Opens with left hand
Opening disinfectant dispenser	Opens with their left hand	Rotates the dispenser until the right way was facing towards them, then opened the lid with one hand (right).	Opens with right hand.
Taking a wipe	Used their right hand	Used their left hand. Took time to take a piece.	Used their left hand
Pumping disinfectant onto wipes	Pumps 2 times. Seemed like some force was needed.	Passed the wipe to their right hand and pumps twice.	Pumped one time.
Using the wipes	They passed the wipe to their left hand and used their left hand.	They passed the wipe to their left hand and used their left hand.	Used their left hand
Closing wipes dispenser	Closed the lid with their left hand	Closed the lid with their left hand	Closed with right hand
Closing disinfectant dispenser	Closed with their right hand	Used their right hand to hold the lid and close it. The dispenser tilted and moved but did not close until after a few attempts.	Closed with left hand. The dispenser tips and rotates and falls over. They catch the dispenser mid-roll and place it upright.

Participant F			
Action	Object 1	Object 2	Object 3
Opening wipes dispenser	Opens with right hand. The dispenser falls backwards. After opening the disinfectant dispenser, they used the heels of both hands to right the dispenser.	Opened the lid with right hand	Opened the lid with right hand. The dispenser tilted backward.
Opening disinfectant dispenser	They attempted to open the dispenser with their left hand only but the dispenser did not open. They then used their other hand to hold the bottom part and open the dispenser.	Used left hand to rotate the dispenser to face the right way. Used right hand to hold the bottom part and left hand to pull the lid open	Used right hand to hold the bottom part and left hand to pull the lid open
Taking a wipe	They struggled to take only one piece. Right hand used.	They struggled to take only one piece. Right hand used.	They struggled to take only one piece. Right hand used.
Pumping disinfectant onto wipes	They passed the wipe to their other hand (left) and pumped the dispenser 3 times.	They used both hands to hold the wipe and pump the dispenser	Used right hand only to pump. They already had an item in their other hand.
Using the wipes	Used their left hand.	Used their right hand.	Used their right hand.
Closing wipes dispenser	Closed with their right hand.	Closed with their right hand.	Closed with right hand
Closing disinfectant dispenser	Closed with their left hand. They pressed down on the lid with some force. Note: their preferred hand may be due to the location of the dispenser.	Held the bottom part with their left hand and closed the lid with their right.	Closed with left hand

Participant G			
Action	Object 1	Object 2	Object 3
Opening wipes dispenser	Opened the lid with their right hand and used their other hand to hold the bottom part	Opens with their right hand. The dispenser moves backwards and they stop it with their other hand.	Grips the side of the lid with their right hand (same as the other 2 objects). Uses left hand to hold the bottom part.
Opening disinfectant dispenser	Lifted the dispenser with their left hand to reposition it and used the same hand to open the lid.	Rotated the dispenser with their left hand, used their right to nudge the bottom part down (it lifted up) while opening the lid with the other hand.	Rotated the dispenser with their left hand, used their right to hold the bottom part while opening the lid with the other hand.

Taking a wipe	Used their right hand	Used their right hand. The wipes were partially vertical and it seemed to make it easier for them to take a piece.	Used their right hand. Took some time to take a piece.
Pumping disinfectant onto wipes	Pumps 2-3 times with right hand	Pumps 2-3 times with right hand	Pumps 3 times with right hand
Using the wipes	Passed the wipe to their left hand for the first attempt. Continued using their right for their other attempt.	Used right hand. For the 2nd & 3rd attempt, they passed the wipe to their left hand.	Used right hand, also swaps to left hand.
Closing wipes dispenser	Closed with right hand	Closed with right hand	Closed with right hand
Closing disinfectant dispenser	Closed with left hand. They used their thumb to press on the bottom part of the dispenser and their other fingers on the lid.	Closed with left hand	Closed with left hand

APPENDIX N
User observation study:
Interviews

POST-OBSERVATION INTERVIEWS

Participant	Process	Pain points	Hand dominance	Experience	Extra comments regarding the experiment	Quotes
A	They take the necessary items (i.e. scissors, tweezers) from the drawers and place them on top of said drawers. Then, they clean the table with RNase Away. While working, the dispenser is always on top of the drawers which they drag from its original location by the wall to the side of the table. They never place the dispenser on the table. They clean their tools by the table and leave them on a clean piece of tissue paper. Also, they close the dispensers after use because there might be a lot of blood with their work and they do not want to contaminate the dispensers. They dry their tools with tissue papers but if they have more time, they leave it to airdry. After finishing their work, they clean the table again and the camera sometimes. They never clean the dispensers.	Taking the wipes out of the dispenser because it is difficult and time-consuming to just take one piece. Also, sometimes they pump out too much disinfectant at a time but finds that it is nice that the wipes get wet enough/that they can get as much disinfectant as they want by pressing down on the dispenser pump to get the wipes wet enough.	Right-handed	15.5 years		
B	The dispenser is always in/on the drawers. They leave them open the whole day but closes them after work and place them in the drawers. During work, the chest of drawers is placed by the table.	They do not like the dispenser because taking the wipes out of it is difficult as they cannot just take one piece easily. Their gloves are not always clean so if they take a few sheets, they will just use them.	Right-handed	15 years		
C	During work, the chest of drawers is placed by the table. The dispensers are on the drawers most of the time but not in every lab. They always leave them there and doesn't put them back themselves, not even when they leave the lab. The dispensers are always open during their investigation (work) and they close it when they leave the lab, but not always. Aside from that, they lay out their tools/instruments on a piece of tissue paper. They clean the tools before they start their work.	Taking the wipes out of the dispenser because it is difficult to just take one piece. The disinfectant dispenser tends to splash disinfectant everywhere, when they do not put their hand on the pump part "quite well".	Right-handed	10 months		
D	Firstly, they clean the table and get their tools (i.e. tweezers, scissors) from the "sluis" (a room adjacent to the lab where they get dressed and where equipment is stored). The dispensers are already in the laboratory. They clean the tools before use and place them on a sheet of tissue paper (or paper) on the table. The dispensers stay on top of the chest of drawers. They do not clean the dispensers. The dispensers stay open the whole time they are working and they only close it when they leave the lab.	Opening the dispenser is inconvenient. Taking the wipes out of the dispenser because it is difficult to just take one piece.	Right-handed	5 weeks	Working with oil on their gloves feels "bit more glitchy" because it is difficult to clean an object but they know it will not be clean because there is something on their hands.	
E	The dispensers are normally on the chest of drawers or sometimes in them. They close the dispenser when they are finished with the item they are working on but not everytime. They dry their tools with wipes so they do not get any disinfectant on the "trace". Clean tools go on a piece of tissue paper on the drawers.	Taking the wipes out of the dispenser because it is difficult to just take one piece. The disinfectant dispenser splashes disinfectant everywhere when the top pump part is pushed down (to dispense the disinfectant).	Right-handed	11 years		
F	Before they start with their case, they place all the tools on top of the chest of drawers and clean them with RNase Away and wipes. They then dry them. After that, they place the tools on a sheet of tissue paper. They always close the disinfectant dispenser after use but not the wipes dispenser. They clean the dispensers depending on the case they're working on. If there is a lot of blood and if they think they can get a lot of DNA from the SVO (stuk van overtuiging, meaning evidence) on their gloves, then they will clean the dispensers.	Taking the wipes out of the dispenser because it is difficult to just take one piece. They have to clean their gloves as well since they touch more than one wipe at a time.	Left-handed	7 years. 2.5 years at the sporenonderzoek	When they clean tools, everything is done "automatically" due to muscle memory.	
G	Most of the time the dispensers are already on top of the chest of drawers. They clean the tools, as in the experiment, and while letting them dry, they open the evidence or work on the computer. If the tools are still wet, they take a dry piece of tissue paper and place them on it. If there is a lot of work on one evidence item (e.g. a lot of blood), they place the tools and dispensers on the table because it is more convenient for them.	Taking the wipes out of the dispenser because it is difficult to just take one piece. It is also annoying that the wipes do not fit exactly in the dispenser. The lid does not close easily sometimes, or it breaks.	Right-handed	8 years	So sometimes I pick five and I think, OK, expensive, but yeah. It's really annoying and it annoys me that it doesn't fit in the box.	

APPENDIX O
Interviews with the
police

SUMMARY: INTERVIEWS WITH THE POLICE

Participant	1	2	3	4
Job	Operationeel Specialist A, Forensische Opsporing. With the police. 60-70% of their time is spent on crime scene investigations.	Operationeel Specialist A, Forensische Opsporing	Operationeel specialist A, Forensisch onderzoeker	Generalist Forensische Opsporing
Experience	12.5 years. Senior investigator for 5 years now.	Started out at the Police Academy in 2012 and has been working in the forensic department since 2014. Therefore, 8 years.	14 years.	5 years
Workplace	They generally start the work day at the office, at the police station. About half the time, they are at crime scenes. They also have night shifts and may get called in to work for big cases at night.	They normally work two days a week at crime scenes, or be on call for crime scene investigation. One day a week, they will work in cold cases and missing persons which consists of a lot of file and evidence research.	They work in the laboratory, usually in Drachten, but sometimes they work in other areas. The labs are generally all the same - the major difference being the age of the building. The tools and equipment used are mostly the same.	They work in their office at the police station, where they normally start their work day, and at crime scenes, when they are called to them. They go to crime scenes everyday.
Tools/equipment used (examples)	Scales, camera, flashlight/torch, items used for sampling, markers	Scissors, zip ties, ruler, camera. Most tools are individually packaged and for one time use.	Scissors, tweezers.	N/A
Tool cleaning process	They make a sterile area with a special sheet. This area depends on the crime scene. It can be indoors or outdoors. For example, if the crime scene is a house and they want to go in through the front door, the sterile area would be in front of the front door. They place their items on the sheet and put on their PPE (a suit, gloves, a face mask and a hairnet) on the sheet as well. In the recent years, they have started to clean their PPE with disinfectant because they realised that the chance that they are contaminated is quite big. After that, they will clean their tools. They might forget to clean them but it depends on the case. They think that all their tools are contaminated. Then, the first place they step into is the crime scene.	They set up a clean area where they place their suitcases with all the equipment and tools. This can be at the entrance to a crime scene. They decide where to place the dirty tools. They then clean them with RNase Away and with clean gloves on, and place them in a separate section to the dirty tools. They do not clean all their tools before use (camera, for example). "We do not work as surgeons. We are not sterile but we are very keen on how we avoid contamination from DNA."	Firstly, they will clean the table. Then they will clean every tool they plan on using and after each piece of evidence, they will clean them again. Currently, they are using the RNase Away disinfectant but they are aware of the new disinfectant FMD Away. The dispenser is cleaned before it is put on the table and cleaned again before it is put back into the cabinet.	How they set up their workspace at crime scenes depends on the crime scene itself. They are not ideal workspaces and most of the time, they have to work on the floor and there are no tables. They have to work kneeling. They lay down a sterile sheet on the ground to work on. If it's raining, they have tents although things may get wet. "Crime Scene investigation is sometimes improvising with weather, with space you have; you have to be flexible about where you're working"
Dispenser/item used to clean tools	Cardboard box of dry wipes and sprayer (similar to a window cleaner sprayer) with RNase Away. The sprayer has half a litre of disinfectant. How long this amount lasts depends on the case they are working on. Sometimes ethanol wipes. They used to have individually packaged wipes that they found easy and good to use.	A cylindrical container of wet wipes. They pull the wipes out at the top. The dispenser is labelled.	A cylindrical container of wet wipes. They pull the wipes out at the top. They have the new dispensers as well but they will only start using them once the current ones run out.	They use prepackaged alcohol wipes to clean smaller things because the wipes are already wet, and quick and easy to use. To clean bigger items, they use RNase Away on tissue paper (generally the blue coloured one that comes in a roll). They say that the tissue paper is probably not sterile.
Storage	Their tools are always kept in small labelled cases in their car and they take the required cases to the crime scenes as necessary. The cases are shared between colleagues. They do not know who might have used the car, and the tools, before them. They also have a private bag with some tools. However, specialist equipment, such as expensive lights, are kept in storage at the police station.	They bring just one dispenser to the crime scene. However, in their car, they have a few more. They prepare what they need from the car and take as few items as possible. They share their car with another colleague but it is also used by other colleagues sometimes, which means that their equipment is also used by other colleagues.	The laboratory, in a cabinet. They take it out during work and put it back after. During work, they make a small clean space on a big table where they place the dispenser and all their equipment. The lab is shared with the same 3-4 people.	In a van which they share with their department. See figures X-X.
Current dispenser design	The current process is not quick/easy because it is a two step process (spray and then wipe). There might also be a risk of spraying too much disinfectant. Aside from that, they do not refill the disinfectant dispenser. It is disposed of and they get a new one.	It's not always easy because the lid of the dispenser can be difficult to open with gloves on. They also have to hold the dispenser, else they are unable to pull out the wipes.	They find that it is okay for lab use, because they use it more frequently. However, they hear from colleagues who work on crime scenes that they have issues with the wipes drying out. They also noticed fungus on the wipes. Aside from that, they think that the current dispenser is easy to use because they just have to pull out the already moistened wipes. In regards to the new dispenser at the NFI, it is a two-step process (take wipe and moisten). If this current dispenser stayed available, they would continue to use it. Moreover, they have to refill their dispensers but there is a risk of contaminations so the dispensers have to be cleaned thoroughly before refill. Lastly, the dispenser is made of plastic and the lid breaks over time (sometimes just around the one year mark depending on the frequency of use).	The process is not "really practical". The bottle of disinfectant is stored in their van and when they pick it up, their gloves get dirty and then they have to clean their tools. They might change gloves but it is a lot of changing to do and having to think if whether what they are holding is clean or not. They do not clean the bottle before use. They also tried the latest dispenser at the NFI and they like that it is something that you put down and not have to pick up to use. They think that it could dispense more disinfectant per pump, especially for when they are cleaning larger objects.
Ideal dispenser design	1) They think that a plastic, as opposed to a cardboard, dispenser would be easier to clean. The chance of transferring DNA onto it might be smaller. Additionally, it may secure the wipes better. 2) Easy to clean 3) Easy to take and to put away 3) As few edges as possible 4) Contact-free	An automatic dispenser (motion sensor). In regards to the new dispenser at the NFI, they think that it is useful to have a disinfectant pump that presses down so they do not have to use both hands to take a wipe.	They think that the size of the disinfectant dispenser should not be too big because of the expiration date of the disinfectant. Sometimes, they see that their colleagues use materials that are almost expired or already expired and they believe a smaller size would remedy this. They label the expiration dates on the dispensers personally, with a sticker and they do not have a better idea for this. The dispenser should be clearly labelled.	Something like an automatic soap dispenser, where there is no need to touch.
Investigative process	Their general approach to an investigation is almost always the same, no matter the location (e.g. car, house, outdoors). They follow the "vier face" (four face) model, which is taught at the Police Academy. They start by orientating ("What do we see? What do we need? What are we going to do? Do we need some more stuff?"). Then, they make a plan. Thirdly, they carry out the investigation which includes taking photographs. When they are finished, they carry out the first step again to ensure that they do not forget anything.	They do not regularly clean tools at crime scenes because their tools are generally single use only.		

APPENDIX P
Data Management Plan
(DMP)

Design of a dispenser for crime scenes and laboratories

0. Administrative questions

1. Name of data management support staff consulted during the preparation of this plan.

Question not answered.

2. Date of consultation with support staff.

Question not answered.

I. Data description and collection or re-use of existing data

3. Provide a general description of the type of data you will be working with, including any re-used data:

Type of data	File format(s)	How will data be collected (for re-used data: source and terms of use)?	Purpose of processing	Storage location	Who will have access to the data
Informed consent form	PDF	Via e-mail or tablet	To register informed consent	External hard drive and password-protected laptop of the responsible project leader	TU Delft researchers
Video of (face not in frame) participant working in laboratory (user observations)	Video file	A camera	To learn the participant's workflow	External hard drive and password-protected laptop of the responsible project leader	TU Delft researchers
Interview voice recording	mp3	A phone or laptop	To establish the current scenario that participants face with a product	External hard drive and password-protected laptop of the responsible project leader	TU Delft researchers
Photographs of the test setup	jpg or png	Camera or phone	To show a clear image of how the setup looks, as opposed to just words	External hard drive and password-protected laptop of the responsible project leader	TU Delft researchers
Photographs of the product used by the participant (under UV light)	jpg or png	Camera or phone	To see how the effects of user interaction	External hard drive and password-protected laptop of the responsible project leader	TU Delft researchers
Questionnaire results	Excel sheet and Word document	Qualtrics or MS Teams form	To determine what to test for in user observations	External hard drive and password-protected laptop of the responsible project leader	TU Delft researchers

4. How much data storage will you require during the project lifetime?

- < 250 GB

II. Documentation and data quality

5. What documentation will accompany data?

- Methodology of data collection

III. Storage and backup during research process

6. Where will the data (and code, if applicable) be stored and backed-up during the project lifetime?

- Another storage system - please explain below, including provided security measures

External hard drive and a password-protected laptop. Data will be published onto the TU Delft repository in a report after project completion.

IV. Legal and ethical requirements, codes of conduct

7. Does your research involve human subjects or 3rd party datasets collected from human participants?

- Yes

8A. Will you work with personal data? (information about an identified or identifiable natural person)

If you are not sure which option to select, ask your [Faculty Data Steward](#) for advice. You can also check with the [privacy website](#) or contact the privacy team: privacy-tud@tudelft.nl

- Yes
- The name of the participant on the informed consent form
- The participant's job description from interviews
- Video recording of the participant

8B. Will you work with any other types of confidential or classified data or code as listed below? (tick all that apply)

If you are not sure which option to select, ask your [Faculty Data Steward](#) for advice.

- No, I will not work with any confidential or classified data/code

9. How will ownership of the data and intellectual property rights to the data be managed?

For projects involving commercially-sensitive research or research involving third parties, seek advice of your [Faculty Contract Manager](#) when answering this question. If this is not the case, you can use the example below.

The datasets underlying the published papers will be publicly released following the TU Delft Research Data Framework Policy. During the active phase of research, the project leader from TU Delft will oversee the access rights to data (and other outputs), as well as any requests for access from external parties. They will be released publicly no later than at the time of publication of corresponding research papers.

10. Which personal data will you process? Tick all that apply

- Data collected in Informed Consent form (names and email addresses)
- Signed consent forms
- Photographs, video materials, performance appraisals or student results
- Email addresses and/or other addresses for digital communication

11. Please list the categories of data subjects

Laboratory technicians and crime scene investigators

12. Will you be sharing personal data with individuals/organisations outside of the EEA (European Economic Area)?

- No

15. What is the legal ground for personal data processing?

- Informed consent

16. Please describe the informed consent procedure you will follow:

All study participants will be asked for their written consent for taking part in the study and for data processing before the start of the interview/user observation study/questionnaire.

17. Where will you store the signed consent forms?

- Same storage solutions as explained in question 6

18. Does the processing of the personal data result in a high risk to the data subjects?

If the processing of the personal data results in a high risk to the data subjects, it is required to perform [Data Protection Impact Assessment \(DPIA\)](#). In order to determine if there is a high risk for the data subjects, please check if any of the options below that are applicable to the processing of the personal data during your research (check all that apply).

If two or more of the options listed below apply, you will have to [complete the DPIA](#). Please get in touch with the privacy team: privacy-tud@tudelft.nl to receive support with DPIA.

If only one of the options listed below applies, your project might need a DPIA. Please get in touch with the privacy team: privacy-tud@tudelft.nl to get advice as to whether DPIA is necessary.

If you have any additional comments, please add them in the box below.

- None of the above applies

22. What will happen with personal research data after the end of the research project?

- Other - please explain below

Pseudonymised data will be archived at 4TU.ResearchData. Permission will be asked in the informed consent form.

23. How long will (pseudonymised) personal data be stored for?

- 10 years or more, in accordance with the TU Delft Research Data Framework Policy

24. What is the purpose of sharing personal data?

- For research purposes, which are in-line with the original research purpose for which data have been collected

25. Will your study participants be asked for their consent for data sharing?

- Yes, in consent form - please explain below what you will do with data from participants who did not consent to data sharing

The data from participants who did not consent will not be collected.

V. Data sharing and long-term preservation

27. Apart from personal data mentioned in question 22, will any other data be publicly shared?

- All other non-personal data (and code) underlying published articles / reports / theses
- All other non-personal data (and code) produced in the project

29. How will you share research data (and code), including the one mentioned in question 22?

- All pseudonymised data will be uploaded to 4TU.ResearchData with restricted access

30. How much of your data will be shared in a research data repository?

- < 100 GB

31. When will the data (or code) be shared?

- As soon as corresponding results (papers, theses, reports) are published

32. Under what licence will be the data/code released?

- CC BY-NC-ND

VI. Data management responsibilities and resources

33. Is TU Delft the lead institution for this project?

- Yes, leading the collaboration - please provide details of the type of collaboration and the involved parties below

The Netherlands Forensic Institute is a partner in this project. Furthermore, there will be participants from the police.

34. If you leave TU Delft (or are unavailable), who is going to be responsible for the data resulting from this project?

Dr.ir. Arjo Loeve (mentor). E-mail: A.J.Loeve@tudelft.nl

35. What resources (for example financial and time) will be dedicated to data management and ensuring that data will be FAIR (Findable, Accessible, Interoperable, Re-usable)?

4TU.ResearchData is able to archive 1TB of data per researcher per year free of charge for all TU Delft researchers. We do not expect to exceed this and therefore there are no additional costs of long term preservation.

APPENDIX Q
Human Research Ethics
Committee (HREC)
approval

Human Research Ethics Committee
TU Delft
(<http://hrec.tudelft.nl/>)

Visiting address
Jaffalaan 5 (building 31)
2628 BX Delft

Postal address
P.O. Box 5015 2600 GA Delft
The Netherlands

Ethics Approval Application: Design of a dispenser for crime scenes and laboratories
Applicant: Josephine Leong Zhen Nian, Josephine

Dear Josephine Josephine Leong Zhen Nian,

It is a pleasure to inform you that your application mentioned above has been approved.

Please note that this approval is subject to your ensuring that the following conditions are fulfilled:

- 1) The Informed Consent form (including a statement with information on the research project) is presented to the participants separate from the entire documentation on the study;
- 2) Participation is indeed voluntary for participants (e.g. there is no (implicit) pressure on participants from the employer to participate);
- 3) Reflections are made on the involvement of the NFI and Police with respect to possible risks to participants and no raw data will be shared with both institutes.

We advise a precautionary approach: in principle we advise not to publish transcripts – and if it's necessary to do so care must be taken to make sure that transcripts are not

Good luck with your research!

Sincerely,

Dr. Ir. U. Pesch
Chair HREC
Faculty of Technology, Policy and Management

APPENDIX R
List of requirements and
sources

LIST OF REQUIREMENTS: SOURCES

Number	Demand/wish	Source	Quote
D1	The product should not exceed 30cm in height. As for the other dimensions, the aim should be to make the product as compact as possible.	NFI	somewhere between 0-30cm
D2	The product should be able to fit into the cases that CSIs use for storage in their vehicle and the cases used at the NFI.	NFI & interview	Has to fit in CS cases. easy to take with you to put away
D3	The volume of disinfectant that the product can contain, if refillable, should be <250ml to ensure that the disinfectant is used up before the expiry date. In the case of disinfectant contamination or the case that the disinfectant's efficacy reduces from, for example, being stored in the uncertain conditions like in the CSIs' vehicles, a smaller volume can be disposed of with less corresponding waste produced.	Interview & e-mail	because of the conditions in the crime scene cars (extreme heat during summer or cold during winter) and the risk of contamination (when you use a bigger bottle you will probably use it on more crime scenes) that I think it's better to use smaller bottles, that you replace more frequently.
D4	The product should not be more than 1kg, without the disinfectant.	NFI	somewhere between 0-1 kg (without the liquid)
D5	The product must be portable.	See introduction chapter	
D6	The material(s) used should be easy to clean with wipes/tissue paper and disinfectant (i.e. smooth finish).	Interview	Easy to clean
D7	The product should be able to withstand being cleaned with disinfectant.	NFI	Has to withstand the harsh cleaning fluid
D8	The product should be suited for cleaning with UV light.	NFI	easy to clean, also with UV-light.
D9	The total number of units to be produced is >1000. The NFI would require ~20 and the police would require 1000+ (this figure is based on FreeRef, a measuring equipment mounted on cameras, and each police unit should have one).	NFI	about 20 for the NFI. If the police is also going to use it (what we hope/think/would be nice for them to) than about 40 maybe for the FO labs and then the CSI people; hard to say how much exactly, but I think about 200 in total. # Police hard to tell. For the FreeRef (measuring equipment on camera) they estimated 1000+. As each unit should have one. Same applies here I guess.
W1	The product should have the logo of the NFI and the TU Delft displayed on it.	NFI	would be nice to have NFI on it (and maybe TU Delft?)
W2	The product should have a section that is transparent so that the level of disinfectant inside can be easily seen for refills.	NFI	Transparent so one can see whether it should be refilled or not
D10	There should be an area on the product to display information about the disinfectant and wipes (such as a code, number and/or expiry date).	NFI	A place to add a code/number/expiry date of the fluid/tissues (by hand or adhesive)
W3	The product should have as few edges as possible to facilitate easier cleaning.	Interview	as less edges if possible
D11	The product should be suitable for indoors and outdoors use. This would include considerations for varying ambient temperatures and uneven surfaces.	Interview & e-mail	it can be a room. Sometimes it's outdoors. It depends on the crime scene.
D12	The product should be suitable for use in both the laboratory and at crime scenes.	See introduction chapter	
W4	The product lifespan should be >1 year if it is refillable. There is preference for the product to be refillable to keep total overall costs down as disinfectant and wipes will be used frequently.	NFI	at least 1 year if it's refillable, if it's disposable than only 1 use. long lasting and more expensive to cheap for shorter use
D13	If the product is not refillable, then the lifespan should be one use only.	NFI	at least 1 year if it's refillable, if it's disposable than only 1 use
D14	The product should be durable and thus parts should work optimally for the entirety of its lifespan.	User observation insight	
D15	The product should cost 0 – 20 EUR. If the product lifespan is longer, then the cost can skew towards the higher end of the range and vice versa.	NFI	somewhere between 0 – 20 euros. Depending on if it's disposable or not and how many function it has, and how strong it is (if the product life span is higher, than the costs are also allowed to be higher).
D16	The product must dispense either the RNase Away or FMD Away disinfectant.	See introduction chapter	
D17	The product must dispense the Contec AmplitudeTM DeltaTM 10cm x 10cm wipes.	See introduction chapter	
D18	The product should perform better than its predecessor (i.e. more convenient and quicker for the user to use). This could be tested by carrying out the same user observation study that was conducted with the predecessor.		
W5	The product should dispense the ideal amount of disinfectant each time (which is the same amount as 3 pumps of disinfectant with the current dispenser).	User observation insight	
W6	It should be a one-step process to use the product, meaning that the user only must carry out one action to dispense disinfectant and wet the wipe.	User observation insight	
D19	Usage should be contact-free from the user or involve as little contact as possible (e.g. one-handed operation).	See introduction chapter	
W7	There should be feedback to the user after closing the product so that they know that it is closed.	User observation insight	
D20	The use cues of the product should be easily understandable.		
D21	The product should be easy to refill, if refillable.		

APPENDIX S
Ideation session Miro
board

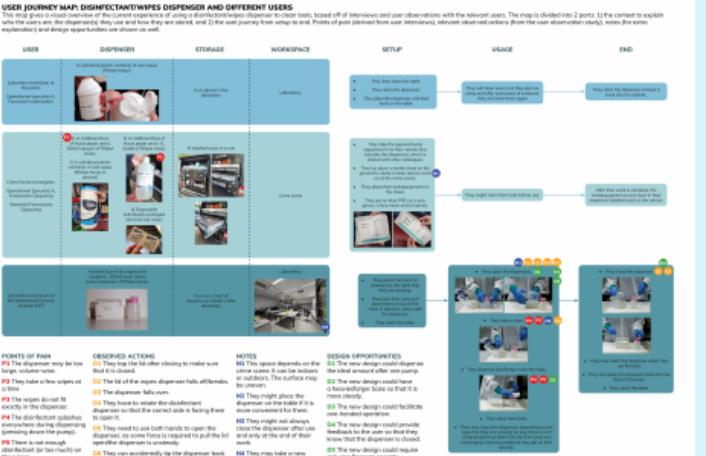


15 minutes

INTRODUCTION

Project brief
Design a device for dispensing and moistening (with disinfectant) wipes.

Problem statement
Create a new dispenser(s) for **disinfectant and dry wipes** that is **contamination-safe** with a **streamlined use process**, to be used by both **laboratory technicians and CSIs** from the police/the NFI in the laboratory or at crime scenes.



BRAINSTORM

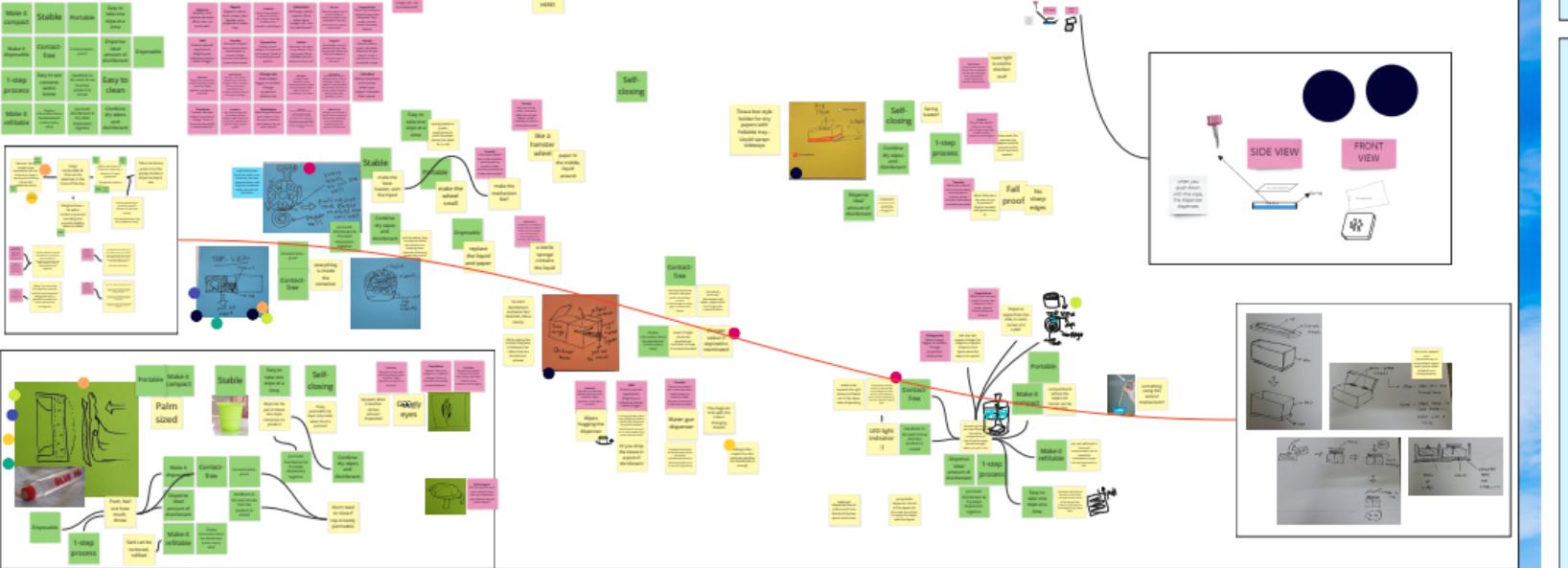
Guide

Come up with 1 concept each - 5 mins
Use the green "How To" cards - 5 mins
Use the pink "What If" cards - 5 mins
Change your "What If" cards! - 5 mins

UNDER THIS SKY, THERE ARE: NO LIMITS, NO JUDGEMENTS, NO CONSEQUENCES!

How To

What If



25 minutes



5 minutes

VOTING

Participant 1	●
Participant 2	●
Participant 3	●
Participant 4	●
Participant 5	●
Participant 6	●
Participant 7	●

Put a dot on your favourite idea!

REFLECTION & FEEDBACK



I think that...

Fun!

Not enough time

There are other ways to do this

APPENDIX T

Ideas processing

Contact-free

everything is inside the container

Individual disinfectant pods (like detergent pods) that come around melts/disappears when gets in contact with tissues

Completely eliminate disinfectant and wipes, expose tools to UV light with a special device

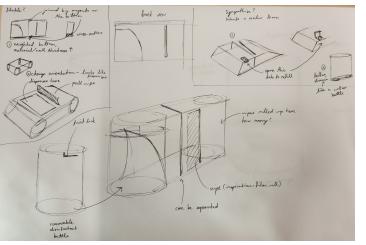
motors can squeeze the right amount of liquid out of the wipes when dispensing

Automated!!! like with motor to roll the wipes out and maybe a motion sensor to know when you have to touch anything (e.g. Hold the container) to get a wipe

Make it refillable

you can add liquid in the lid compartment, which should be transparent so you can see how much is left.

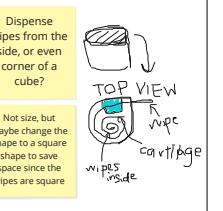
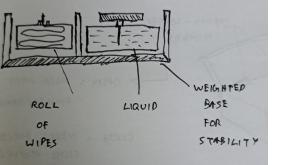
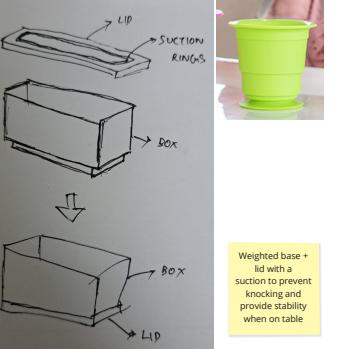
Sack can be removed, refilled



Stable

make the base heavier, with the liquid

Rubber feet for stability



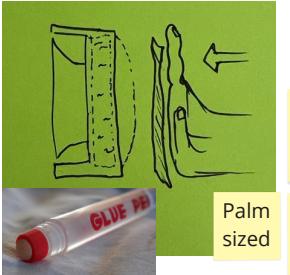
What if kids were to touch the product? (Similar to adults with gloves using it)

Fall proof
No sharp edges

Wipes hugging the dispenser

compartment where the wipes are stored can be adjusted

Form



Push, feel out how much, throw

Thinly permeable top layer only oozes when front is pressed

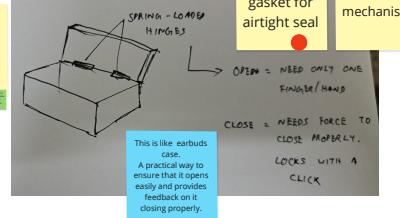
a sterile 'sponge' contains the liquid

While pulling the tissues, they pass in between two rollers that are disinfectant-infused

Spring loaded?

Spring loaded or similar mechanism to push the paper pieces (no need for a roll)

Optional: Spring loaded hinge mechanism for one-handed (or finger) opening and closing (Think TWS earphone cases)



Self-closing

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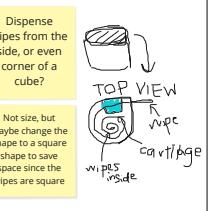
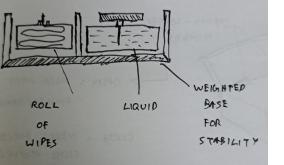
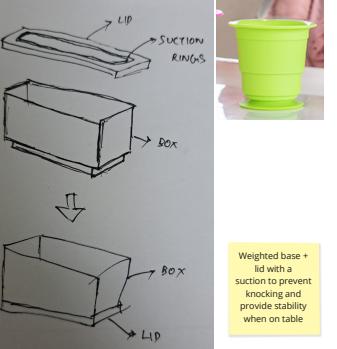
motors can squeeze the right amount of liquid out of the wipes when dispensing

Automated!!! like with motor to roll the wipes out and maybe a motion sensor to know when you have to touch anything (e.g. Hold the container) to get a wipe

Stable

make the base heavier, with the liquid

Rubber feet for stability



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Wipes hugging the dispenser

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Form

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Insert UV light inside the disinfectant container to keep it uncontaminated
Changes colour if expired/co contaminated

Feedback to let users know that the product is closed

LED light indicator

Squeaks when it reaches certain amount dispensed

Magnetic closure

Silicone gasket for airtight seal

Push latch mechanism?

This is like earbuds case. A practical way to ensure that it opens easily and it provides feedback on its closing properly.

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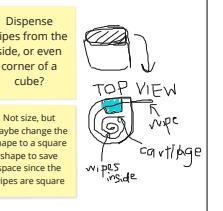
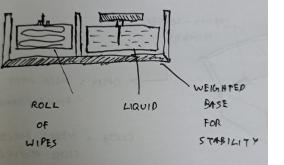
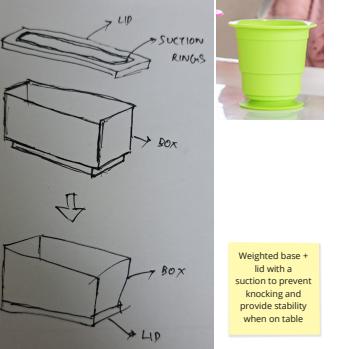
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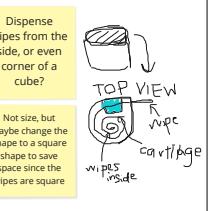
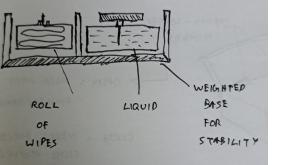
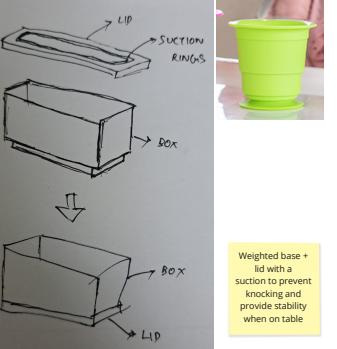
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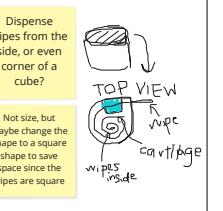
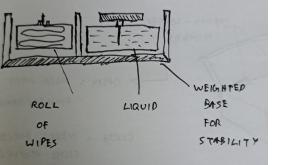
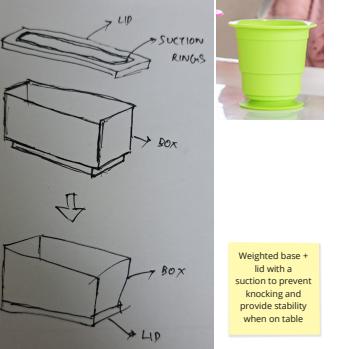
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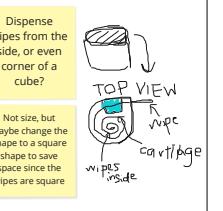
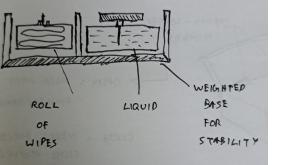
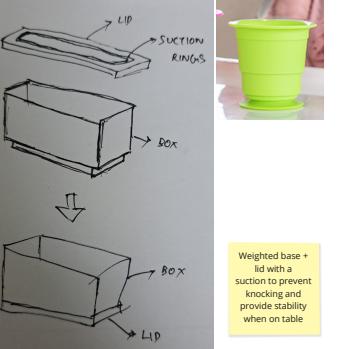
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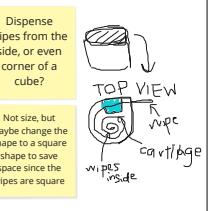
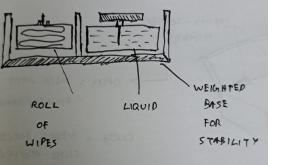
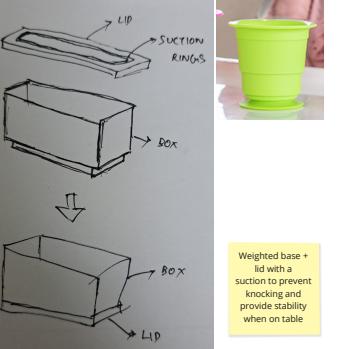
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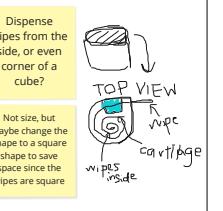
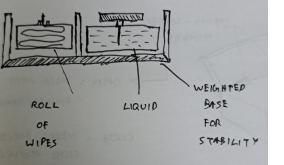
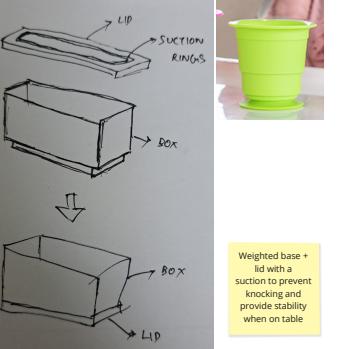
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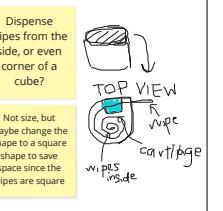
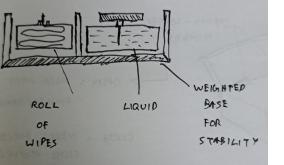
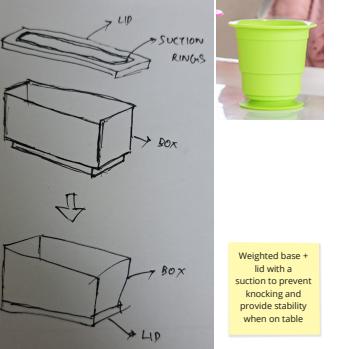
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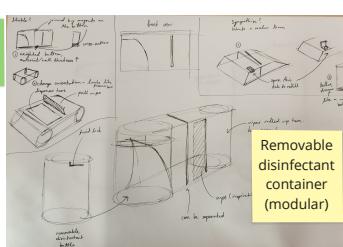
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LED light indicator</p

Wipes/disfectant container

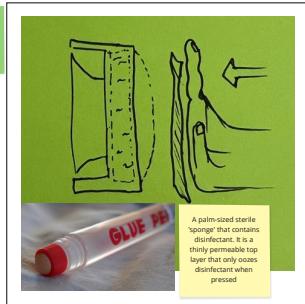


compartment where the wipes are stored can be adjusted

Wipes hugging the dispenser

Removable disinfectant container (modular)

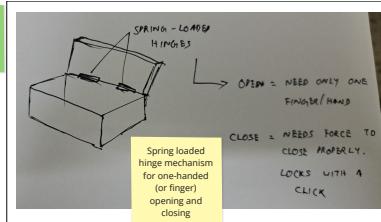
Material soaked in disinfectant



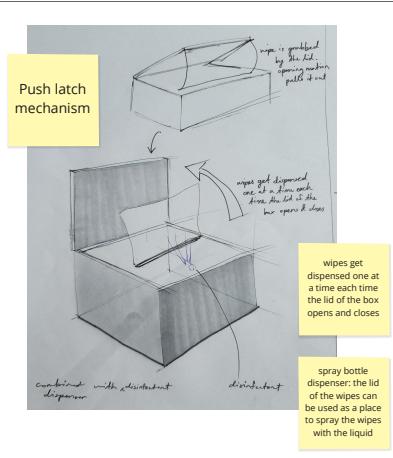
While pulling the tissues, they pass in between two rollers that are disinfectant-infused

A palm-sized sterile 'sponge' that contains disinfectant. It is a thin porous layer that only oozes disinfectant when pressed

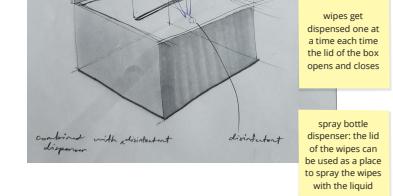
Opening/closing



Push latch and spring-loaded mechanisms are the same thing



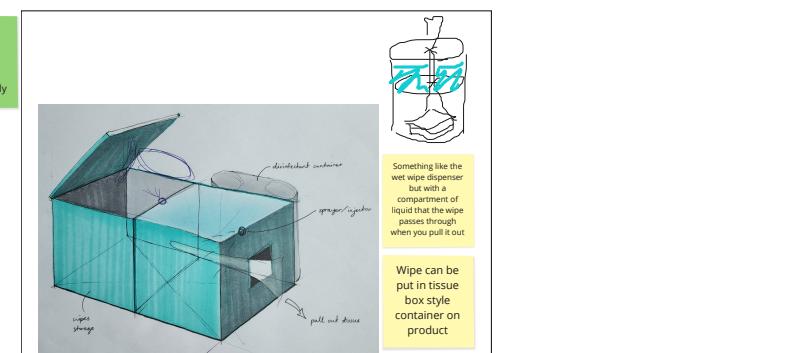
Magnetic closure



disinfectant

spray bottle dispenser: the lid of the wipes can be used as a place to spray the wipes with the liquid

Combine



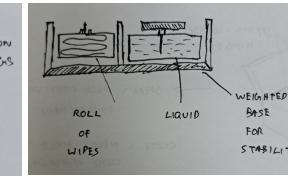
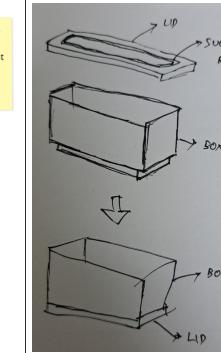
disinfectant container
spray/suction

pull out tissue

Wipe can be put in tissue box style container on product

Stability

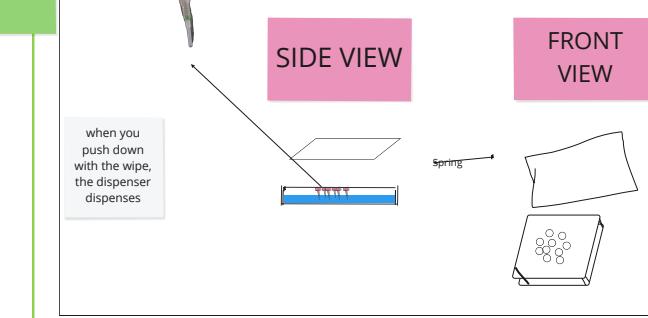
Weighted base + lid with a suction to prevent knocking and provide stability when on table



Rubber feet for stability

Combine

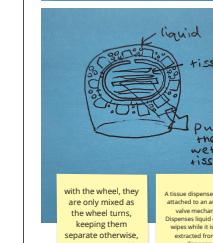
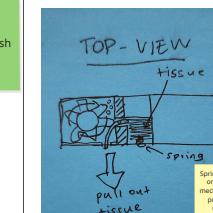
Dispensing



SIDE VIEW

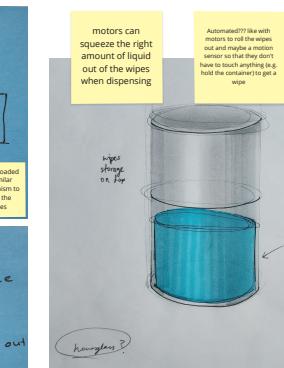
FRONT VIEW

Wheels to dispense/push out wipes



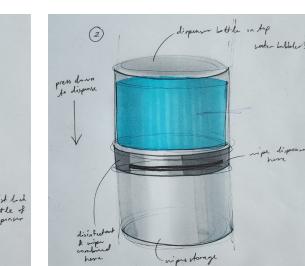
with the wheel, they are able to turn as the wheel turns, keeping them separate otherwise, preventing mould

A tissue dispenser system with a wheel and a check valve mechanism. Dispenses liquid onto the wipe as it is being extracted from the dispenser.



wipes storage or for

Automated? like with motors to roll the wipes out and maybe a motor to move the container don't have to touch anything (e.g. hold the container) to get a wipe

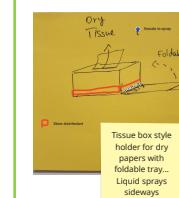


press down for dispense

Automated? like with motors to roll the wipes out and maybe a motor to move the container don't have to touch anything (e.g. hold the container) to get a wipe

DISCARDING, COMBINING & REFINING IDEAS

Something using this kind of mechanism?



Something using this kind of mechanism?

In a long cylinder, when user pushes the button a tissue falls freely and at a precise moment disinfectant is sprayed on it, at the bottom you receive the wet tissue

Dispense wipes from the side, or even corner of a cube?

APPENDIX U

Idea(s) development

Post-its in pink are discarded ideas

