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Nudging healthcare workers towards a circular intensive care unit

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Abstract

To offset the environmental damage caused by emissions from the healthcare sector a transition towards a circular economy is needed, whereby resources are reduced or reused, before they are recycled or end up as waste. To contribute to the emerging research on healthcare sustainability, this paper explored the behaviour of healthcare workers when it comes to reducing material usage within the intensive care unit of the Erasmus Medical Centre in Rotterdam. A behavioural nudge intervention was implemented to reduce the uptake of single-use aprons specifically, thereby limiting the use of aprons to the situations in which it is required to wear one. The intervention consisted of a visual prompt and a priming element, and the experiment was conducted according to a pre-post study design. The results provided no evidence for the effectiveness of the intervention. Instead, incidental observations hint at the presence of aversion among the healthcare workers towards the intervention. More beneficial results may be achieved by combining behavioural interventions with a higher level of transparency on the sustainable solutions that have been chosen, as well as their respective impact.

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1. Introduction

Perhaps the greatest challenge of current times is the problem of global warming, which leads to a number of consequences such as natural disasters and vulnerable populations (Mathiesen, Oroschakoff, Coi, & Busquets Guàrdia, 2021). The record-breaking temperatures that countries have been experiencing are the result of the emission of greenhouse gasses and carbon dioxide into the atmosphere, spurred on by human activities such as material consumption and pollution.

To combat the threat of global warming, the European Green Deal was put in place in 2019. The European Green Deal strives for a climate neutral European Union by 2050. This implies a transformation from a linear to a circular economy, with "no person and no place left behind" (European Commission, 2019). Instead of a linear economy that relies on the continuous provision of new resources for products that ultimately end up as waste, a cyclical flow model calls for reducing and reusing materials, before deciding to recycle it (Abdul-Rahman & Wright, 2014). Therefore, a circular economy is a suitable approach for economic development in a sustainable environment.

Once the world was hit by the Covid-19 pandemic the carbon footprint of one industry in particular came to light, namely that of the healthcare industry. While plans such as the European Green Deal were formed to move towards a circular economy, there was a surge in demand for throw-away plastics, such as face masks and other personal protective products, to get through the pandemic (Makki, Lamb, & Moukaddem, 2021). Already before the pandemic, 4.4% of global net emissions came from the healthcare sector (Health Care Without Harm, 2019). This is caused for a great part by the production, transport, and waste processing of medical supplies (De Gruijter, 2021).

With an aging population and the hazardous consequences of global warming, the significance of a sustainable healthcare sector becomes increasingly apparent, as a greater

number of people will demand care (Rijksoverheid, 2019). However, while technological advancement and an increase in medical knowledge improves our life expectancy and general health – these processes also, ironically, contribute to a substantial increase in healthcare waste and thus further intensify global warming (Rijksoverheid, 2019). Hence, creating a sustainable healthcare sector that will benefit the planet in the long term is crucial.

1.1. Sustainable Intensive Care

In order to contribute to the field of healthcare sustainability and reduce healthcare waste, a collaborative project has been set up between the Erasmus Medical Centre (Erasmus MC), Delft University of Technology, and Erasmus University Rotterdam. The project aims to explore the possibilities of transitioning the intensive care unit (ICU) at the Erasmus MC from a linear to a circular economy approach. In other words, to create a sustainable ICU.

The ICU is taken as a starting point due to its substantial contribution to the problem of healthcare waste. A measurement taken by the Erasmus MC showed that the treatment of one patient results in 7 trash bags of waste per day, which translates to a total of 250,000 kilograms of waste per year for the ICU at the Erasmus MC alone (De Gruijter, 2021). This includes gowns, gloves, compresses, syringes, and other medical supplies – all wrapped up in plastic or paper packaging. By mapping out the current amount and kind of material consumption, solutions can be designed that have the potential of reducing overall material usage and increasing the re-use of materials – thus, following the principles of a circular economy.

1.2. Relevance of this study

This paper explores one area where a reduction in generated waste could already be achieved, which is the uptake of aprons by the healthcare workers in the ICU. The aprons are made of a nonwoven fabric and an additional coating made of waterproof polyethylene.

Originating from Czechia, they arrive at the hospital packed in cardboard boxes. Each box contains three plastic liners with each 50 aprons inside. The environmental impact of such items depends on a multitude of factors, including the exact weaving methods and layering compositions (Ivanovic, Meisel, Som, & Nowack, 2022). A case study on similar aprons and gowns have shown that the carbon footprint may range from 65 to 905 carbon dioxide equivalents (Rizan, Reed, & Bhutta, 2021), making the two items the biggest contributor within the category of personal protective equipment. Moreover, the same study combined the carbon footprint all personal protective equipment distributed to medical sector in the UK over a six-month time period and found that this was equal to 26,662 times the environmental impact by an average person over the same time frame. These findings indicate that a reduction in usage would lead to considerably lower emissions.

Aprons fall under the category of single use personal protective equipment for non-isolation patients and should be worn by the healthcare workers during certain situations as stipulated by the infection prevention protocol issued by the hospital. Initially, aprons had to be worn whenever healthcare workers came into contact with a patient but due to a revised protocol this rule changed to only having to be worn when in contact with excreta (bodily waste including faeces, urine, and mucus) or blood since there is no evidence for an increased risk of infection. As a result, there are less situations in which healthcare workers are required to wear an apron and material usage within the ICU can be reduced.

However, when implementing more sustainable solutions, it is important to take the behaviour of those subject to the changes (in this case the healthcare workers) into account (Muranko, Andrews, Newton, Chaer, & Proudman, 2018). For one, while people may intent to act in a pro-environmental way, this does not always translate to actual behaviour (ElHaffar, Durif, & Dubé, 2020). Additionally, sustainable decision making is often complicated due to the urge to rely on automatic and effortless thinking (Trudel, 2019). In the specific case of

apron usage, strategies may need to be implemented to counter what is likely to be automatic behaviour.

The change in policy provided a unique opportunity to examine the behaviour of the medical staff of the ICU, and to encourage them to reduce their uptake of aprons – thereby reducing the amount of generated healthcare waste. This study aims to examine whether a behavioural intervention can be implemented to achieve such a decrease. The healthcare workers were nudged into lowering their uptake of aprons, limiting it solely to the situations in which they are required to wear an apron. The relevance lies in the contribution that the study provides to developing solutions for a greener ICU and subsequently creating a more sustainable healthcare sector in the long run.

A nudging intervention consisting of a *visual prompt* and *priming* was designed for the purpose of this study. It is hypothesized that the two nudge types combined have the potential of inducing the desired behavioural change – decreasing the usage of aprons. Hence, this paper will answer the following question:

Can a nudging intervention in the form of a visual prompt and a priming element effectively reduce healthcare waste in the Intensive Care Unit?

2. Literature review

2.1. Healthcare sustainability

The healthcare sector negatively impacts the environment in multiple ways. Pharmaceutical residues end up in fresh water sources, damaging aquatic ecosystems and complicating water treatment for drinking (Green Deal, 2019). Emissions are created by energy consumption, transport, and product manufacture and use (Health Care Without Harm, 2019). Another substantial contributor to the medical sector's environmental footprint are the waste streams, which can be classified over two categories - hazardous and non-hazardous waste (Ranjbari et al., 2022). The latter is similar to household waste and includes waste from administrative activities, packaging from various equipment, and food residues. Hazardous waste on the other hand, which includes infectious and radioactive waste, carries higher environmental risks and requires more complex and costly disposal methods. The resulting damage from all these factors spark concern and have brought the environmental impact from the healthcare sector to light.

With this increased awareness on the environmental footprint resulting from the medical sector, a new area of healthcare sustainability science has surfaced (Sherman et al., 2020). Contributions within this field aim to improve the quality, safety, and value of medical activities by investigating the resulting emissions and the use of resources. Within the Netherlands policies and projects are established to encourage such research. For instance, in 2019 the Dutch organization Milieuplatform Zorg introduced a Green Deal specifically for the healthcare sector in The Netherlands (Green Deal, 2019). More than 200 parties (organisations and institutions from the medical sector and the government) agreed to reduce carbon dioxide emissions, reduce the number of pharmaceutical residues in water sources, and to follow a circular approach to procurement. Similar to the overarching project that this paper is subject

to, the overall goal is to expand the field of healthcare sustainability and to create a sustainable healthcare sector that will benefit the planet in the long term.

2.1.1. Principles of a circular economy

Within the branch of healthcare sustainability tools such as life cycle assessments and circular economy models are employed to assess environmental impact and design solutions (Sherman et al., 2020). Life cycle assessments may be used to assess the environmental impact of a product by quantifying all emissions created over the product's entire life cycle and in turn compare it to possible alternatives (Klöpffer, 1997; Sherman et al., 2020). Circular economy principles can further steer the medical sector to a higher degree of sustainability by assessing products and processes and looking for the best fitting solution in each case, before deciding to recycle it (Wuyts, Marin, Brusselaers, & Vrancken, 2020).

A commonly used framework for circularity is that of the *Three R's* – reduce, reuse, and recycle (Abdul-Rahman & Wright, 2014). Here, the principle of reusing also entails the improvement of product design to extend its product-life and allow it to be repurposed, refurbished, or remanufactured (Korhonen, Honkasalo, & Seppälä, 2016). However, perhaps the most significant principle in waste management is that of reducing material or product consumption (Abdul-Rahman & Wright, 2014). Arguably, the most effective way of decreasing waste is to not generate it.

While not every medical supply can simply be subject to a reduction in usage, there has been a surge in debate on the use of single-use personal protective equipment specifically. Personal protective equipment such as gowns, gloves, aprons, and face masks are used for infection prevention (both to protect the patient and the healthcare worker) and to protect the uniforms worn by the healthcare workers from staining. These supplies are most commonly made of plastics that are known to break down slowly, such as polypropylene and polyethylene

(Zhang, Philips, Shaban, & Kam, 2021), and can be considered hazardous waste. The excessive disposal of single use plastics has a detrimental impact on our environment as the medical waste is either incinerated or, due to waste mismanagement and improper disposal, ends up polluting marine and land environments (Dean, 2020).

While personal protective equipment is a necessity when it comes to infection prevention, the use of these items has increased due the Covid-19 pandemic. The same amount of single use personal protective equipment that had been distributed in the United Kingdom in 2019 (2.3 billion items), was distributed from February to July of 2020 alone (Zhang et al., 2021). This increase is expected to persist even beyond the pandemic, even if there is no evidence to support the excessive usage (Zhang et al., 2021).

2.1.2. Barriers to circular solutions

Apart from research on the topic of healthcare sustainability being relatively recent and fragmented, there are several other barriers to implementing circular economy principles to the healthcare sector. For one, the process of reusing and remanufacturing is complicated due to a substantial part of the waste streams being considered as hazardous (Ranjbari, et al., 2022). Hospitals may also be faced with the burden of a limited budget, outdated technologies, or buildings that are not adapted to accommodate new processes (Thakur, Mangla, & Tiwari, 2021). All these factors may delay the process of transitioning towards circularity.

Another important barrier within the healthcare sector is safety. There are many regulations surrounding product design that need to be adhered to (Kane, Bakker, & Balkenende, 2018). It is crucial that products and processes remain efficient and safe, since they should not endanger the patients or hinder the care they receive. Moreover, perceptions from medical staff regarding both patient and personal safety may arise with the introduction

of sustainable solutions (MacNeill et al., 2020). This too can hinder the process, since, ultimately, the medical staff will need to utilize the products.

Overall, it is important to further consider people's behaviour, as this can also form a significant barrier to the successful implementation of circularity (Muranko et al., 2018). Previous research has highlighted multiple factors linked to people's approach to sustainability. For instance, there are several general properties to the environmental problem that affect people's willingness to act sustainably (Thaler and Susntein, 2021). These include present bias (people tend to be more concerned with the present than with environmental consequences that will only happen in the future) and the difficulty of attributing the consequences of one single action to the harms caused by climate change. On a personal level, behaviour may depend on social and environmental values, such as altruism and concern over climate change (Barr, 2003). Generally, all these factors may be useful predictors for behaviour.

Theoretically, if an individual has the right attitude towards sustainability, actions consistent with that attitude should follow (Fahy, 2005). However, in reality, even when people are *willing* to act sustainably, this intention does not always result into actions consistent with sustainable values. While research on attitudes and behaviour of healthcare workers towards sustainability is still limited, research conducted in areas such as fashion consumption and tourism has indeed demonstrated this point (Park & Lin, 2020; Tölkes, 2020). This discrepancy is more commonly referred to as the intention-behaviour gap (ElHaffar et al., 2020)).

The explanations for the occurrence of the intention-behaviour gap depend on whether it arises in a commercial (e.g., buying sustainable products) or a non-commercial setting (e.g., recycling; ElHaffar et al., 2020). Through a survey, Fahy (2005) was able to identify reasons for the intention-behaviour gap in a non-commercial setting – specifically in the domain of waste management. Two of the most apparent reasons were a perceived lack of time and a lack of composting and recycling facilities. Barr (2003) also argued that, while the threat of

environmental consequences has the potential of stimulating pro-environmental action, the extent to which people will behave sustainably depends on the perceived time they have. In addition, Barr (2003) also argued that the perceived effectiveness of an act is linked to actual behaviour. This was also demonstrated in a study on waste sorting in China, where individuals were more likely to separate their waste if they had a higher perception of policy effectiveness (Wang & Mangmeechai, 2021). Overall, these findings highlight an important insight: an individuals' intention to act sustainably cannot be assumed to be equal to their actual behaviour.

2.2. Nudging

To induce behavioural changes and to overcome the intention-behaviour gap, behavioural interventions such as nudging can be applied. Nudging refers to an intervention whereby subjects are not limited in their choices or convinced of what their choice should be, but rather steered in the desired direction (Thaler & Sunstein, 2008). Encouraging people to choose a certain option is often done by implementing small changes within the choice environment and thereby increasing the salience or convenience of that option (Lin, Osman, & Ashcroft, 2017). The main rationale behind this is that applying well designed changes to the choice environment by making actions simple or activating automatic responses can prove to be more effective than directly asking people to do what is desired of them (Thaler & Sunstein, 2021). Hertwig and Grüne-Yanoff (2017) further refer to nudging interventions as being nonregulatory and nonmonetary interventions (i.e., a nudge should not change economic incentives).

Nudging rests on the notion of libertarian paternalism (Thaler & Sunstein, 2003). The paternalistic aspect refers to the idea that people are encouraged to opt for the choice that is in their best interest. Concurrently, nudge interventions should remain cheap and easy to avoid for those exposed to it, thereby leaving them at liberty to make the choice themselves. Thaler

and Sunstein (2003) argue that interventions that rely on libertarian paternalism are justified since people do not always make perfectly rational decisions. This may be due to incomplete information or a lack of willpower, but judgements are also inevitably influenced by the context of the choice environment. As a result, a person's preferences are not always clear.

People's fallibility in judgements can be further explained by the dual process theory, which makes a distinction between two types of cognitive systems (Kahneman, 2011). The first, System 1, is associated with being an automatic response that drives people towards their wants in a fast, effortless manner (Chriss, 2016). System 1 is activated by heuristics - mental shortcuts that people take in their thinking process. System 2 on the other hand is considered a more reflective system. When utilizing this system people are closer to a rational economic agent, making more controlled, slow, and deliberate decisions (Chriss, 2016; Thaler & Sunstein, 2021). While rational economic agents would always make decisions based on System 2, System 1 drives many decisions that occur daily, thereby prioritizing immediate satisfaction over long term consequences (Chriss, 2016).

Sustainable decision making often requires more cognitive processing, even when people generally desire to be sustainable (Trudel, 2019). For instance, active deliberation is needed to overcome the urge to just throw trash away in the nearest bin instead of recycling it. Moreover, within the ICU grabbing an apron may simply have become habitual behaviour. Long-term consequences of acting in a pro-environmental way need to be kept in mind to override the effortless and automatic system 1 (Trudel, 2019). To do so, system 2 can be activated by creating awareness and encouraging more controlled thinking to consider better (i.e., sustainable) choices (Leal & Oliveira, 2021). Thus, while the two systems complicate sustainable behaviour, nudging can play into these cognitive processes by steering people towards behaviour that is consistent with their goals or preferences (Hertwig & Grüne-Yanoff, 2017).

Following the reasoning behind the dual process theory, nudges can be categorized into two groups. Type 1 nudges target automatic behaviour and does not require any conscience decision from the recipient's side (Hansen & Jespersen, 2013). Examples of such nudges include the placement of food items in a buffet to encourage healthier food choices; and changing the default settings on a printer. Type 2 nudges on the other hand are aimed towards the reflective system and do involve deliberation and choice (Hansen & Jespersen, 2013). Examples of type 2 nudges include calorie labels and framing of risks related to medical treatments.

Over the years, nudging has often been criticised for being a manipulation technique (Hansen & Jespersen, 2013). However, Hansen and Jespersen (2013) argue that when nudging affects reflective choices and when it has a certain degree of transparency (i.e., those being nudged can be expected to infer the intention behind the nudge), it should not be considered a form of manipulation. Therefore, this paper will explore two type 2 nudges to achieve a lower uptake of aprons. Visual prompts were implemented within the actual choice environment (this is in the patient rooms, where the aprons are stored), and a priming element was used to prepare the healthcare workers for this point-of-decision.

2.2.1. Visual prompts

Visual prompts are signs, often in the form of posters or stickers, that provide information directly and in a simplified way. Hence, a visual prompt is an informational intervention that functions as a reminder, catching the people's attention and triggering them to act according to the desired behaviour (Comber & Thieme, 2013; Chui, Wai, & Ahmad, 2015; Michalek & Schwarze, 2020). This way the reflective system is engaged, and the intention behind it can be deduced – making it a transparent type 2 nudge (Hansen & Jespersen, 2013).

The use of a visual prompt was chosen due the practical implications of setting up a field experiment[1], and based on further evidence on its effectiveness as presented in previous research. Namely, these signal triggers can be especially effective since they induce people to act instantly (Sunstein, 2014) and studies show that likelihood of behavioural compliance is highest when the target behaviour is convenient and repetitive to perform (Geller, Winett, & Everett, 1982; Shearer, Gatersleben, Morse, Smyth, & Hunt, 2017). One example of such behaviour is hand washing, which people may intent to do but then ultimately skip. To counter this, one study implemented a visual cue in the form of arrows leading to a sink in public restrooms (Blackwell, Goya-Tocchetto, & Sturman, 2017). This prompt saw a significant increase in handwashing rates of 7% for males and 15% for females. Arguably, choosing not to take an apron is also convenient behaviour to perform. Therefore, implementing a visual prompt to reduce apron usage seems fitting.

The use of visual prompts has also proven to be effective in encouraging more sustainable behaviour. One intervention that was found to be successful was the use of a sticker that was distributed among households to encourage and remind them to recycle food waste (Shearer et al., 2017). The sticker, depicting a waste bin and a persuasive message, increased recycling rates significantly by 20.74%. A similar sign (a written message with an image of a light switch) hung up in washrooms prompted people to turn off the lights significantly more often when leaving the room. The odds that a light switch would be turned off in washrooms with a sign were 0.8, compared 0.1 in washrooms where no sign was placed (Sussman & Gifford, 2012). The application of such a persuasive and informative poster was also found to be effective in encouraging composting behaviour in a cafeteria setting (Sussman, Greeno, Scannell, & Gifford, 2013). The percentage of people demonstrating the desired composting

[1] Implementing a placement nudge instead of a visual prompt had also been proposed, but this proposal was rejected by the hospital. See Appendix A.

behaviour significantly increased from 12.5% to 20.5% after the application of the visual stimulus. These findings show that visual prompts can be effective in a variety of settings to encourage sustainable behaviour that do not require a lot of effort.

Visual prompts may also be combined with other forms of nudges to further increase the salience of the desired behaviour. De Visser-Amundson and Kleijnen (2019) sought to reduce food waste among chefs and found evidence for the effectiveness of two types of nudges, each combined with an additional visual prompt. The first intervention included a pre-commitment letter that was handed out twice during a period of eight days. The letter contained several questions on food waste and its environmental impact as well as one question asking the chefs to declare that they will do their best to reduce food waste. The letter was further combined with a subtle reminder throughout their working shift by sticking green smiley faces on the waste bins. The second intervention was a social norm nudge in combination with the smiley faces, which exploited the authority-status of the chefs within the kitchen. Both interventions resulted in a significant reduction of food waste (33.50% on average per day for the first intervention; 25.02% for the second intervention), thereby showing that visual prompts can be effectively combined with other nudges.

Overall, for a visual cue to be effective, its design should remain visible, simple, and clear (Shearer et al., 2017). Due to this often simple yet practical design, this type of intervention satisfies several fundamentals for effective nudges, such as being of low cost and high durability (Redelmeier & Thaler, 2021). Written messages should be constructed using positive and polite language, and the use images that are congruent with any written information can result in more effective communication (Jae, Delvecchio, & Cowles, 2008; Sussman & Gifford, 2012). The design of the visual prompt for this study followed these guidelines.

2.2.2. Priming

As the healthcare workers do not spend much time in the patient rooms other than the provide care to their patients, it was key to stick to a simple design of the visual prompt. However, this did not leave much room to communicate the entire protocol. Since there are multiple scenarios and steps to consider regarding personal protective clothing, the mere addition of a visual prompt related to apron usage might seem arbitrary. Therefore, it was opted to combine the visual prompt nudge with priming.

Priming refers to the exposure of cues that have the ability to unconsciously alter an individual's behaviour (King et al., 2016). Priming can happen through any type of visual stimuli or the provision of information that subtly introduces the topic linked to the desired behaviour [2]. The exposure to such cues often happens ahead of the point-of-decision so that the subject is gently prepared for that moment (Mirsch, Lehrer, & Jung, 2017). Examples that have been explored in previous literature include eliciting people's intention to vote or get vaccinated (Sunstein, 2014) and creating a green ambience in a canteen to encourage healthier choices at the buffet (Friis, et al., 2017). Hence, priming can take on various forms.

Especially for more complex behavioural changes, such as health or environmental related issues, more persuasive communication such as priming can be added to strengthen the effect of an intervention (Cialdini, 2016). A study on neuromarketing sought to examine the effect that priming messages can have on people's preference for sustainable fashion (Lee et al., 2020). Participants were primed in a laboratory setting with a video on the environmental problem, after which they were shown multiple, green-labelled clothing products as well as products where the green logo was absent. The authors found that priming consumers beforehand significantly increased their attentiveness to the visual prompt (the green-labelled

[2] According to the nudge categorization of Hansen and Jesperson (2013), priming is not necessarily a type 2 nudge. However, as can be seen in section 3.3., the form priming takes in this study can be argued to belong within the type 2 category since it engages the reflective system.

clothing). Hence, these results suggest that priming can indeed strengthen the effectiveness of visual prompts and that combining the two nudges is a viable option.

The point-of-decision in this study occurs within the patient rooms when the healthcare workers have to decide whether to use an apron or not for the care they are about to deliver. This study hypothesises that priming healthcare workers before this point-of-decision and the addition of a visual prompt to the actual choice environment can significantly decrease the uptake of aprons and thereby overcome behavioural barriers to circularity within the ICU. The following hypothesis was formulated:

H1: A combination of priming and a visual prompt decreases the usage of aprons among health care workers at the ICU.

3. Methodology

A field experiment was conducted at the ICU of the Erasmus MC to test whether the nudge intervention could effectively reduce healthcare waste. The experiment is part of an overarching project which aims to create a circular ICU. Two other studies that were also part of this project were conducted around the same time. One study aimed to identify motivators and barriers to sustainable behaviour among healthcare workers; the other study also tested a nudge intervention but did so by exploring the effectiveness of social norms.

Prior to the start of the experiment, the Erasmus School of Economics IRB-E granted ethical approval for this study under application code ETH2122-0751. This means the proposed study sufficiently respects the safety and rights of the participants and recognises the responsibilities of the researchers involved as well as their host organisation.

3.1. Context

3.1.1. Personal protective clothing

The medical staff at the ICU wear two types of personal protective clothing, depending on whether they deliver care to an isolation patient or a non-isolation patient. This may be either a yellow isolation gown or a white apron, both of which are worn over the healthcare workers' uniforms. The two types of protective clothing are depicted in Figure 1.

The yellow isolation gowns are used for care delivered to isolation patients. These patients can either be in isolation due to an infectious disease such as Covid-19 or an MRSA infection, or because they are extremely susceptible to germs brought in by others entering their room. Therefore, the gowns cover the entire length of the arms. Moreover, they must be worn during any touchpoint with an isolation patient (i.e., upon every single entry into a room with an isolation patient).

The white aprons, which do not cover the arms, are used for non-isolation patients and are the focus in this study[3]. Initially, healthcare workers were obliged to wear the aprons during any care that brought them in direct contact with a patient. However, once the revised protocol that this research exploits came into effect, aprons were only required when a healthcare worker comes in contact with excreta (bodily waste including faeces, urine, and mucus) or blood[4]. Aprons would no longer need to be worn when delivering care like moving the patient in their bed. This change in policy was issued by the hospital (in accordance with the infection prevention centre) in order to reduce the amount of personal protective equipment that was disposed of. If adhered to correctly, this change can mean a reduction in the amount of disposed material within the ICU.

[3] A discussion on the considerations that were made regarding the scope of the experiment can be found in Appendix A.

[4] The same goes for the use of gloves. An exception to this rule is the use of face masks. As a temporary Covid-19 precaution these must always be worn when in contact with a patient.

Figure 1. A depiction of the personal protective clothing. On the Left: a yellow isolation gown; on the right: a white apron.

3.1.2. Setting

The ICU of the Erasmus MC consists of individual rooms that are spread over four units (i.e., hallways) located on the same floor. The units are numbered A to D. The units can be viewed as two separate pairs – one pair being A and B, the other one C and D. Each pair of units is connected by a multifunctional room, situated in the middle of the hallway. This room is used by nurses and doctors alike to take short coffee breaks or to hold meetings.

One unit alone contains nine rooms, each separated from the hallway by automatic sliding doors. Outside the rooms, next to these sliding doors, instructive posters are placed in frames. These posters depict the steps that must be taken regarding personal protective equipment and thus differ depending on the type of patient in the room.

Within every room, there is a counter alongside the wall opposite of the patient's bed. This is where bedlinen, towels, equipment such as syringes, and the white aprons are stored. Every morning the support staff makes their round to stock these items. The white aprons are placed on top of the counter next to the sink – see Figure 2. Aprons are stored per bag of 50

pieces. If the support staff find the previous bag open during their morning round, they usually place another one below it (regardless of the number of aprons left in the opened bag). This check is done once more during the evening shift. Occasionally the nurses themselves grab a new bag from the general storage. However, a measurement taken by the hospital in 2019 showed that on average 16 aprons are used per patient per 24 hours. This indicates that a bag of 50 aprons should be sufficient to last the entire day. Hence, refilling the aprons rarely ever happens outside the two daily checks by the support staff.

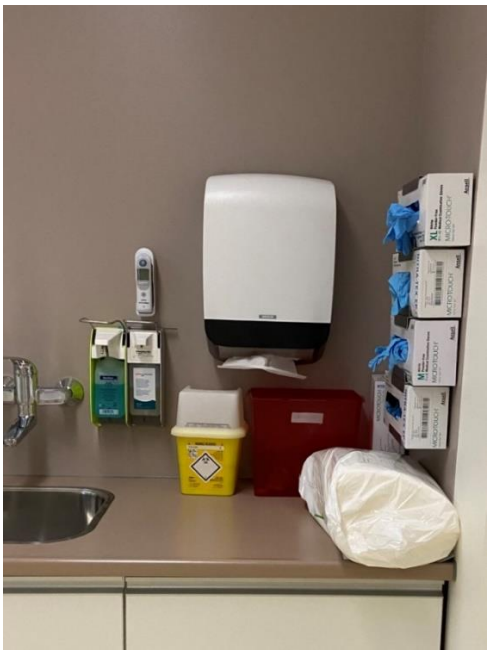

Figure 2. Counter in a room in the ICU, with the plastic bag of aprons on the right.

3.2. Experiment design

The research relevant for this study concerns a field experiment in a natural setting. First, once the revised protocol came into effect, a baseline measurement of the uptake of aprons was established. Following this, the nudge intervention was implemented with the aim of reducing this apron usage. Observations were made to compare this period to the baseline measurement.

This means the study follows a one-group pre-post study design[5] with a pre-intervention and a post-intervention period.

Ideally, a control group would have been created. However, this was not possible for two reasons. First of all, another experiment took place in unit C and D at the same time as the experiment for this study[6]. As a result, including those two units was not feasible since bias would arise from participants being exposed to another treatment. Secondly, implementing the intervention in only one unit (either A or B) was not feasible either. The presence of the multifunctional room (which has large windows facing each unit) could give cause for concern regarding spill over effects, as it is utilized by the medical staff from both units. For that reason, the pre-post study design was chosen.

Healthcare workers are randomly allocated to one of the four units and, for every shift, randomly assigned to a patient in that specific unit. Patients are also randomly assigned to the units. Furthermore, healthcare workers will always work within the same unit (e.g., a team member from unit A will never have a shift in one of the other units). This means that there is no interaction between the healthcare workers of different units except for the time spent in the multifunctional room that connect each set of units. One of these multifunctional rooms is shared by the team from unit A and B, the other one by the team from unit C and D. In other words, there are hardly any interaction moments between the two sets of units and spill overs from A and B to C and D (and vice versa) are unlikely to be an issue.

3.2.1. Outcome variable

The possibilities to obtain measurements were limited. For instance, due to privacy reasons, the behaviour of the healthcare workers could not be observed through cameras. Moreover,

[5] A one-group pre-post study design is an experimental study design that measures the variable of interest on the same group before and after the implementation of an intervention (Marsden & Torgerson, 2012).
[6] As part of the overarching project, a social norm nudge intervention was tested in unit C and D.

simply counting the number of disposed aprons was not possible since used protective equipment is classified as hazardous waste and it would not be safe for the observers to manage these. Instead, the contents of the bags of aprons stored within the rooms were counted to determine the daily usage.

Counting happened twice a day for each occupied room with a non-isolation patient – once in the morning before the start of the day shift, and once in the afternoon at the end of the day shift. The data was collected per room as it was not possible to retrace the usage to one individual (multiple people enter the rooms throughout the day, nurses and doctors alike). Additionally, the decision was made to only include the uptake during the day shift in the study, since the healthcare workers carry out most patient-related care during this shift. By subtracting the two measurements taken per room each day, the uptake of aprons per room during the day shift could be calculated. Hence, the outcome variable is the number of aprons used per room per day shift.

As observations were gathered per room (as opposed to the unit in its entirety), the obtained data could be corrected for rooms with any inconsistencies – e.g., the patient being placed in or moved from the room during the day shift, or the patient suddenly being considered an isolation patient. By noting down the room number and the corresponding patient[7], the differences in occupation between the two daily observation moments could be compared. That is to say, rooms that were measured in the morning but contained a new patient in the afternoon did not get a second measurement as this would not yield a proper estimation of apron usage within that room (the patient might have left the unit shortly after the morning observation, while the new patient might only have arrived towards the end of the day). As a result, only

[7] Privacy is ensured as any patient information that was denoted in the excel file was deleted right after observations were taken in the afternoon.

patients that were in the ICU for the full day shift were included (disregarding any time spent in an operating room).

The way the outcome variable is comprised has an effect on the study design. Theoretically, the pre-intervention and post-intervention period contain the same participants, since some healthcare workers from unit A and B would likely have had shifts in both periods. In turn, this would mean the study follows a within-subject design. However, for a within-subject design it would be more advantageous to obtain the uptake of aprons per employee instead of per room – so that observations can be properly matched. Since the observers were restricted in ways to obtain the measurements, obtaining the uptake of aprons per employee was not feasible. Moreover, the subject pools from the two periods are not identical as shifts generally vary and part of the medical staff was on summer break (meaning they may only have been present for one of the two periods). Therefore, though the two periods may overlap in terms of participants, the study does not follow an actual within-subject design.

3.3. Materials

The implemented intervention consisted of two parts, a visual prompt sticker and a priming element. The priming element is made up out of the banner presented in Figure 3. The banner was projected on television screens in the multifunctional room shared by the staff from unit A and B. These television screen display a continuous loop of various instructive slides. The decision tree on the banner essentially provided an overview of the possible scenarios during which personal protective equipment needs to be worn, along with a visual depiction of the relevant items (gloves and either gowns or aprons; face masks were added as a separate precaution at the bottom). This visualization of all possible scenarios was used to prime[8] the

[8] Moreover, the first decision node, regarding whether the patient is an isolation patient or not, occurs outside the room. Displaying such a decision tree inside of the rooms, as opposed to using it to prime the staff, would be futile.

healthcare workers to the later point-of-decision (whether to use an apron or not) and to strengthen the effect of the visual prompt.

Several considerations were made regarding the design of the banner. The sentence ‘for a safe and more sustainable ICU’ hints at both the safety of each outcome as well as the other reason why they should carefully consider which protective equipment is needed - to create a more sustainable ICU. Additionally, the word ‘sustainable’ has been written in green since this colour is associated with environmental friendliness and therefore it has been found to be more effective in signalling sustainability (Lim, Baek, Yoon, & Kim, 2020). Overall, the design of the picture followed the layout in terms of colour scheme and font of previous instructive stickers issued by the hospital so that these additions would be perceived as more familiar and less intrusive (Evers, Marchiori, Junghans, Cremers, & De Ridder, 2018).

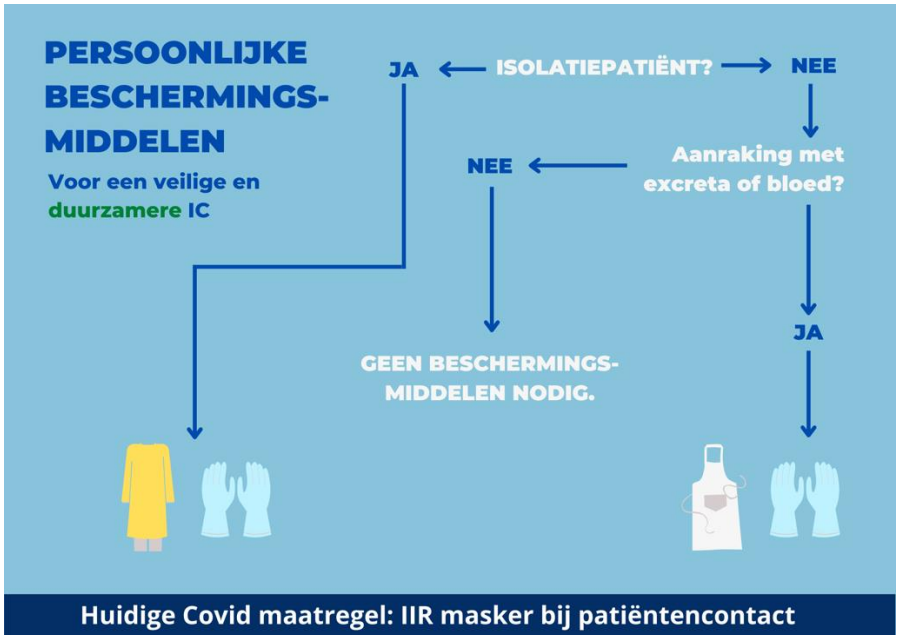

Figure 3. The decision tree used to prime the healthcare workers.

The actual decision-making process when it comes to wearing an apron or not still occurs within a room, therefore the priming message in the multifunctional room was paired with a

visual prompt within the actual choice environment. The visual prompt sticker is presented in Figure 4. The sticker contained a picture of an apron and followed the same layout style as the decision tree. The sticker also contained the sentence ‘aprons when in contact with excreta or blood’, thus forming a last reminder for the subjects of the desired behaviour.

Figure 4. Visual prompt nudge regarding the aprons.

3.4. Procedure

Figure 5 shows the timeline of the experiment. The new policy around personal protective equipment was announced on July 4th, 2022, through the weekly newsletter sent out to ICU workers. The announcement can be found in Appendix B. The instructive posters depicting the steps that need to be taken when entering and leaving a room with a non-isolation patient were updated the morning after in order to reflect the renewed protocol[9] and can be found in Appendix C. That morning marks the start of the pre-intervention period as the protocol came into effect that day.

[9] The other instructive posters were not updated for the purpose of this study, but its layout was changed by the hospital between the 11th and the 13th of July.

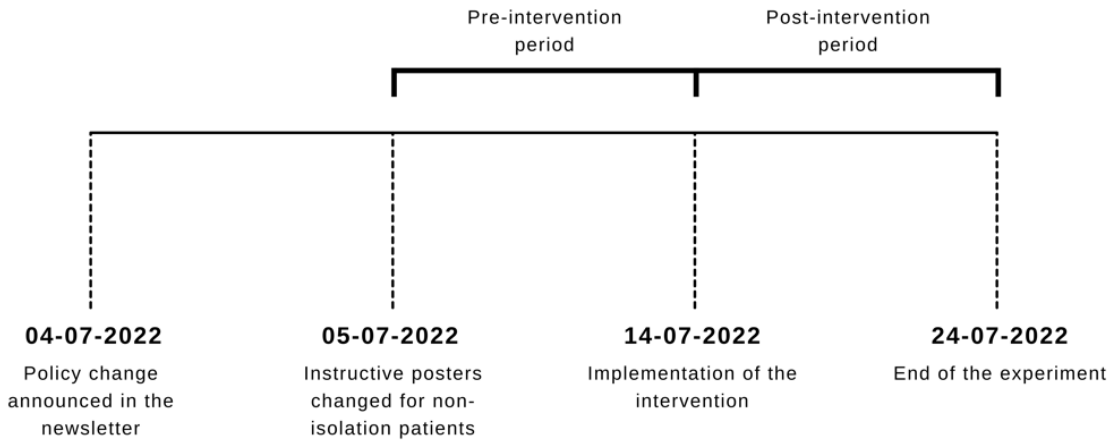

Figure 5. Timeline of the experiment

Measurements were taken by observers. They wore white jackets equal to the ones worn by the medical staff and would count the aprons within the occupied rooms twice a day. The first measurement was taken at 07:30, when the support staff made their morning round to restock the rooms, and the second one at 16:00, which corresponds to the end of the day shift. To guarantee an accurate measurement of the aprons the support staff was relieved from their task of stocking the aprons throughout the duration of the experiment. Instead, the observers took on the responsibility of restocking the aprons whenever a room would be almost out.

The intervention was implemented during the second phase 9 days later, on the 14th of July[10]. That day, before the morning observations were taken, the observers placed the visual prompt stickers on the paper towel dispensers directly above the bags of aprons (see Figure 6). Furthermore, the decision tree was projected on the screens in the multifunctional room until

[10] Previous research studying the effectiveness of visual prompts used a period of 5 days to 16 weeks to make post-intervention observations (Sussman et al., 2013; Blackwell et al., 2017; Shearer et al., 2017; De Visser-Amundson & Kleijnen, 2019), or even returned after 11 weeks of no observations for a follow-up phase (Sussman & Gifford, 2012). The time frame for this study was determined after conducting an a priori power calculation (see section 3.5.2.).

the end of the experiment. During this second phase (the post-intervention period), observations were made according to the same procedure as the first period.

Figure 6. The visual prompt nudge in place in a room in the ICU.

Once the data collection period had ended, the medical staff was debriefed on the experiment through their weekly newsletter. The purpose and results of the study were explained, and they were given contact details should they have any questions. Finally, they were also thanked for their participation. The complete debriefing message can be found in Appendix D.

3.5. Data analysis

3.5.1. Non-parametric test

Several assumptions need to hold in order to conduct a parametric test, such as the homogeneity of variance assumption and the normality assumption. As can be seen in Figure E1, the normality assumption does not hold for this study since the frequent uptake of aprons is

clustered around the lower end of the scale[11]. Therefore, a non-parametric test was conducted to analyse the data. Though non-parametric tests are less powerful than their parametric counterparts, they form a suitable alternative when not all assumptions are met.

For a study with the same participants appearing in each phase, a Wilcoxon Matched-Pairs test would need to be used. However, the two subject pools are not exactly the same and the observations were gathered per room instead of per individual. So, while the subject pools are not exactly different either, the data is not suited to create pairs to compare over the two time periods.

Therefore, a Mann-Whitney U test was conducted in order to compare the results from the pre-intervention period and post-intervention period. For a Mann-Whitney U test, the data for each group is pooled and ranked in increasing order. The sum of ranks of the two periods will be similar if the two samples are similar in their distribution. However, if either period has systematically higher outcomes, this will result in a higher sum of ranks for that period. The test statistic is calculated according to the following equation:

$$U = n_i n_j + \frac{1}{2} n_i (n_i + 1) - R_i$$

where n is the sample size and R_i is the sum of ranks for sample i.

Essentially a Mann-Whitney U test compares the two samples to each other by examining differences in distribution. The test thereby tests the following null hypothesis:

$$H_0: average\ uptake\ of\ aprons\ per\ patient\ pre - intervention$$
$$= average\ uptake\ of\ aprons\ per\ patient\ post - intervention$$

[11] A more detailed discussion on the variance assumption and the normality assumption can be found in Appendix E.

Thus, if the null hypothesis holds, it means the designed nudge did not effectively decrease the uptake of aprons. If the null hypothesis is rejected, it means that H1, which states that the visual prompt and priming combined can reduce apron usage, can be accepted.

3.5.2. Power calculation and sample size

The sample size required for this study to be of adequate power was calculated prior to the start of the experiment. The sample size was computed based on a probability level of 0.05 (the level at which an effect is accepted as being statistically significant) and the aim of reaching the recommended 0.8 statistical power (80% chance of detecting an effect if one exists; List, Sadoff, & Wagner, 2011). Furthermore, according to a recently conducted meta-analysis, nudge interventions can induce behavioural change with a small to medium effect size (Mertens, Herberz, Hahnel, & Brosch, 2022). Therefore, the sample size computation was further based on a desired effect size of 0.5, which corresponds to a medium effect size.

There was no a priori knowledge on the direction of the difference between the two groups. Though the nudge was designed to obtain a negative effect (a reduction in apron usage), it was unclear whether the intervention would result in a positive or a negative effect. Therefore, the sample size computation was done for a two-tailed Mann-Whitney U test. This computation resulted in a sample size of 134 observations, which implies that the uptake of aprons needed to be measured for at least 67 rooms per period.

Following this calculation, it was estimated how many observations one day would yield, to subsequently determine the duration of the experiment. The hospital gave an estimated average of two isolation patients per unit. This means that seven out of nine rooms were theoretically available for the experiment each day. Hence, to reach 67 observations with 14 beds a day, both periods in the experiment would need to continue for five days. However, these rooms were unlikely to be continuously occupied or accessible to the observers (e.g., due

to family being present in the room). Instead, to have sufficient time to reach the required number of observations, it was determined that both periods would last nine days.

The pre-intervention period indeed lasted nine days. However, from the start of the post-intervention period it became clear that the occupation within the ICU was considerably lower and that a time frame of nine days would not yield enough observations. Thus, for the study to be of adequate power, the post-intervention period continued for a total number of 11 days (when 67 observations for the post-intervention period had been reached).

4. Results

4.1. Descriptive statistics

In total, apron usage per room was observed 158 times. However, 15 observations only included a measurement taken at the start of the day shift, which means that the uptake of aprons could not be calculated. These observations were not considered in the analysis. Furthermore, one room had likely been restocked throughout the day as one observation indicated an uptake of -7 aprons. This observation was also taken out. As a result, the final sample included 142 observations, 74 of which were taken in the pre-intervention period and 68 in the post-intervention period.

An inspection of the data prior to conducting any statistical analysis yielded the results presented in Table 1. The average number of aprons used per room during the day shift in the pre-intervention period was 5.973. This average is very similar during the post-intervention period, 5.838 aprons per room, suggesting that the nudge intervention may only have resulted in a trivial decrease.

Table 1. Descriptive statistics on the uptake of aprons per room during each period.

	N	Mean	Std. Deviation	Min	Max
Pre-intervention	74	5.973	4.068	1	20
Post-intervention	68	5.838	3.445	0	17

Figure 7 presents a visualization of the collected data, whereby the daily average uptake of aprons per room is plotted over the duration of the experiment. The intervention was implemented on day 10. The depiction shows no clear drop in uptake from the start of either period or a similar pattern during the days after. Interestingly, two larger decreases in uptake can be observed, on day 5 and on day 12. Both days were Saturdays. Generally, there should be no difference between days, but there may be less consult visits in the ICU rooms during the weekend. This could explain the lower observed uptake on these two particular weekend days.

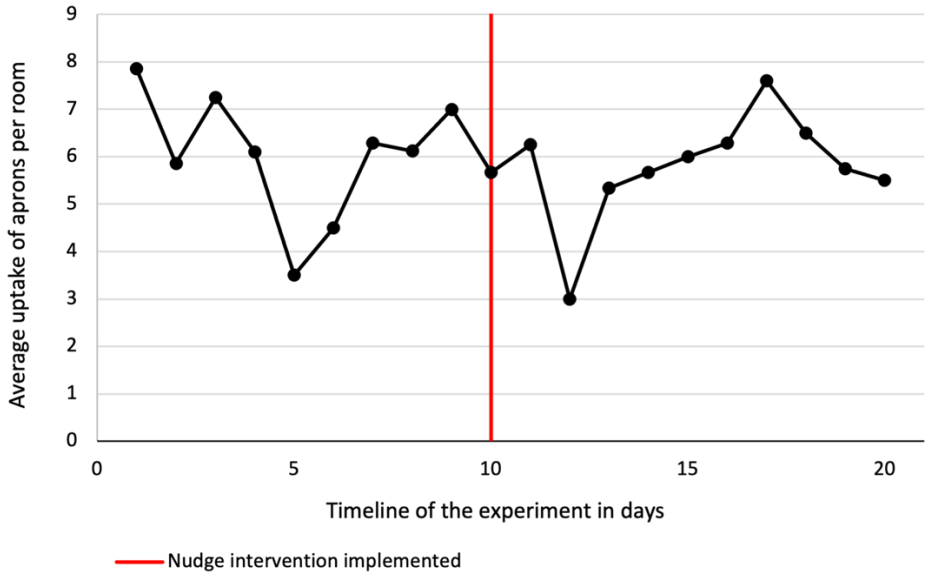

Figure 7. Average uptake of aprons per room per day of the experiment

4.2. Mann-Whitney U test

The results from the Mann-Whitney U test can be found in Table 2 and can be used to assess H1, which states that there is a difference in the uptake of aprons between the pre-intervention and the post-intervention period. A significant difference in uptake between the two periods would have signalled an effect of the implemented intervention. More specifically, ideally the intervention would have resulted in a significantly lower uptake, as this would suggest the intervention effectively promotes more sustainable behaviour in the ICU. However, as the p-value produced by this test is equal to 0.871 and thus higher than 0.05, the results indicate no such significant difference between the two periods. Consequently, there is not enough evidence to reject the null hypothesis that there is no difference between the averages of the two periods.

Table 2. Mann-Whitney U test results.

	N	Mean	Rank sum	Expected
Pre-intervention	74	5.973	5251.5	5291
Post-intervention	68	5.838	4901.5	4862
Z	-0.162			
P-value	0.871			
Cohen's *d*	0.356			

Note: sample based on a pre-intervention period of 9 days and a post-intervention period of 11 days.

The same analysis was conducted based on a post-intervention period that was equal in length to the pre-intervention period, which means that the observations taken on day 10 and 11 were not included. These results are presented in Table 3. The obtained average for the post-intervention period is similar to the previously obtained average, 5.889 compared to 5.838. Moreover, the obtained differences between the two periods are insignificant as the p-value,

0.927, is once again higher than 0.05. This indicates that the slightly longer post-intervention period did not considerably change the results for this study.

Table 3. Mann-Whitney U test results, based on an equal duration of both periods.

	N	Mean	Rank sum	Expected
Pre-intervention	74	5.973	4754	4773
Post-intervention	54	5.889	3502	3483
Z	-0.092			
P-value	0.927			
Cohen's *d*	0.217			

Note: sample based on a pre-intervention period and a post-intervention period of nine days each.

5. Discussion

It was hypothesized that a combined intervention consisting of a visual prompt and a priming element could induce behavioural changes regarding the use of personal protective equipment. However, the results suggest that the intervention does not have the ability of effectively lowering the uptake of aprons in this setting. There may be several reasons why.

Firstly, the use of personal protective equipment is likely to depend on perceptions of safety (both patient and personal; MacNeill et al., 2020). Possibly, these perceptions may have been too strong for the healthcare workers to set aside after having been exposed to the nudge. Indeed, interview findings from a master's thesis[12] demonstrated that healthcare workers from the ICU in the Erasmus MC place high importance on quality of care and may therefore feel uncertain about sustainable alternatives and patient safety (Maanicus, 2022). Perhaps the intervention for this study did not sufficiently play into these concerns. This would imply that, when implementing sustainable solutions and interventions, explicit information must also be

[12] The thesis identified the motivators and barriers to sustainable behaviour among healthcare workers. The data was collected by conducting interviews, a survey, and a focus group discussion amongst the healthcare workers at the ICU at the Erasmus MC just before the start of the experiment for this research.

provided on both patient and personal safety (in this case to properly communicate that it is not always necessary to wear an apron).

Another possibility is that while the intervention may have induced some healthcare workers to work more sustainably, it may also have made the situations during which aprons are supposed to be worn more salient to others. In other words, the intervention may have induced some healthcare workers to wear an apron more frequently than they did before. In turn, this could have offset any favourable results. Regarding the design of the nudge, a balance needed to be maintained between two elements – discouraging apron use on the one hand; and not undermining infection prevention rules on the other. However, perhaps the addition of the word 'sustainable' in green did not sufficiently communicate the purpose of the sticker and a stronger statement should have been considered instead.

Finally, the results may be affected by healthcare workers not consistently adhering to the infection prevention protocol. Previous studies show that compliance has been found to vary, even if there are clearly established rules and a general awareness of the importance of infection prevention practices (Houghton et al., 2020; Lai et al., 2020; Alhumaid et al., 2021; Ashinyo et al., 2021). This can entail situations where personal protective equipment ought to be worn but is not, or situations during which a used apron is not timely disposed of but instead set aside to wear at a later point in time. It is unclear which of the two scenarios was more common but, indeed, on several occasions the observers came across used aprons that were hung up within the room. Possibly, they were set aside to wear again at a later point in time. Even in light of sustainability and circularity, the importance of infection prevention should not be underestimated. Therefore, when implementing pro-environmental initiatives, closer inspection of infection prevention compliance may need to be carried out to ensure that there are no undesirable consequences affecting the quality of care.

5.1. Psychological reactance

Finally, incidental observations and experiences while making observations lead to the believe that some healthcare workers in the ICU experienced a certain degree of psychological reactance to the intervention. Psychological reactance refers to negative reactions that arise when individuals perceive an attempt to alter their behaviour as a threat to their freedom (Brehm, 1966). To illustrate, Kavvouris, Chrysochou, and Thøgersen (2020) find that pro-environmental social norm messages, another form of nudging, produce higher levels of psychological reactance when phrased in an injunctive rather than descriptive way. That is to say, normative campaigns providing information on what behaviour is desired may result in people feeling more intense pressure to comply, which in turn provokes a higher threat of freedom and a lower intention to conduct the desired behaviour. Hence, the arousal of such feelings may lead to a resistance to the imposed intervention and possibly an increase in unintended behaviour. This could potentially have offset any favourable results in this study.

One indication of psychological reactance occurring in this study are the snippets of conversations between the nurses that were overheard by the observers. This included frequent murmurs of disapproval or suspicion, as well as a sceptical attitude towards the presence of the observers. On one occasion a more extensive conversation was overheard during which a group of nurses discussed how they perceived the intervention to be an unwelcome restriction to their choices. Though they were open to working more sustainably, they did not approve of the imposition. Additionally, they mentioned the use of reusable gowns, which in their opinion were both more comfortable to wear and, as they concluded, far more effective in creating a sustainable work environment[13].

[13] The implementation of reusable gowns had been considered for this study, but the proposal was rejected by the hospital due to constraints in time and logistics. See Appendix A.

A second indication is the general response seen to a similar study conducted at the same time in unit C and D. That study tested a social norm nudge, also in the form of stickers on the towel dispensers. Several healthcare workers continued to remove the stickers from the towel dispensers, which meant the observers had to reapply the intervention every few days in several rooms. This suggests that the experiment was indeed perceived as an unwelcome intrusion of their work environment. It is possible that similar feelings arose in unit A and B – though with less noticeable consequences.

This lack of acceptance of the pro-environmental initiative contradicts some results from a master's thesis on motivators and barriers to sustainable behaviour among healthcare workers (Maanicus, 2022). The paper suggests that increasing the salience of which sustainable choices can be made can encourage healthcare workers to implement these choices during their shifts, especially if this sustainable option does not require more time and effort (Maanicus, 2022). Moreover, the results indicated that some healthcare workers recognized the benefit of decisions on sustainable solutions being made at a higher level, to subsequently be imposed upon the staff of the ICU. Finally, though resistance to change has previously been identified as a barrier, this has not been proven to be the case for the medical staff in the ICU (Maanicus, 2022). These findings seem to counter the findings from this study as (a) enhancing the salience of a sustainable choice (one that would not require more time or effort) did not yield the desired results; and (b) the imposition of the intervention was not entirely welcomed by the staff.

Especially for nudges that are in essence transparent, the acceptance of the nudge depends on whether people trust the institution that imposes the nudge (Leal & Oliveira, 2021). Increasing information transparency on the intervention might be a solution. In fact, the provision of information on *why* a certain initiative is the sustainable option was identified as an important motivator for sustainable behaviour (Maanicus, 2022). Moreover, the perceived effectiveness of sustainable policies can be enhanced when people have more knowledge and

understanding on the matter – which in turn can lead to higher compliance (Wang & Mangmeechai, 2021). Finally, Ölander and Thøgersen (2014) argued that the provision of information combined with nudging can create longer lasting changes in behaviour as it can achieve cognitive changes.

However, while evidence has been found for the increased effectiveness of default nudges combined with information transparency (Paunov, Wänke, & Vogel, 2020), it has also been argued that transparency does not alter people's responsiveness to a nudge (De Ridder, Kroese, & Van Gestel, 2022). Moreover, it has been hypothesised that transparency on the presence and purpose of a nudge could actually lead to more articulated preferences, which could potentially weaken the effectiveness the nudge (De Ridder et al., 2022).

While there is mixed evidence on the influence of transparency, it may be an area worth exploring. Especially since an intervention such as the one used in this study can already be characterised as a transparent nudge (Hansen & Jespersen, 2013). Perhaps implementing behavioural interventions *and* informing the healthcare workers on which sustainable initiatives have been considered (as well as the respective impact of these initiatives) can lead to a lower degree of resistance and to an increase in pro-environmental behaviour.

5.2. Limitations and future research

There are several limitations to the conducted research in this paper. First of all, the study seems to violate the independence assumption. It was assumed that the behaviour of one healthcare worker would not influence that of another, since the care the healthcare workers deliver is often carried out alone. However, the discussions between the staff indicate that the experiment was a topic of conversation outside the rooms. Thus, the observations are unlikely to be independent and this would have increased the chance of obtaining a false positive.

Secondly, no observations were made prior to the announcement of the renewed protocol since it was unclear whether it would actually be possible to conduct a field experiment at the ICU until just before the proposed start. Consequently, it is unclear whether an initial change in uptake of aprons had already occurred prior to the nudging intervention. If there had indeed already been a decrease in apron usage, the change in protocol should be considered an intervention in itself. If so, it can be concluded that the second intervention shortly afterwards (the nudging intervention) was not strong enough to induce yet another reduction.

Thirdly, it was not possible to observe every point-of-decision moment. In other words, there is no knowledge of the number of times a healthcare worker opted for an apron when they indeed should have according to the infection prevention rules, or when they did but should not have. Possibly, the obtained results are already as low as they should be, in which case the nudging intervention may have been redundant. In the future, it may be beneficial to take a more extensive period of time to observe the healthcare workers and then adjust behavioural interventions accordingly.

Next, a one-group pre-post study design brings several limitations that could threaten the internal validity of the study. For one, it does not allow for any control over a change in external factors that influence the outcome variable (Marsden & Torgerson, 2012). An example of a change that could have occurred between the pre-intervention and the post-intervention period is that the healthcare workers were exposed to yet another pro-environmental campaign. Alternatively, a change in perception regarding infection prevention due to a new surge in Covid-19 cases could influence the uptake of personal protective equipment. However, no such developments occurred while conducting the experiment.

Another threat to internal validity is the influence that taking measurements during the pre-intervention period may have had on the post-intervention period (Marsden & Torgerson,

2012). The healthcare workers were aware that their behaviour was observed as the observers were openly walking around and thus visibly collecting data. This may have altered the behaviour of the healthcare workers and may have intensified the psychological reactance. The problem of a change in behaviour is known as the Hawthorne effect and is common in observational studies (Mostafazadeh-Bora, 2020). A solution would have been to have the healthcare workers dispose the aprons in a separate bin, which could then be weighed to determine the number of disposed aprons per room. However, this also would have complicated the logistics of the experiment, which is why this was not chosen as a viable option for this research. Though this study was restricted in ways to make observations, future experiments should explore different experiment designs in order to obtain an accurate representation of behaviour.

Overall, the psychological reactance does raise several interesting points for further research. Since resistance from the healthcare workers can be a barrier to the implementation of sustainable solutions, future research could focus on drivers behind the psychological reactance that seemed to arise as well as on ways to prevent it. A combination of behavioural interventions and information transparency may prove to be more effective when implementing principles of a circular economy.

Furthermore, the incidental observations in this study do suggest an interest amongst healthcare workers in transitioning to reusable gowns altogether. This raises the question of whether solely providing reusable gowns, thus limiting the freedom to choose, would also be perceived as a threat to freedom or whether this would be accepted as a suitable development within the ICU.

6. Conclusion

The healthcare sector is a major contributor to the current environmental problem due to the production, transport, and waste processing of medical supplies. At the same time, the

hazardous consequences of global warming will result in a greater number of people demanding care. Hence, reducing the carbon footprint of the healthcare sector and making a transition towards a circular economy is crucial in order to combat this cycle.

The ICU of the Erasmus MC has taken the first steps towards circularity by mapping out their material consumption and designing pro-environmental solutions and policies. However, human behaviour can be a significant barrier towards circularity. This research aimed to fill the gaps in the field of healthcare sustainability by examining the behaviour of healthcare workers.

A nudge intervention was implemented in order to encourage the healthcare workers to reduce their uptake of single-use aprons. The intervention consisted of (a) a visual prompt sticker to remind people of the desired behaviour, which has previously been found to be effective when the desired behaviour involves convenient and repetitive tasks; and (b) a visualization of all possible scenarios during which personal protective equipment needs to be worn, which was used to prime the healthcare workers ahead of the point-of-decision. The field experiment was conducted at the ICU of the Erasmus MC according to a pre-post study design.

No evidence was found for the effectiveness of the proposed nudge intervention. Instead, incidental observations raise the question of whether psychological reactance amongst the healthcare workers will form a barrier when implementing pro-environmental solutions within the ICU, and whether increased information transparency can help counter this. Additionally, the relationship between the intervention and infection prevention compliance remains unclear. Both the resistance towards behavioural interventions and the response regarding infection prevention can be explored in the future to further contribute to the emerging research on healthcare sustainability and, ultimately, to the transition of the ICU towards circularity.

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Appendix A - Considerations

This section provides an overview of the research angles that have been explored prior to the start of the experiment.

Reusable gowns

Initially, this study had the aim of introducing reusable gowns in the ICU. The national Green IC committee issued a document describing these reusable gowns as an approved 'best-practice' for ICU's (NVIC, 2022). The gowns can be washed up to 100 times before a new protective coating is required. Even so, according to a Life Cycle Assessment, the reusable gowns are a more environmentally friendly option than the disposable gowns on all indicators (CO2, water usage, and waste production). Finally, the gowns would result in a cost reduction for the hospital.

With the possible introduction of the reusable gowns came the concern that the healthcare workers would not discard their gowns after having used them, but instead set them aside only to wear them again at a later point in time. This would mean that the reusable gowns would not be properly and timely decontaminated. The aim of the proposed experiment was to examine healthcare workers adherence to the infection prevention practices as stipulated by the hospital and subsequently test the effect of a nudge intervention in encouraging timely disposal of these gowns.

However, the introduction of the gowns requires contract negotiations with the supplier, clear agreements with the external laundry service, and a careful evaluation of the safety and logistics within the hospital. Consequently, along with the time constraints of this thesis, the proposal for this experiment was abandoned.

Disposable isolation gowns

Another angle that was explored was to examine the uptake of the disposable yellow isolation gowns. The motivation behind this was the suspicion that some healthcare workers use these gowns regardless of the type of patient they care for or the type of act they carry out. During the height of the pandemic these gowns were the default. As a result, some might now perceive the aprons or the use of no personal protective equipment to be unsafe.

It is unclear if, and if so, how often this situation occurs. The idea was not explored any further once it became clear that obtaining accurate measurements of the uptake of the yellow gowns was unlikely. The gowns are stored outside the rooms, which made it impossible to estimate the number of gowns used per room. Considering the time constraints of this thesis, obtaining a measurement for the entire unit as a whole would not yield enough observations for an adequate statistical power of the study. Furthermore, the gowns are not disposed of in a separate bin. Hence, estimating the uptake based on the number of used gowns was also not possible.

Placement nudge

Finally, a behaviourally oriented intervention was considered. Behaviour oriented nudges aim to influence behaviour in a more subconscious way and without drawing any visual attention to the intervention (Cadario & Chandon, 2020). Examples include changing the default option or enhancing the convenience of a particular option.

Following the notion that observing a particular object stimulates interaction with that object and that when more effort is required to reach an object people may be discouraged from doing so (Ensaff, 2021), a change in the placement of the aprons was suggested. Instead of restocking the aprons on the top of the counter, the aprons could be placed in the cabinets below. This way the aprons would not be directly visible upon entering the room. This change

could result in a lower likelihood of the healthcare workers reaching for the aprons out of habituation. Since a combination of a behaviour-oriented nudge and a more cognitive oriented nudge has proven to be more effective than either one alone (Cadario & Chandon, 2020), the placement nudge would be combined with the projected decision tree.

This proposal was also abandoned out of fear that it would result in the uptake of aprons being too low and thereby increasing the risk of infection. The setting calls for an intervention that discourages the use of aprons, but not in those scenarios where wearing them is simply a requirement. Finding a proper balance between sustainable solutions and simultaneously maintaining the safety on the ICU is key.

Appendix B – Newsletter announcement

Original text

Vanaf 5 juli 2022 wijzigt het beleid van het gebruik van handschoenen en isolatiejassen voor niet-isolatie patiënten. Dit wordt aangepast om aan te sluiten bij het beleid in de rest van het ziekenhuis en om duurzamer te gaan werken.

Wat verandert er:

- Voortaan alleen handschoenen aan bij handelingen waarbij je in aanraking komt met bloed (incl open bloedafname), faeces, urine, slijm, wonden of gevaarlijke stoffen,
- Voortaan alleen een wit schort aan bij handelingen waarbij je in aanraking komt met bloed, faeces, urine, slijm, wonden of gevaarlijke stoffen.

Het standaard aantrekken van handschoenen en gele isolatiejas komt hiermee te vervallen.
Handschoenen zijn geen vervanging van handdesinfectie, pas altijd de 5-momenten van handhygiëne toe.

Het beleid voor isolatie patiënten verandert niet.

Appendix C – Instructions non-isolation patients

On the left: the poster placed outside the rooms, depicting the instructions (to be carried out in the room) for entering a room with a non-isolation patient.

The steps state the following: 1) disinfect hands and wrists with hand sanitizer; 2) put on a white apron when in contact with excreta or blood; 3) put on non-sterile gloves when in contact with excreta or blood.

On the right: the poster placed inside of the rooms, depicting the instructions (to be carried out in the room) for leaving a room with a non-isolation patient.

The steps state the following: 1) take off gloves and dispose of in the bin; 2) take off the apron and dispose of in the bin; 3) disinfect hands and wrists with hand sanitizer.

Both posters contain the temporary Covid-19 precaution concerning face masks in a separate box at the bottom of the poster.

Appendix D – Debriefing message

Original text

Beste IC'ers,

Jullie hebben waarschijnlijk gemerkt dat wij (Tamarah Verhoog en Theo Post) in juli een aantal weken op de afdeling hebben rondgelopen, zoals toen ook is aangekondigd in de nieuwsbrief. Graag leggen we uit waarom.

Wij zijn twee economiestudenten die in het kader van onze scripties deelnemen aan een project dat vanuit het green team is georganiseerd. Het doel van dat project is een volledig circulaire IC in 2030. Daarbinnen is ruimte gegeven aan studenten, ook niet-medische studenten, om onderzoek te doen.

In de lente werd bekend dat de infectiepreventie een soepeler beleid wilde invoeren, waar schorten niet meer bij alle contactmomenten met patiënten maar enkel bij contact met excreta nodig waren. Die gelegenheid hebben we aangepakt om eerst een periode te tellen hoeveel schorten er gebruikt werden. Vervolgens hebben we in A&B een herinneringssticker boven de schorten geplakt. In C&D hebben we informatie, gebaseerd op een enquête in het UMC Utrecht, boven de schorten geplakt. Het doel van beide stickers was de nadruk leggen op het nieuwe beleid en daarmee het schortgebruik verminderen.

Uit het onderzoek zijn weinig spannende resultaten gekomen: gemiddeld worden er tijdens de dagshift per kamer 5 à 6 schorten gebruikt, en dat aantal is in de stickerperiode niet veranderd. De reden dat we tijdens het experiment niet hele concrete antwoorden konden geven over wat we precies deden is de zuiverheid van de resultaten: als een deelnemer zich niet bewust is onderdeel van een experiment te zijn, is de kans groter dat de deelnemer zich normaal gedraagt, precies wat bij een experiment de bedoeling is.

Bij vragen kunnen jullie natuurlijk altijd contact opnemen. Ook zijn we van plan in de nabije toekomst onze scripties op het EMC te presenteren, waar jullie uiteraard ook welkom zijn.
We willen jullie allemaal vriendelijk bedanken voor onze leuke tijd bij het EMC: vergeleken met Woudestein was het een geheel andere wereld, die niet alleen interessant was voor het experiment maar ook heel gaaf om een keer in het echt te zien.

Met vriendelijke groet, en nogmaals bedankt voor de (onbewuste) deelname!

Tamarah & Theo

Appendix E – Homogeneity of variances and normality assumption

The homogeneity of variance assumption requires the variance of the outcome variable to be the same in both periods. A Levene's test was used to test whether the variances of the uptake of aprons in the two periods are equal. The test produced insignificant results, which suggests that the assumption of homogenous variances does hold for this study (see Table E1).

Table E1. Test of Homogeneity of Variances

Outcome variable: number of aprons used per room				
	Levene's Test Statistic	df1	df2	P-value
Centered at the mean	1.041	1	140	0.309
Centered at the median	0.898	1	140	0.345
Centered using the 10% trimmed mean	0.952	1	140	0.331

The normality assumption requires the data to be sampled from a normal distribution. This can be inspected by examining the distribution of the sample data. The frequency distribution of the uptake of aprons is depicted in in Figure E1 and displays a positive skew. This suggests that the assumption of normality is violated. Consequently, not all the required assumptions for a parametric test are met.

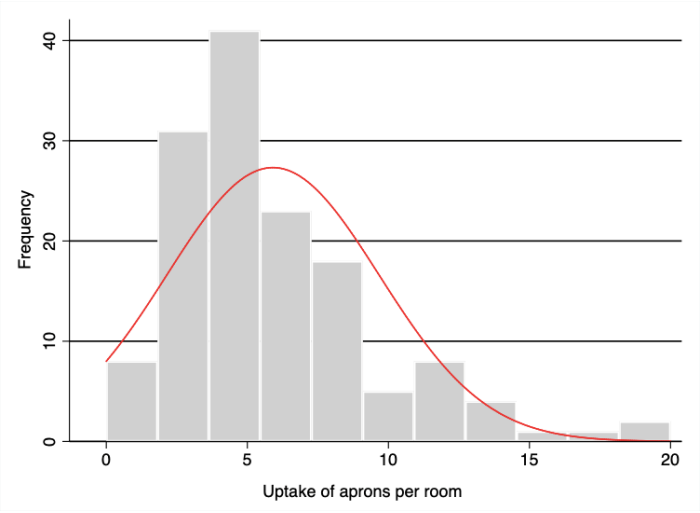

Figure E1. Frequency distribution of the uptake of aprons per room