INFECTION CONTROL IN OUR HANDS:

DEVELOPING AND EVALUATING A NOVEL INTERVENTION TO IMPROVE THE HAND HYGIENE BEHAVIOUR OF NURSES IN ACUTE CARE HOSPITAL UNITS IN THE UNITED STATES

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DECLARATION

I, Madeline Sands, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Signed: [redacted]

Date: 27 February 2020

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ABSTRACT

Healthcare associated infections burden patients, raise healthcare costs, and can lead to death. It has been shown that adequate hand hygiene among healthcare workers is the simplest and most effective measure for preventing these infections. However, hand hygiene compliance rates are generally poor, with many initiatives seeking to address this problem. While there has been success in producing short-term changes, the effects are typically minimal and not sustained.

The aim of this thesis was to develop and evaluate an original hand hygiene intervention based on the Behaviour Centred Design approach for nurses in acute care hospital units. The thesis assessed the current state of hand hygiene interventions through a systematic literature review and conducted formative research to explore underutilized factors that influence this behaviour. The review found that current interventions focus on individual-level psychological factors and incorporate behaviour change techniques that are cognitive in nature; for example, many of the studies had nurses create goals and plan how to best facilitate hand hygiene, compared both individuals' and the group's behaviours to others, and focused on the consequences arising from not practicing hand hygiene. The formative research—which used a questionnaire administered to a panel of nurses working in acute care units of US hospitals— discovered that nurses' compliance is influenced by factors including management's openness in communication, increased interactions with patients and peers, and reduction in busyness and cognitive load. These findings influenced the creation of a three-part original intervention, the *Mainspring Intervention*, consisting of: a self-affirmation exercise to reduce defensiveness, a

message that challenged nurses' perceptions about their practice, and an implementation intention activity to link behaviour to a cue.

The intervention was evaluated in a multiple baseline study across two hospitals in the US during 2016-2017. Analysis of the outcome variable— the observed hand hygiene compliance— showed a statistically significant increase in compliance rates at the aggregate level, with striking variation in impact at the hospital unit-level. The evaluation process found that relatively few nurses were reached by the intervention and those who were reached did not actively engage. In addition, the context in which the intervention was delivered impacted the nurses' responses to the intervention itself.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

ABHR	Alcohol-based hand rub
AHQR	Agency of Healthcare Research and Quality (an agency within the U.S. Department of Health and Human Services)
BCD	Behaviour Centred Design
BCT	Behavioural change technique
BCW	Behaviour Change Wheel
C. difficile	*Clostridium difficile*
CAUTI	Catheter-associated urinary tract infection
CDC	Centres for Disease Control
CDI	*C. difficile* infection
CL	Control limit
CLABSI	Central line-associated bloodstream infection
ECM	Electronic compliance monitoring
EMR	Electric medical record
EPOC	Effective practice and organization of care
HAIs	Health care-associated infections
HBM	Health belief model
HIC	High-income country
HICPAC	Healthcare Infection Control Practices Advisory Committee
HCW	Health care worker
HH	Hand hygiene
HHC	Hand hygiene compliance
ICA	Intervention Component Analysis
ICU	Intensive care unit
ILI	Influenza-like-illness
ITS	Interrupted time series
LCL	Lower control limit
LSHTM	London School Hygiene & Tropical Medicine
MBD	Multiple baseline design
MRC	Medical Research Council
MRSA	Methicillin-resistant *Staphylococcus aureus*
NREVSS	National Respiratory and Enteric Virus Surveillance System

OSCE	Objective structure clinical examination
PHHP	Patient hand hygiene protocol
PRECEDE	Predisposing, Reinforcing, and Enabling Constructs in Educational/Environmental Diagnosis & Evaluation
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analyses
PROCEED	Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development
QCA	Qualitative Comparative Analysis
RANAS	Risks, Attitudes, Norms, Abilities, and Self-Regulation
SCT	Social Cognitive Theory
SIS	Surgical site infection
SPC	Statistical process control
SRHI	Self-Reported Habit Index
TIDierR	Template for Intervention Description and Replication
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TTM	Transtheoretical Model
UCL	Upper control limit
UTI	Urinary tract infection
VAP	Ventilator-associated pneumonia
WHO	World Health Organization

CHAPTER 1: INTRODUCTION

Introducing the problem at hand: Background on healthcare acquired infections, hand hygiene, and behaviour change theories in the context of addressing frontline healthcare workers' poor hand hygiene compliance rates in hospitals

PREAMBLE

This chapter sets forth the introduction to the thesis. As this thesis concerns an intervention study to improve hand hygiene practices among healthcare workers in hospitals, it first provides background on the different types of healthcare-associated infections, discusses the importance of hand hygiene practices in healthcare delivery, reviews current hand hygiene initiatives, and delves into the various health behaviour theories and frameworks commonly used in hand hygiene promotion. This chapter then presents the Behaviour Centred Design approach— the framework that guided this research project. Finally, this chapter presents the outline of the thesis and explains its significance, the rationale, the aims and objectives, and the candidate's contributions to the work.

BACKGROUND: HEALTHCARE ASSOCIATED INFECTIONS AND HAND HYGIENE

Healthcare Associated Infections (HAIs)

Healthcare today involves invasive procedures that use various types of devises such as catheters or ventilators. There are four main healthcare-associated infections (HAIs) associated with these devices and procedures: 1) central line-associated bloodstream infection (CLABSI), 2) catheter-associated urinary tract infection (CAUTI), 3) surgical site infections (SSI), and 4) ventilator-associated pneumonia (VAP). Lower respiratory tract and bloodstream infections are the most lethal while urinary tract infections (UTIs) are the most common.[1] There are also two organism-specific HAI categories: methicillin-resistant *Staphylococcus aureus* (MRSA) infection and *Clostridium difficile* infection (CDI). These organism-specific HAI categories have been created due to the increasing incidence and morbidity associated with these organisms in the acute care setting.[2]

Central Line-Associated Bloodstream Infection

A central line-associated bloodstream infection (CLABSI) occurs when bacteria enter the blood via the central line catheter. A central line is a catheter placed into the large vein of a patient; it is used to draw blood, give fluids, or administer medications. Depending on the patient's length of stay, the catheter can be in place for several weeks. Risk of CLABSI in acute care settings— especially intensive care units (ICUs)— is high due to the frequent insertion of multiple catheters, the use of specific types of catheters inherently associated with substantial risk (such as a pulmonary artery catheter), and the fact that catheters are frequently inserted during emergency circumstances, repeatedly accessed throughout the day, and often needed for extended periods of time.[3] One in four patients who develop CLABSI die.[4]

Catheter-Associated Urinary Tract Infection

A catheter-associated urinary tract infection (CAUTI) occurs when bacteria and yeast are introduced into the bladder or kidney through the urinary catheter. A urinary catheter is a thin tube inserted through the urethra to drain urine. Approximately 15-25% of hospitalized patients receive urinary catheters during their stay.[5] These infections are one of the most common types of HAIs,[6] and account for more than 30% of HAIs reported by acute care hospital units.[7] Prolonged use of the urinary catheter is the most important risk factor for developing a CAUTI as the daily risk of acquisition of bacteriuria (bacteria in the urine) increases by 3%-7% for a patient with an indwelling urethral catheter.[6] While attributing morbidity to a single use of a catheter is limited, the high frequency of catheterization in hospitalized patients actually means that the cumulative burden of CAUTI is significant.[6, 8] Even more so, inappropriate treatment of the bacteria can promote antimicrobial resistance and *Clostridium difficile* infection, especially in acute care facilities.[9] All patients will become bacteriuric if catherised long enough.[10]

Surgical Site Infection

A surgical site infection (SSI) develops after surgery around the surgical site. SSIs are common complications in acute care facilities, occurring in 2%-5% of patients undergoing surgery.[11] It is estimated that 160,000-300,000 SSIs occur annually in the United States. SSIs are one of the most common and most costly HAIs, accounting for 20% of all HAIs in hospitalized patients and associated with a prolonged hospital stay of 7-11 additional postoperative hospital-days.[11-13] It is estimated that SSIs annually account for $3.5-$10 billion in healthcare expenditures using the consumer price index for inpatient hospital services with cost estimates adjusted accordingly.[12] Of patients with a SSI who have died, 77% are directly attributable to the SSI itself.[11] And yet, approximately 60% of SSIs are estimated to be preventable by using guidelines.[12]

Ventilator-Associated Pneumonia

A ventilator-associated pneumonia (VAP) infection develops in the lung of a patient who is on a ventilator. The ventilator machine helps the patient breathe by delivering oxygen through a tube placed in the patient's mouth, nose, or a through a hole in the front of the neck. VAP can occur when bacteria enter through the tube and infect the patient's lungs. While the true incidence of VAP is difficult to determine due to subjective and nonspecific surveillance definitions, historically 10%-20% of ventilated patients have developed VAP.[13] Recent clinical surveys suggest that 5%-15% of ventilated patients develop nosocomial pneumonias.[13, 14] It is estimated that the attributable mortality of VAP is approximately 10%; however, this varies considerably based on the kind of patient and their medical condition.[13] VAP extends the patients' duration of mechanical ventilation, lengthens the patient's hospital stay, and increases mortality risk.[13, 15]

Methicillin-Resistant Staphylococcus aureus (MRSA) Infection

Methicillin-resistant *Staphylococcus aureus* (MRSA) is a type of *Staphylococcus* bacteria that is resistant to beta-lactam antibiotics such as methicillin, penicillin, amoxicillin, and oxacillin. MRSA can be transmitted through the patient environment (bed linens, bed rails, bathroom fixtures, and medical equipment) and by the hands of both healthcare providers and visitors. HAIs caused by MRSA are common in acute-care facilities.[16] The United States' National Healthcare Safety Network (NHSN) reported that from 2009-2010, 54.6% of *S. aureus*-CLABSIs, 58.7% of *S. aureus*-CAUTIs, 48.4% of *S. aureus*-VAP episodes, and 43.7% of *S. aureus*-SSIs were caused by MRSA.[16,

[17] Due to the increased antimicrobial use in hospitals, MRSA has a select advantage to survive. MRSA-colonized and MRSA-infected patients contaminate their environment, and healthcare personnel that come into contact with the patient or the patient's environment contaminate their hands, clothing, and equipment allowing for the spread of the bacteria.[16] As there is resistance, treating these infections can be difficult to do. Thus, HAIs caused by MRSA are associated with significant morbidity and mortality.[18]

Clostridium difficile Infection (CDI)

Clostridium difficile (C. difficile) is a bacterium that causes colitis (inflammation of the colon). While *C. difficile* is shed in faeces, any surface or material that becomes contaminated with the faeces can serve as a reservoir. It is estimated that in 2011, *C. difficile* has caused almost half a million infections in the United States. *C. difficile* currently rivals MRSA as the most common bacterial cause of HAIs in the United States.[19, 20] CDI rates are at all-time high levels with numerous reports of an increase in CDI severity.[19, 21] CDI increases the length of a patient's hospital stay by 2.8-5.5 days,[22] costs US hospitals an estimated $1.0-4.9 billion per year,[22] and has an attributable mortality of 5%-10% leading to an estimated 14,000-20,000 deaths each year in the United States slone.[19] Lincosaminde antibiotics (such as clindamycin) and beta-lactam antibiotics (such as cephalosporin and ampicillin) are major predisposing antibiotics.[19, 23]

Transmission of HAI Pathogens via Hands

HAI pathogens are not only from infected or draining wounds but also from intact patient skin. As normal skin sheds daily, objects in the immediate environment of the patient become contaminated with patient flora. Following contact, microorganisms can survive on hands for varying lengths of time (2-60 minutes).[24] Healthcare workers' hands become increasingly colonized with commensal floral in addition to potential pathogens during patient care. In the absence of proper hand hygiene (HH) action, microbial transfer between patients is likely to occur. The transmission pathway is depicted in Figure 1-1.

Hand Hygiene to Control HAIs

Extensive evidence shows that HH is a critical factor in the control of HAIs.[25] Through patient care and interacting with the patients' environments, the hands of healthcare workers (HCWs) easily become contaminated with transient microorganisms. Yet, transient flora is easily removed by handwashing.[26] Traditionally, soap— either plain or with an antimicrobial agent— and water have been used in handwashing to reduce HAIs.[25, 26] However, with the introduction of alcohol-based hand rubs (ABHRs), these rubs are now more often used to decontaminate hands between contact with patients. A number of studies have looked at HH product efficacy against bacteria and have found that ABHRs (with concentrations between 62% and 95%) are more effective than plain or antimicrobial soaps.[27] In addition, several studies have shown that ABHRs are better at removing several different viruses than soap (plain and antimicrobial) and water.[27] There is a consensus view—held by both the World Health Organization (WHO) and the Centers for Disease Control (CDC)— on the indications for use of ABHRs: they should be used routinely during delivery of patient care so long as hands are not visibly soiled.[24-26, 28]

Hand Hygiene Recommendations

Various indications for HH during patient care have been described extensively in the literature.[29] Several frameworks have been developed that explain how to understand, monitor, and report HH practices. However, there are two leading guidelines on HH followed by hospitals throughout the world. The WHO, as part of its First Global Safety Challenge, launched the "My 5 Moments for Hand Hygiene" campaign.[24] The "My 5 Moments" concept was designed to be easily learned and applicable to a wide range of healthcare settings (Figure 1-2).[30] The moments include five main indications for HH:

Moment 1: Before Touching Patient—HCWs need to clean hands before touching a patient. This is to protect the patient against colonization and exogenous infection by the pathogens found on hands.

Moment 2: Before Clean/Aseptic Procedure— HCWs must clean hands immediately before accessing a critical site with infectious risk for the patient. This is to protect the patient from harmful pathogens, including the patient's own germs, from entering the patient's body.

Moment 3: After Body Exposure Risk— Hands must be cleaned immediately following the completion of a task that involves exposure risk to body fluids (and after glove removal). This is to protect the HCW from colonization or infection with the patient's germs and to protect the healthcare environment from the spread of pathogens.

Moment 4: After Touching a Patient— Hands must be cleaned after leaving the patient's side or after having touched the patient. This is to protect the HCW from colonization with patient germs and to protect the healthcare environment from the spread of pathogens.

Moment 5: After Touching Patient Surroundings— HCWs need to clean hands after touching any object or furniture when leaving the patient surroundings, without having touched the patient This is to protect HCWs from colonization with patient germs that may be present on surfaces in patient surroundings and to protect the environment against pathogen spread.

The second guideline is provided by the CDC, which cites 12 indications for HH:

1. When hands are visibly dirty or contaminated with proteinaceous material

or are visibly soiled with blood or other body fluids, hands must be washed with either a nonantimicrobial soap and water or an antimicrobial soap and water.

2. If hands are not visibly soiled, an alcohol-based hand rub can be used for routinely decontaminating hands in all other clinical situations. Hands can alternatively be washed with antimicrobial soap and water in all the same situations.
3. Decontaminate hands before having direct contact with patients.
4. Decontaminate hands before donning sterile gloves when inserting a central intravascular catheter.
5. Decontaminate hands before inserting indwelling urinary catheters, peripheral vascular catheters, or other invasive devices that do not require a surgical procedure.
6. Decontaminate hands after contact with a patient's intact skin.
7. Decontaminate hands after contact with body fluids or excretions, mucous membranes, non-intact skin, and wound dressings if hands are not visibly soiled.
8. Decontaminate hands if moving from a contaminated-body site to a clean-body site during patient care.
9. Decontaminate hands after contact with inanimate objects in the immediate vicinity of the patient.
10. Decontaminate hands after removing gloves.
11. Wash hands with a non-antimicrobial soap and water or with an antimicrobial soap and water before eating and after using the restroom.
12. Wash hands with non-antimicrobial soap and water or with antimicrobial soap and water if exposure to *Bacillus anthracis* is suspected or proven.

The CDC guidelines focus on HH in healthcare settings particularly directed to high-income countries (HICs). The WHO guidelines seek to focus on healthcare settings globally. Despite the target audience, there are similarities between the two guidelines. For instance, both guidelines indicate that there are situations in which one should use soap and water to decontaminate hands while there are other situations in which ABHR is preferential. The two guidelines agree about the need to wash hands with soap and water during the following clinical care situations: when hands are visibly soiled and after known or suspected exposure to *Clostridium difficile* and to *Bacillus anthracis*. There is agreement about the preferential use of ABHR in the following situations: before direct patient contact, before putting on gloves before an invasive procedure, before and after handling medical equipment such as urinary catheters, after direct patient contact, after removing gloves, after contact with the patient or the patient's direct environment, and when moving from a contaminated body site on the patient to a clean body site.

Variation in How Hand Hygiene Is Observed

Many organizations have adopted these guidelines, and while the WHO's concepts of the 5 Moments and the CDC's 12 Indications are taught, the measurement of hand hygiene compliance (HHC) has been simplified to only the moments directly before and after patient care (corresponding to the entry and exit of a patient's room).[27] Moreover, many healthcare institutions in the United States have compressed the number of HH opportunities to "entry to" and "exit from" a patient care area. The Joint Commission, an organization in the United States that accredits healthcare organizations and programs, has primarily promoted room entry/exit HH practice. As it is difficult to observe all HH opportunities, the Joint Commission's primary method of measurement is restricted to observing "in" and "out" of patient rooms only.[31] There is concern that by not emphasizing and measuring HH at other moments—such as before an aseptic procedure and after coming into contact with a body exposure risk— there will be a negative impact on the HH experience for the entire patient encounter.[27] However, there has been evidence to support the entry and exit method to be an adequate proxy for measurement of HH.[27, 32, 33]

Measuring Hand Hygiene Compliance Rates Among HCWs

The terminology used to measure and discuss HHC rates is as follows:

- The term *opportunity* is used to describe the correct moment for HH.
- *Action* is used to describe when HH has been practiced.
- Therefore, the *HHC rate* is the number of instances of HH performed (*actions*) divided by the number of hand hygiene opportunities (*opportunities*).

While there are large methodological differences across studies in measuring HHC rates, numerous systematic reviews have confirmed that HHC rates are universally low and vary quantifiably depending on situational factors.[34-36] The frequency of HH opportunities and hence the number of times HH is practiced per hour and shift differ significantly by unit, type of care, and even by monitoring method. Thus, while the reported compliance of HCWs has been variable, the rates are frequently sub-optimal. Moreover, self-reports of HHC tend to overestimate HHC, and are thus less reliable and often inaccurate.[37, 38] In all, mean baseline HHC rates range from 5% to 89% with an overall mean of 38.7%.[24, 26, 39-46]

As mentioned previously, the number of opportunities for HH varies markedly between hospital units. For example, nurses in ICUs have an average of 40 opportunities for HH as compared with an average of 8 opportunities for nurses in outpatient pediatric units per hour.[24, 40, 47] The number of opportunities depends on the type of care provided. The higher the number of opportunities for HH, the lower the compliance has typically been.[24, 39, 40, 47-51]

Factors Affecting HHC Rates

Risk factors for poor adherence to HH have been identified through several observational studies or interventions seeking to improve adherence.[24, 26, 34, 39, 47, 52-58] In 1999, Pittet et al. conducted the largest hospital-wide survey of HH practices among HCWs to identify predictors of poor adherence.[47] The study took place in Geneva. The average compliance rate was 48% for 2834 observed opportunities. Predicting variables included professional category, hospital unit, time of day/week, and type and intensity of patient care, defined as the number of opportunities for hand hygiene per hour of patient care.

The study found that nurses had the highest compliance rates as compared with other HCWs. Compliance was highest during the weekends. The ICU had the lowest HHC rates as compared with other internal medicine units. Also, HHC rates were noticeably lower during procedures that carried a high risk of bacterial contamination and when the intensity of patient care was high. For every increase of 10 opportunities per hour, compliance decreased on average by 5%. Not surprisingly, the lowest adherence rate (36%) was found in ICUs, where indications for HH were more frequent (an average of 20 opportunities per patient-hour). The highest adherence rate (59%) was observed in paediatrics units, in which the average intensity of patient care was lower than in the other units (average of eight opportunities per patient-hour).

Pittet at al. (1999) emphasized that full and complete adherence to HH guidelines is unrealistic.[47] However, the main suggestion was to make HH easily accessible by placing ABHR dispensers at the point-of-patient care. Other publications agree with these results[24, 34, 59, 60] and have also found that access to ABHR at point-of-care leads to an increase in HHC rates.[40, 41, 61, 62] In addition, other studies have also observed the inverse relationship between intensity of patient care and adherence to HH.[49, 51, 63]

The factors provided by Pittet at al. above were derived from observation.[47] Other studies have directly asked HCWs—through interviews and surveys— about the factors they perceive as leading to poor HHC.[64] Reported barriers to practicing HH include skin irritation caused by hygiene agents, inaccessible hygiene supplies, the perception that HH will interfere with the HCW-patient relationships, priority of care (the patients' immediate needs are prioritized over HH), the wearing of gloves, forgetfulness, lack of knowledge of the guidelines, insufficient time for HH, high workload, and understaffing.[64]

Current Hand Hygiene Initiatives

Numerous researchers have begun to try to identify what kinds of interventions lead to an increase in HHC.[65, 66] The most common HH interventions are those that contain education on when and how to practice HH and also on the importance, reminders to practice HH, feedback on performance, and easy access to ABHR.[67] It has long been understood that multimodal interventions are necessary for an increase in compliance[52, 68] with the majority of interventions taking on one of two main approaches: either the intervention includes education, reminders, and feedback alone, or the intervention includes improved administration support and access to ABHR in addition to the basic components of education, reminders, and feedback.

Yet, the interventions do not always have long-lasting effects. One reason is that a common tactic in many interventions is to use posters and signs to convey these educational messages, to promote slogans, and to serve as reminders.[69, 70] However, it's been found that point-of-use signs do not significantly improve HHC as compared to not having signs.[71] Another surprising finding is that HCWs have the opinion that the impact of a HH campaign materials are actually greater on other HCWs' behaviours rather than on their own, furthering the notion that posters do not have a significant or direct impact on behaviours.[72]

Another reason HH interventions struggle to produce long-lasting effects is that changing people's behaviour is extremely difficult, and many of the interventions do not focus on what components of the behaviour need to be specifically changed. Several researches have tried to truly understand HCWs' perceptions of barriers to HH. One research team interviewed senior hospital managers about current strategies to improve HH and found that campaign messages to practice HH need to be refreshed and renewed constantly; over time, HCWs grow accustomed to the messages and they become part of the background noise.[73] The Senior Hospital Managers also conveyed that the WHO's "Five Moments" need to have grounding in the everyday; while the Five Moments are specific moments in which HH should be practiced, the Managers emphasized the importance of connecting these moments to particular care settings and applying the framework to the whole patient journey. The Managers also stressed the need for actionable audit results and to take disciplinary means when necessary.

Another research team observed HCWs throughout the day and asked about noncompliance in real-time by having the HCWs explain why they did not practice HH after a missed opportunity.[74] Over two-thirds of the explanations were attributed to two domains. The first was "memory/attention/decision-making" in which HCWs either forgot to clean hands, were concentrated on completing another task, were distracted by another non-urgent task, or made a conscious decision not to clean hands to attend to another matter. The second domain was “knowledge” in which HCWs had a lack of knowledge of the rules, protocol, or indications governing HH (such as performing HH after wearing protective gloves).

Additional research sought to provide explanations for why HCWs practice HH. One study in particular looked at nurses’ infection prevention behaviours through semi-structured interviews and vignettes.[75] A main theme that emerged was “protection from dirt.” There was a clear distinction between infection and dirt. Fear of contact with dirt, especially dirt belonging to those who were unknown, was a key driver in behaviour carried out to reduce perceived threat. Familiarity with the patient resulted in a reduction of the protective behaviours required. These behaviours were primarily a form of self-protection rather than part of an infection prevention strategy. It was also found that HCWs wanted to give a good impression and present themselves as knowledgeable practitioners even if procedure and policy were not always followed.[76] Their own behaviour was rationalized, and any deviations from policy were logistically justified. When deviations to HH protocol by other HCWs were mentioned, the participants being interviewed could not justify or rationalize the missed HH opportunity.

Each of these studies has highlighted the complexity of HH in the healthcare setting and the shortcomings of many current HH interventions. Interventions that change health related behaviours may be more effective if grounded in appropriate behaviour change theory.

BACKGROUND: BEHAVIOUR CHANGE THEORIES

Effective health promotion initiatives and programs help people maintain and improve health. Good health leads to improved well-being and self-sufficiency for individuals and communities.[77] Such successes require behaviour change at many levels. Not all health programs and initiatives are equally as effective. Those most likely to achieve the desired outcomes are based on theory.[78] Theory provides a systematic way of understanding phenomena. Using theory to develop and manage these initiatives helps to lead to successful programs. In this section, the term 'theory' is used instead of 'model' and the term 'construct' is used instead of 'variable' when referring to a part of the theory.

Health promotion and the related literature are filled with an overabundance of behaviour change theories. Yet, there is little consensus as to which approach provides the best guidance for programme development and implementation. Moreover, it is difficult to determine which theories have the greatest impact on behaviour and which approaches are the most appropriate to utilize for certain behaviours. Theories are generally used singularly and in isolation, and so have not been truly tested against each other.[79]

Main Theories of Health Behaviour Change

Health behaviour change involves a variety of social, emotional, and cognitive factors.[80] The most widely used theories of health behaviour change often have overlapping factors; however, there are major differences in the underlying philosophy. The main theories are Theory of Reasoned Action (TRA), Theory of Planned Behaviour (TPB), Social-Cognitive Theory (SCT), the Health Belief Model (HBM), and Transtheoretical model (TTM). The theories can be categorized into two main theoretical perspectives: cognitive and stage.[81]

The cognitive perspective includes theories such as the TRA, TPB, SCT, and HBM.[78-82] These theories hold that behaviour change is influenced by cognitive constructs, and that attitudes and beliefs as well as outcomes and expectations, are major determinants of health related behaviour.[81, 83] When an individual is confronted with various alternatives, the theories hold that the individual will choose the action that will lead most likely to positive outcomes.

There are major critiques of these theories. The first is that human behaviour is complex. Simply assuming that behaviour is a result of self-interest—that rational behaviour is the result of cognitive deliberation— completely overlooks the fact that behaviour is embedded in a collective and social decision-making context with multiple factors at play. Individual preference is continually being shaped by various factors, especially factors that are non-voluntary. Even more so, humans do not always behave rationally, especially when emotions are involved. Emotional or affective responses confound cognitive deliberation.

The second critique is that the theories do not address how to ensure adherence. Behaviours can be changed, but it is sustaining the change where many efforts and initiatives have fallen short. The third critique is that the theories do not seek to understand the social norms surrounding behaviour. Norms support and embed certain practices.[84] So to change behaviour, a new set of norms must be created in order to eliminate a negative practice. Without identifying the norms that influence the specific behaviour, sustainably changing behaviour will be difficult to do. Fourth, there are numerous factors at play such as social status and social reputations that also impact adherence to a specific behaviour. These types of factors are largely overlooked by the theories.

Theory of Reasoned Action & Theory of Planned Behaviour

The basic premise of the Theory of Planned Behaviour (TPB) and the related Theory of Reasoned Action (TRA) is that behavioural intention is the most important determinant of behaviour. The stronger the behavioural intention, the more likely someone is to perform the desired behaviour. Behavioural intention is influenced by the person's attitude toward performing a behaviour and by the person's beliefs of how those individuals important to the person may perceive and support a behaviour (subjective norm). All other factors such as culture and the environment are assumed to operate through the models' constructs, and do not independently explain the likelihood that a person will behave a certain way.[80]

The TPB is an extension of the TRA. In addition to attitudes and subjective norms, the TPB includes a third construct: perceived behavioural control. This construct centres on people's own beliefs that they can control behaviour and addresses the TRA's limitation in accounting for situations in which people's behaviour is influenced by factors beyond their control. It is argued that people's perceptions of controllability can influence behaviour. People might try harder to perform a behaviour if they have the perception of having more control over it.[85]

Health Belief Model

The Health Belief Model (HBM) postulates that people's beliefs regarding health problems, perceived benefits of action and barriers to action, and self-efficacy determine health-promoting behaviour. A stimulus, or cue to action, must be present to trigger the behaviour. The HBM centres on a person's readiness to act, and perceptions are fundamental in influencing beliefs. People are ready to act if they believe that they are susceptible to the condition (*perceived susceptibility*), believe there are serious consequences (*perceived severity*), believe that acting would reduce susceptibility or severity (*perceived benefits*), and believe the benefits outweigh the cost of acting (*perceived barriers*). In addition, people must be confident in their ability to perform the action (*self-efficacy*) and must also be exposed to factors that trigger action (*cue to action*). Thus, there are six main constructs that influence people's behaviour:

1. Perceived susceptibility
2. Perceived severity
3. Perceived benefits
4. Perceived barriers
5. Cue to action
6. Self-efficacy

Social Cognitive Theory

Social Cognitive Theory (SCT) posits that people learn not only from their own experience, but from observing the actions of others and seeing the advantages of those actions. There are three constructs that impact the likelihood of someone changing a health behaviour: self-efficacy, goals, and outcome expectancies. People can change their behaviour even in the presence of challenges if there is a sense of personal agency (self-efficacy). Feeling like one has control over their health behaviour translates into motivation that allows the individual to persist when faced with obstacles. Adopting new behaviours leads to changes in the person as well as in the surrounding environment.

SCT is an amalgamation of cognitive, behaviourist, and emotional models of behaviour change. As such, it includes various factors such as self-efficacy, reciprocal determinism, behavioural capacity, expectations, observational learning, and reinforcements. The underlying principle is that behavioural acquisition occurs by watching the actions and outcomes of other people's behaviour (*observational* *learning*). Before one can perform a behaviour, the person must know what to do and how to do it (*behavioural capacity*). A behaviour is not performed in isolation. There is a dynamic interaction between the person, behaviour, and the environment in which the behaviour is performed (*reciprocal determinism*). When a person performs a behaviour, there are anticipated outcomes of a behaviour (*expectations*). Positive outcomes lead to further performance of healthful behaviour. Reinforcements are the responses to an individual's behaviour that affect the likelihood of reoccurrence. Positive reinforcements increase the likelihood of repetition.

Transtheoretical Model

The Transtheoretical Model (TTM) holds that behaviour change is a process, not an event. There are five stages a person passes through when changing behaviour: precontemplation, contemplation, preparation, action, and maintenance. People at different points along this continuum of behaviour change have different informational needs. As such, the TTM posits that interventions should be designed for the various stages. This theory is circular, meaning that people do not systematically progress from one stage to the next, but can enter the process at any stage, slide between various stages, and even cycle through the process repeatedly.

The TTM is in a group of stage perspectives, which focuses on behaviour change as being part of a process with various stages. Change in behaviour is not quick and decisive. A major criticism of this approach is that little information is provided on how people change.[86] Ensuring sustainable change requires an understanding of how the change is taking place. Even more so, Bandura (1997) argues that human behaviour is complex and multifaceted making it extremely difficult to be grouped into specific and separate stages.[87] There have been further criticisms involving the stage definitions. It has been argued that the stage definitions are ambiguous.[88] Some suggest that the stages can actually be different points on a larger continuum while others argue that the time periods have been arbitrarily assigned to each stage.[81, 88]

Recent Approaches to Behaviour Change

While behaviour change theories provide the basic overview of how to modify behaviour, it is the behaviour change frameworks and models that serve as the detailed roadmaps by providing step-by-step methodologies. Various approaches give descriptions of how to design health promotion interventions derived from theories. While there are over 83 identified theories of behaviour change and approaches to designing interventions,[89] we focus on four specific approaches that have been widely utilized in HH and sanitization interventions: Behaviour Change Wheel (BCW) framework,[90] the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) approach,[91] Intervention Mapping,[92]and the PRECEDE-PROCEED model.[93] These frameworks are structured approaches to developing and evaluating behaviour change interventions. While each approach is grounded in a different theory or philosophy, there are similarities across many of the steps. The descriptions of the different approaches are provided in Table 1.1.

Behaviour Change Wheel

The Behaviour Change Wheel (BCW) was developed by Michie and colleagues as a guide to designing interventions.[94] The BCW incorporates concepts from various frameworks of behaviour change. The wheel consists of three layers (Figure 1-3). The centre of the circle identifies the sources of behaviour that are targets for an intervention. This approach uses the COM-B (*Capability, Opportunity, Motivation, and Behaviour*) model, which describes behaviour as a system involving all these components. The basic premise behind the BCW is that once the context of the behaviour is understood, the full range of effective interventions and supporting policies can then be considered. According to this model, interventions must change one or more of these components to reconfigure the system and to minimize risk of reverting it. The middle layer is comprised of nine intervention approaches that can be pursued based on the COM-B analysis conducted. The outer layer identifies seven policy categories that can then support the delivery of the intervention. When the most feasible intervention function or policy change has been chosen, the behaviour change techniques (BCTs)— listed in a taxonomy— that fit best with this approach are selected through a systematic method and are then implemented.[90] The BCW provides a systematic guide to identifying intervention approaches and policy avenues to pursue based on the targeted behaviour. However, the BCW can be somewhat complicated to use as there are many components to the approach.

The Risks, Attitudes, Norms, Abilities, and Self-Regulation (RANAS) Approach

Developed by Mosler (2012), the RANAS approach involves four steps (Figure 1-4).[91] First, the potential behavioural and contextual factors are identified and then arranged in the RANAS model of behaviour change. A questionnaire is then administered to measure behaviour and the potential behavioural factors, with a doer/no-doer analysis conducted to identify the behavioural factors steering the target behaviour. Doer/non-doer analysis is when responses of people who perform the behaviour (*doers*) are compared to the responses of those who do not (*non-doers*). Differences in responses between doers and non-doers illuminates the behavioural factor(s) in question; the identified behavioural factor(s) can then be addressed with BCTs. The BCTs thought to change the critical behavioural factor(s) are selected from a catalogue for application in behaviour change strategies. To verify the efficacy of these behaviour change strategies and to optimize them, the strategies are evaluated with a before-after control trial. The RANAS Model draws from the Health Belief Model, Motivational Interviewing, Protection Motivation Theory, Implementation Intentions Theory, Health Action Process Approach, and Theory of Planned Behaviour.

The RANAS Model mainly focuses on changes that can be implemented by households themselves. It does not focus on institutions or economic and political systems; furthermore, it does not try to change the environment. This model is valuable in contexts where individuals can change conditions of their daily life without outside help, but struggles to be applied at the meso- and macro-level.

Intervention Mapping

The Intervention Mapping model was developed in 1998 by Bartholomew-Eldridge and colleagues.[95] It uses theory and evidence to take an ecological approach to addressing and intervening in health problems while encouraging community participation.[92] This model is underpinned by the *social ecological paradigm* which sees health as a function of individuals and of the environments in which individuals live.[96] It has been expanded upon to now include six steps (Figure 1-5), which are paraphrased from Kok et al. (2016):[97]

1. Conduct a needs assessment or problem analysis
2. Create matrices of change objectives
3. Select theory-based intervention methods and practical applications
4. Integrate methods and applications into an organized programme
5. Plan for adoption, implementation, and sustainability of programme
6. Generate an evaluation plan

The process is reiterative rather than linear. Intervention Mapping has been described as a complex framework that is often elaborate, expensive, and time consuming.[98] In addition, logic models can be faulty when the essential problem has not been clearly defined, the factors influencing behaviour have not been properly identified, or when an inadequate theory has been chosen.[99]

PRECEDE-PROCEED MODEL

The PRECEDE Model (Predisposing, Reinforcing, and Enabling Constructs in Educational/Environmental Diagnosis & Evaluation) was developed in the 1970s by Green and colleagues.[93, 100] The impetus behind the model was that health education had been focused more on implementation of health programs and not enough on the designing of interventions. In 1991, the framework was expanded with the addition of PROCEED (Policy, Regulatory, and Organizational Constructs in Educational and Environmental Development). This was to account for the forces outside of the individual that influence behaviours—such as industry, politics, and social inequalities. This part of the framework provided an ecological approach to health promotion that was required to understand and address the larger contextual determinants of health behaviour. The model was further revised in 2005 to streamline the approach while also addressing the rise in ecological and participatory approaches and to incorporate new knowledge from the field of genetics.

The PRECEDE-PROCEED Model does not try to predict or explain relationships among factors that are associated with the outcome of interest. Instead, it seeks to provide a systematic structure for applying behaviour change theories and concepts—such as Social Cognitive Theory, the Health Belief Model, Theory of Reasoned Action, and the Theory of Planned Behaviour— in the planning and evaluating of health behaviour change programs.[93] In a way, it is a logic model that links the causal assessment and the intervention planning and evaluation into one overarching planning framework.[93] The model consists of four planning phases, one implementation phase, and three evaluation phases (Figure 1-6). One of the main tenets of the model is that the target population must define their own high-priority problems and goals and be active participants in the development and implementation of solutions. Thus, the target population participates in each step of each phase. This approach guides planners to select theory-based intervention methods that then can be operationalized as specific strategies.

There are challenges in applying the PRECEDE-PROCEED Model. First, it is heavily data-driven, and so application requires substantial financial and human resources, technical skill, and time.[93] Immediate action to address a health problem is not possible with this framework. In addition, the PRECEDE-PROCEED process does not provide specifics of intervention development or methods in detail. Instead, the authors advise planners to reference the Implementation Mapping approach.

Behaviour Centred Design (BCD)

For this thesis, we used an approach to behaviour change called Behaviour Centred Design (BCD), which is a framework that provides guidance not only with respect to the overall intervention development process, but also for the creative design of interventions themselves. Developed by Aunger and colleagues (2016), BCD presents a systematic way to develop a program through five steps (Figure 1-7).[79] The first step—Assess— is concerned with setting out the scope of the intervention and identifying what is known about the target behaviour. This serves as the basis for the following step—Build— which seeks to fill knowledge gaps essential in the development of the

Theory of Change. A Theory of Change, as discussed in De Silva et al. (2014), is a "'theory of how and why an initiative works' which can be empirically tested by measuring indicators for every expected step on the hypothesised causal pathway to impact."[101] Thus, determining the Theory of Change allows for the formation of potential intervention themes, components, scope, and sequences which are necessary for generating the intervention itself in the Create step. The intervention is subsequently implemented in the Deliver step and assessed in the Evaluation step. Intervention design occurs throughout the Assess, Build, and Create steps. The basic premise behind BCD's design process is that the settings where the target behaviour occurs must be disrupted to force revaluation of the desired behavioural option, which then causes people to perform that behaviour. Thus, interventions are tasked with creating surprising new stimuli that run counter to the brain's predictions about the consequences of performing the target behaviour. By doing so, the brain is forced to reconsider its expectations of the value of performing different options resulting in a trial of the target behaviour. The steps are discussed in further detail as follow:

- The first step is to **assess (A)** the current situation. A literature review is conducted, specifically with a focus on gathering information about target behaviors, the target audience, the context, and the parameters of the intervention. A framing statement details what is known about how change can be achieved and then sets out hypotheses about change mechanisms for further exploration.
- The second step is to **build (B)** the foundation upon which the interventions will be created. Formative research will be carried out with the intention of identifying factors that are unknown and to explore hypotheses about the likely drivers of change. The insights

from formative research are ordered into a Theory of Change and summarized into a creative brief for the next phase.

- The third step involves the **creation (C)** of the intervention package. A creative agency—or an in-house creative team— creates interventions that are engaging and motivating enough to stand out in the crowded lives of those targeted by the programs.
- The intervention package is then **delivered (D)**. The implementation may involve direct and indirect contact via various means such as community workers, events, and digital media that are appropriate to the target population and intended impact.
- The fifth step is the **evaluation (E)** of the intervention package. A field trial at scale is conducted to allow for definitive assessment of whether the fundamental processes of the program's Theory of Change have taken place.

BCD focuses on behaviour change both at the individual and community level. It provides a behavioural model that is derived from Reinforcement Learning Theory and the Taxonomy of Needs based in evolutionary biology.[79] It highlights the importance of disrupting *behaviour settings* (a key concept in ecological psychology; this term is further explained below) and provides a list of steps involved in identifying levers that lead to behaviour change and creating programs that bring about the desired change. This approach provides a design process that guides one through the conception, creation, implementation, and evaluation of a behaviour change program.

The Process Model is at the heart of the BCD approach.[79] An intervention must change something in the environment, which then must change something in the brain and/or body of the target individual, which only then can have an impact on behaviour. This progression is seen in the middle of the diagram. The five steps of the BCD development process are depicted along the top and bottom of the diagram.

The middle of the diagram focuses on the understanding of behaviour. In humans, behaviour almost always takes place in specific repeated contexts with particular features. The right behavioural response depends on the physical, social, and temporal context in which people find themselves. These situations are described as *behaviour settings*— a concept developed in the 1950s by ecological psychologist Roger Barker.[102] Behaviour is a function of the setting within which it takes place. The *behaviour settings* concept explains the physical and social relationship between individuals and the environment.[102] *Behaviour settings* are situations where people have learned what to expect from the environment and from other people's behaviours. Each setting has a purpose, a designated place, a set of objects, and a prescribed set of behaviours. Each person entering a setting expects others, who are also contemporaneous participants, to perform their (implicitly) designated roles.

In all, the BCD approach theorises that an intervention can modify an environment leading to a psychological change in the target population causing a change in behaviour, ultimately resulting in changes to the state-of-the-world. Settings must be disrupted to force revaluation thereby causing behavioural transformation. Interventions are tasked with creating surprising new stimuli that run to counter to the brain's predictions. By doing so, the brain is forced to reconsider its evaluations, resulting in a new behavioural performance.

Programs that aspire to change behaviour need to do more than just understand the drivers of behaviour change processes. BCD offers a methodology for designing, delivering, and evaluating behaviour change programs. The process is centred on developing a Theory of Change that encapsulates the program assumptions about how to change the target behaviour.

THESIS OUTLINE

Significance of Research

It has been over 150 years since the Hungarian obstetrician Iganz Semmelweis (1818-1865) published his seminal manuscript on the importance of HH in healthcare delivery. Since then, healthcare professionals and researchers have been creating interventions to increase HH among HCWs and thus reduce the spread of infection. While behaviour change has been noted, sustainable change is generally not seen without continual reinforcement. Finding the key to changing the HH behaviour of frontline HCWs can result in reduced transmission of pathogens and reduced rates of HAIs. The intervention developed for this project, if determined to be successful, will be used by a major U.S. corporation that manufactures HH products for hospitals worldwide; thus, there is the possibility of a considerable significant impact on public health.

Rationale

HAIs burden patients, increase the length of hospital stays, raise healthcare costs for both patients and hospitals, and can most seriously lead to death.[34, 65, 103] HAIs are the most common complication occurring during hospital care.[104, 105] Annually, there are over 1.7 million HAIs reported in the U.S. and 4.1 million in Europe.[106, 107] In the States, nearly 100,000 deaths are attributed to HAIs yearly whereas in Europe it is estimated to be over 140,000 deaths.[106, 107] The financial burden is also significant with HAIs estimated to cost $28-33 billion annually.[107]

Adequate HH among HCWs is the simplest and most effective measure for preventing HAIs.[108] However, the rates of HHC among HCWs are regarded as being poor.[24, 65] There have been various initiatives seeking to address these low rates over the past several decades with mixed results.[34] While many of these initiatives have been successful in producing short-term changes in compliance, the effects are typically small-to-moderate and sustainability is generally low.[34, 65] The dynamics of behaviour change are complicated and multifaceted.[52] As such, researchers and public health officials alike have generally been unable to motivate HCWs to achieve a consistent and appropriate level of HHC.[55, 64, 109] There is an urgent need to identify strategies that will lead not only to an improvement in the HHC rates of HCWs, but will also create a sustainable positive change that can be maintained for months after delivery of the intervention.

In addition, while interdisciplinary collaboration in hospital care is normative in current practice,[110] it is the nurses who have the most direct physical contact with patients within the healthcare delivery team. Nurses have reported that 85-88% of their time is spent on direct patient care.[111] As nurses are on the frontline of patient care, improving their HH behaviour and thus increasing HHC rates has a large impact on reducing transmission and preventing HAIs. The target population selected for this research project was nurses.

Aims and Objectives

Human health behaviour is the consequence of multiple influences from biology, the environment, education, and culture.[52] This research project adopted the BCD approach—which is based upon behavioural science and considers individual, institutional, and community factors— to develop an intervention that aimed to effectively and sustainably improve the HHC rates of nurses in acute care hospital units. The objectives were:

1. To identify the various behaviour change techniques that have been incorporated into HH interventions designed specifically for nurses in the context of hospital settings (Assess step)
2. To identify the factors and levers that impact the HH behaviour of nurses in acute care hospital units (Build step)
3. To create an original intervention using the BCD intervention development framework that seeks to increase the HHC rates of nurses in hospital settings (Create step)
4. To design a multiple baseline study to test the intervention across several acute care hospital units (Deliver step)
5. To analyse and compare the short-term and sustained effects of this novel strategy (Evaluate step)
6. To identify the determinants of success or failure of the strategy through an evaluation of the intervention's process (Evaluate step)

Structure of Thesis

Chapter 1 sets forth the introduction to the thesis. The preamble at the beginning of this chapter provides further information.

Chapter 2 details the results of a systematic review that analysed the behaviour change techniques used in current HH interventions designed specifically for nurses in hospital settings to address Objective 1.

Chapter 3 presents the formative research that was undertaken to assess the potential impact of several unexamined factors on the HH practices of nurses. This was performed via a survey questionnaire. Objective 2 was met through the examination of these potential factors and through the identification of barriers and levers to HHC.

Chapter 4 describes and documents the development of our original behaviour change intervention using the BCD framework. This paper sets forth systematic procedures for designing and refining techniques utilized in the intervention (Objective 3); it also links Objectives 1 and 2, thereby illustrating the process behind the development of the intervention that is missing from most other behaviour change approaches.

Chapter 5 addresses Objective 4 by presenting the study protocol developed for the testing of the intervention.

Chapter 6 provides an outcome evaluation of the multiple baseline design that includes an interrupted time series analysis performed using a quasi-Poisson regression model as well as statistical process control charts to address Objective 5.

Chapter 7 details a process evaluation that enhances our understanding of the results from the outcome evaluation (Chapter 6) by examining how the intervention was implemented in practice, the extent to which the intervention reached the target population, and whether the steps in the theory of change occurred as expected. This piece of work meets Objective 6 by determining *what* was delivered and *how* it was delivered, by testing the causal assumptions that linked intervention activities to outcomes, and by understanding how the context surrounding intervention delivery impacted its implementation and the reported outcomes.

Chapter 8 discusses the main findings of the work presented in the previous chapters and highlights areas for future research.

Contribution of Candidate to Thesis

GOJO Industries Inc. engaged Dr. Robert Aunger of the Environmental Hygiene Group at the London School of Hygiene and Tropical Medicine to provide consultation services on the creation and evaluation of a HH intervention for hospitals in the United States. The candidate was recruited by Dr. Aunger to develop and implement the aim and objectives of the thesis. The contribution of the candidate is provided in the preamble of each research paper. However, a succinct summary of the candidate's contribution for each chapter is provided as follows.

For Chapter 2—the systematic literature review—the candidate was responsible for designing the methods, conducting the data collection and analysis, coordinating the collaborative efforts on the paper, and drafting the manuscript. In Chapter 3, the candidate designed the formative research survey, conducted the analysis, interpreted the results, and drafted the manuscript. Chapter 4 detailed the creation of the original intervention, which was a collaborative effort. However, the candidate documented the design process, identified the theoretical underpinnings of the intervention, and created a Theory of Change. The candidate also drafted the manuscript. Chapter 5 was the candidate's own work. She designed the multiple baseline study in which the intervention would be tested and wrote the study protocol for the project. For Chapter 6, the candidate contributed to the interpretation of results and wrote the manuscript. In Chapter 7, the candidate designed the questionnaires, conducted observations, analysed and interpreted the data in addition to drafting the manuscript.

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FIGURES

Figure 1- 1: Five sequential steps of contamination

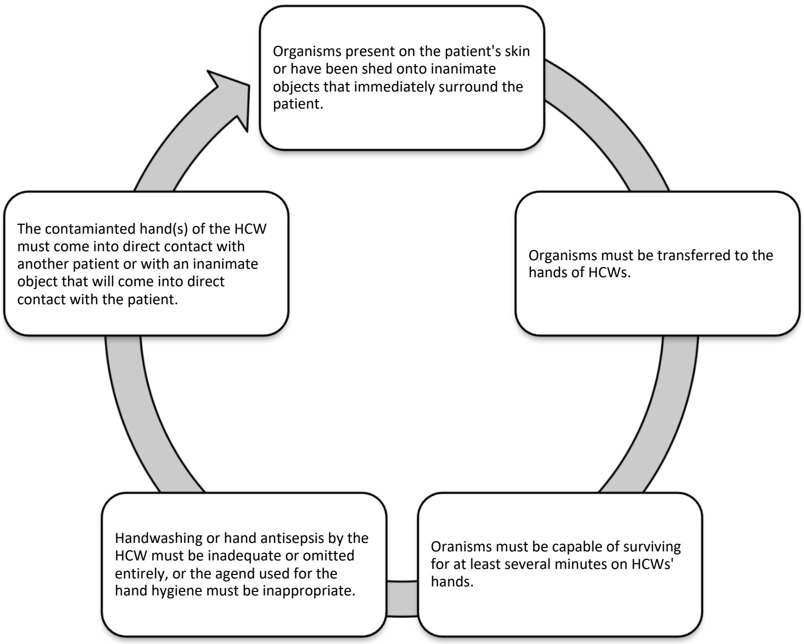
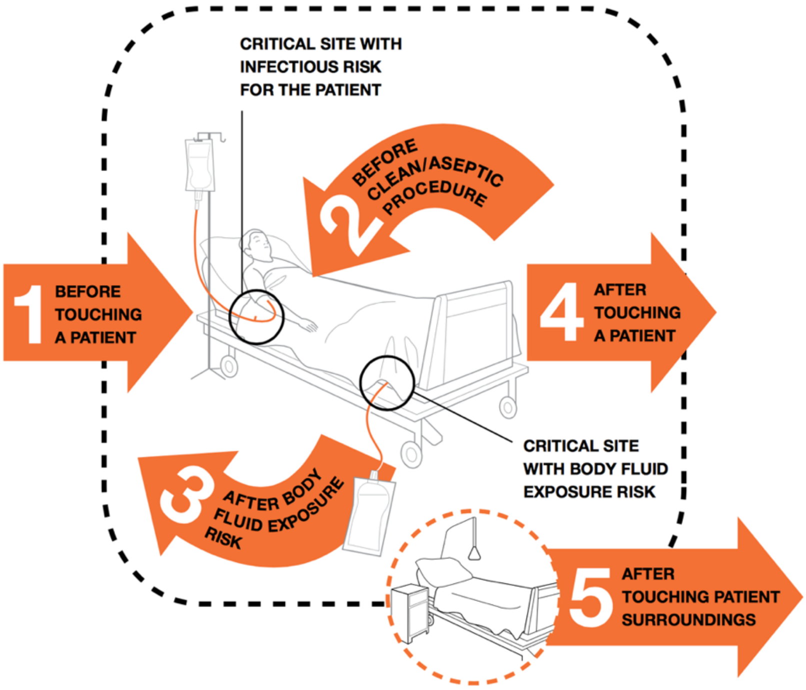
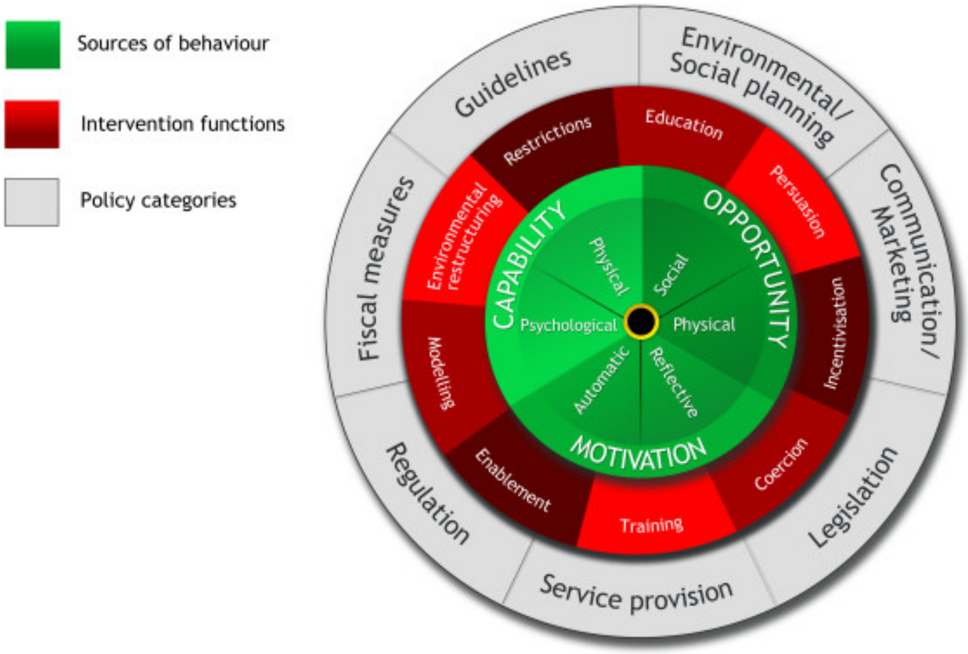


Figure 1- 2: The WHO's *5 Moments for Hand Hygiene*



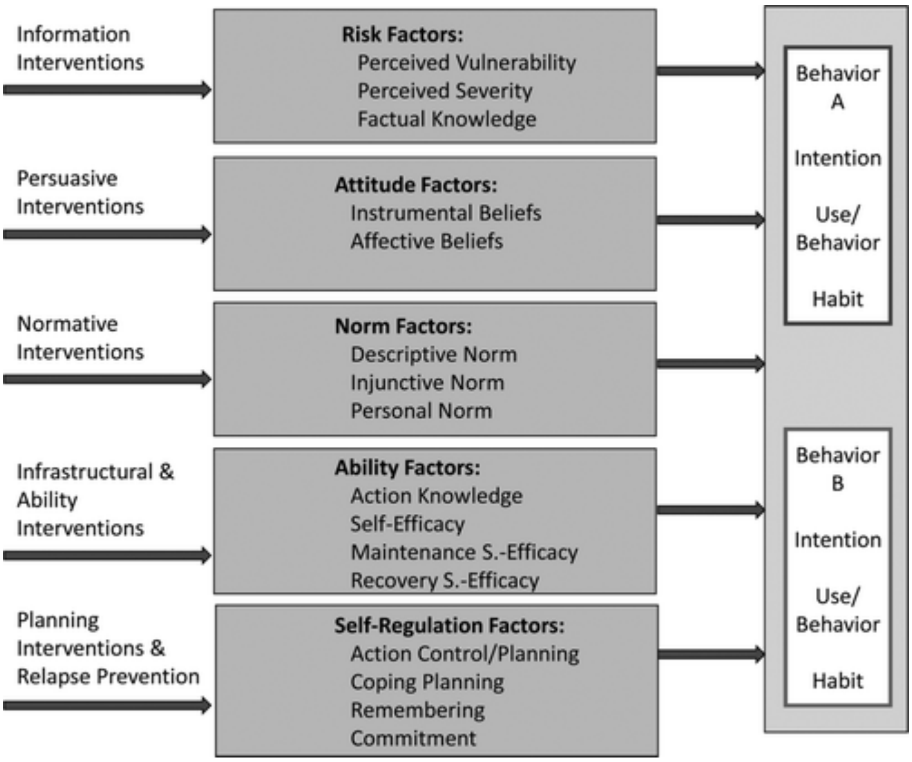
Reprinted from the WHO's Guidelines on Hand Hygiene in Health Care (2009)[4]

Figure 1- 3: The Behaviour Change Wheel



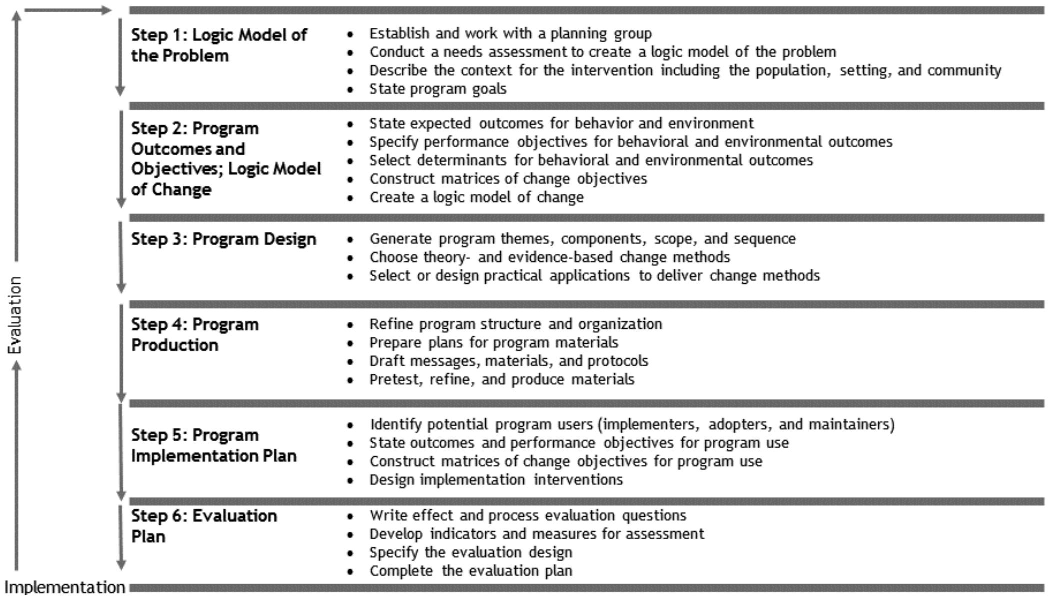
Reprinted from Michie et al. (2011)[93]

Figure 1- 4: The RANAS Model



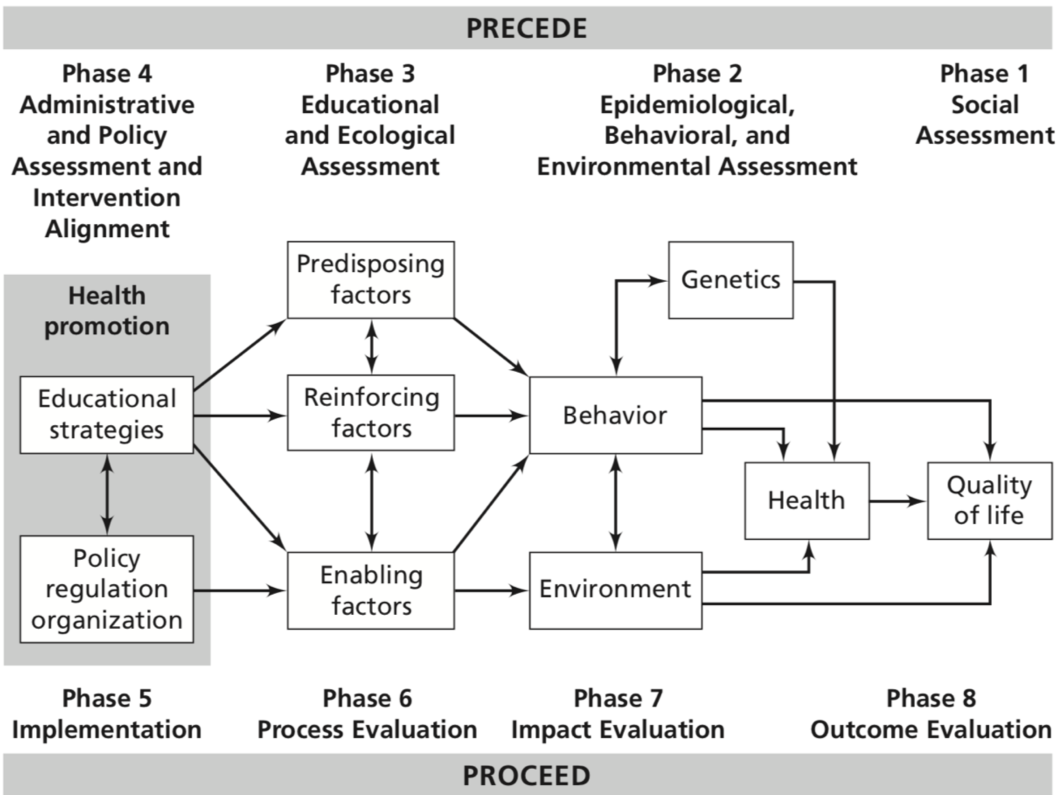
Reprinted from Mosler (2012)[90]

Figure 1- 5: Six Steps of Intervention Mapping



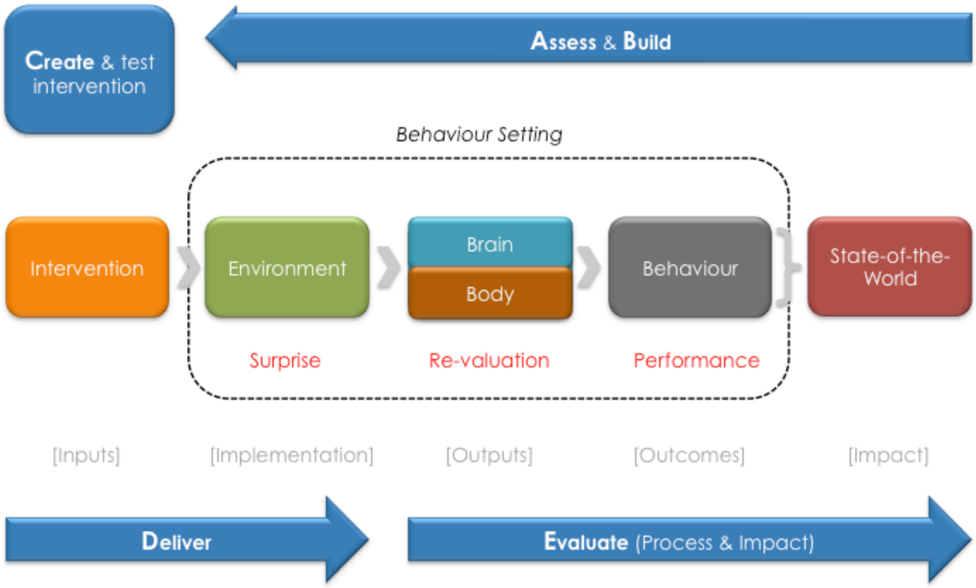
Reprinted from Eldredge et al. (2016)[99]

Figure 1- 6: PRECEDE—PROCEED MODEL



Reprinted from Gielen et al. (2008)[92]

Figure 1- 7: The BCD Process Model



Reprinted from Aunger and Curtis (2016).[75]

TABLES

Table 1- 1: Factors and behaviour change strategies examined in the literature.

Approach	Source	Rationale	Context Specified by Authors	Steps, Activities, or Actions*	Strengths*	Limitations*
Behaviour Centred Design (BCD)	Aunger & Curtis 2016[79]	A systematic and comprehensive approach (which makes use of a theory of change) for designing and evaluating interventions[79]	Behaviour change interventions in health; can be used in the design and marketing of technology and products related to public health; can be used in other contexts/settings such as governance and education[79]	Five step design process: A. Assess the current situation by conducting literature review B. Build the foundation upon which the intervention will be created by conducting formative research and using findings to create a Theory of Change and creative brief. C. Create the intervention package including the programme and materials using a creative agency or in-house creative team D. Deliver intervention E. Evaluate the intervention package looking at the outcome as well as the process	• Can be applied to behaviour change problems at population, institutional or individual level • Single-minded focus on behaviour as the key outcome • A theory of behaviour change, rather than of behaviour determination • Has a foundation in the ultimate evolutionary purposes of behaviour • Focuses on the situatedness of behaviour in social and physical setting	• Time intensive • Each step is dependent on previous step so there can be delays • With numerous stakeholders involved, disagreements amongst team members may prove challenging to manage • Lack of detail about actual development of intervention (how to turn a creative brief into an intervention)

* Specified by authors of approach, authors of other approaches, and by O'Cathain et al. (where applicable)

					and the context of other behaviours • Anchors process steps in design thinking	
Behaviour Change Wheel (BCW)	Michie et al. 2014[90] Michie et al. 2011[94]	Extensive and systematic approach, encouraging designers to consider the full range of options through systematic evaluation of theory and evidence[112]	Behaviour change interventions in health; can also be used in other settings[112]	Eight steps in three stages: 1. Understanding the behaviour i. Define the problem in behavioural terms ii. Select the behaviours you are trying to change iii. Specify the target behaviour i.e. who needs to do what differently and when iv. Identify what will bring about the desired behaviour change using COM-B or Theoretical Domains Framework 2. Identify intervention options that will bring about change i. Identify intervention functions ii. Identify policy categories 3. Identify content and implementation options	• Aids in intervention design; improves education and theory development by helping to understand why interventions have failed or how they have worked[90] • Explicitly draws attention to the different levels at which an intervention may need to work[90, 112] • Clear and detailed explanation of each action with multiple examples[112, 113] • Widely used[112]	• Expert knowledge of psychological processes neeeded[113] • Acknowledges that judgments are required where there is no evidence but does not say who should be involved in making these judgments e.g. stakeholder groups

				i. Identify behaviour change techniques from list of 93 e.g. goal setting ii. Identify mode of delivery		
Intervention Mapping	Bartholomew Eldrede et al. 2016[114] Kok et al. 2016[97] Kok et al. 2011[98]	A systematic and thorough approach that uses theory and evidence to produce an effective intervention	Health promotion Public health Complex problems	There are six steps that address the planning, implementation, and evaluation: 1. Conduct a needs assessment or problem analysis 2. Create matrices/logic models of change objectives 3. Select theory-based intervention methods and practical applications 4. Integrate methods and applications into an organised programme 5. Plan implementation and maintenance of program 6. Develop an evaluation plan	• Addresses the environmental and personal factors affecting the problem[97] • Rigorous and elaborate in its approach to intervention development[112, 115] • Widely used[112]	• Elaborate, expensive, and time consuming[98] • Can be difficult to operationalise[112, 115] • Logic models can be faulty when essential problem has not been clearly defined, the factors influencing behaviour have not been properly identified, or when an inadequate theory has been chosen[99]
PRECEDE-PROCEED	Crosby et al. 2011[116] Gielen et al. 2008[93]	An ecological approach that provides systematic structure for applying behaviour change theories and concepts in the planning		There are nine steps in two stages: 1. Planning i. Social diagnosis: ask and answer key questions related to the health issue ii. Epidemiological diagnosis: create measurable, time-limited,	• Target population participates in each step of each phase[93] • Flexibility and scalability[117] • Evidence-based process and evaluability[117]	• Labour, time, and resource intensive[116] • Does not try to predict or explain relationships among factors associated with outcomes • Immediate action to address a

		and evaluating of health promotion activities.		health-related objectives iii. Behavioural and environmental diagnosis: identify key environmental and behavioural factors (sub-objectives) iv. Educational and ecological diagnosis: develop a unique plan to achieve each sub-objective from step 3 v. Administrative and policy assessment: assess capacity and resources available to implement programs and change policies so that step 4 sub-objectives can be met 2. Evaluation i. Implementation: draft and finalise program evaluation plan before program implementation	• Provision of a process for appropriate adaptation of evidence-based “best practices”[117]	health problem is not possible with this framework • Does not provide specifics on intervention development or methods in detail

				ii. Process evaluation: Monitor program to ensure fidelity; provide corrective feedback where necessary iii. Impact evaluation: Assess if the behavioural and environmental sub-objectives (step 3) were met iv. Outcome evaluation: Assess if the program had its intended public health impact		
RANAS	Mosler 2012[91] Contzen et al. 2015[118]	An easily applied method for measuring behavioral factors, assessing their influence on behavior, designing tailored strategies that change behavior and measuring the effectiveness of these.		There are four phases: 1. Identify possible behavioral factors 2. Measure the behavioral factors identified and determine those steering the behavior 3. Select corresponding behavior change techniques (BCTs) and develop appropriate behavior change strategies 4. Implement and evaluate the behavior change strategies.	• Focuses on changes that can be achieved by the households that are not dependent on help from outside e.g. governmental institutions[91]	• Does not apply to the meso- and macro-level, such as institutions, the economic or political system, or even changes in the environment[91] • Focus on psychosocial behavioral factors and does not fully incorporate contextual and environmental dimensions[119]

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RESEARCH PAPER COVER SHEET

PLEASE NOTE THAT A COVER SHEET MUST BE COMPLETED FOR EACH RESEARCH PAPER INCLUDED IN A THESIS.

SECTION A – Student Details

Student	Madeline Sands
Principal Supervisor	Dr. Robert Aunger
Thesis Title	Infection Control in Our Hands: Developing and Evaluating a Novel Intervention to Improve the Hand Hygiene Behaviour of Nurses in Acute Care Hospital Units in the US

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

**If yes, please attach evidence of retention. If no, or if the work is being included in its published format, please attach evidence of permission from the copyright holder (publisher or other author) to include this work.*

SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Public Health Reviews
Please list the paper's authors in the intended authorship order:	Madeline Sands Alexander Aiken Oliver Cummings Robert Aunger
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Madeline Sands made substantial contributions to the conception and design of the work; acquired, analysed, and interpreted the data; and drafted the manuscript.

Student Signature: [redacted] **Date:** 2 October 2019

Supervisor Signature: **Date:** 15 October 2019

CHAPTER 2: SYSTEMATIC REVIEW

The effect of behavioural interventions targeting hand hygiene practices among nurses in high-income hospital settings: A systematic review

ABSTRACT

Background: Hand hygiene is a critical behaviour for infection control but efforts to raise compliance among clinical professionals have met with mixed success. Clinical professionals in different roles respond differently to behavioural interventions, with the largest body of research focusing on nursing staff, and in particular, those working in high-income hospital settings. The aim of this systematic review was to identify the effectiveness of the behaviour change techniques utilised in recent hand hygiene interventions that seek to improve hand hygiene compliance among nurses in hospitals in high-income countries.

Methods: High-quality studies among nurses in high-income countries were surveyed from the scientific literature, following PRISMA guidelines, to identify which kinds of behaviour change mechanisms have been used to effectively increase hand hygiene compliance. Only seven studies met all inclusion criteria. A formal meta-analysis was not conducted due to the heterogeneity of the included studies. Instead, the review analysed studies in line with the Intervention Component Analysis approach to identify which differences in intervention characteristics appear to be important. Analysis proceeded in two steps: first, the Effective Practice and Organization of Care

Data Extraction Checklist was used to identify the study design and to describe the intervention, target population, setting, results, outcome measures, and analytic approach. The second step involved inferring the behavioural change techniques used in the complex study interventions. Following coding, logic models were then inferred for each study to identify the Theory of Change behind each intervention. These Theories of Change were then examined for suggestions as to which behaviour change techniques were likely to have been responsible for any effectiveness observed.

Results: *Goals and planning* (to achieve specific ends), *comparison of behaviour* (to peers or some ideal) and *feedback and monitoring* (observing and providing feedback about behaviour or outcomes) were the most frequently used behaviour change technique groupings used across studies and within interventions.

Conclusion: The complexity of the interventions used and lack of sufficient studies makes assignment of responsibility for behaviour change to specific behaviour change techniques difficult. Delivery channels and activities identified in the study Theories of Change were also highly individualized and so difficult to compare. However, we identified a temporal shift in types of techniques used in these recent studies on HH interventions, as compared with studies from prior to the review period. These newer interventions did not focus on providing access to alcohol-based hand rub or trying to solely encourage administrative support. Instead, they had nurses create goals and plan how to best facilitate HH, compared both individuals' and the group's behaviour to others, and focused on providing feedback.

INTRODUCTION

Hand Hygiene in the Healthcare Setting

Healthcare associated infections (HAIs) burden patients, increase the length of hospital stays, raise the costs incurred by patients and healthcare facilities, affect treatment, and can lead to mortality.[1-3] Adequate hand hygiene (HH) among healthcare workers (HCWs) is considered to be the simplest and most effective measure for preventing HAIs.[4] However, observed practice of recommended HH behaviours among HCWs suggests that rates of compliance are typically below 50%.[2, 5] There have been various initiatives seeking to address these low rates of hand hygiene compliance (HHC) over the past several decades with mixed results.[1] While many of these initiatives have been successful in producing short-term changes in compliance, the effects are typically small-to-moderate and sustained increased is low.[1, 2]

Many HH interventions introduced in hospital-settings target multiple types of HCWs. However, rates of HHC have been shown to vary amongst the different healthcare professions; nurses have the highest compliance rates as compared to other HCWs.[5, 6] Research has even shown that HCWs can respond differently to the same intervention.[7, 8] These results suggest that a ”one-size-fits-all” strategy to hospital-wide education and quality improvement may not be the best strategy.[7] While interdisciplinary collaboration in hospital care is normative in current practice,[9] it is nurses who have the most direct physical contact with patients within the healthcare delivery team.[10] As nurses are on the frontline of patient care, improving their HH behaviour and thus increasing HHC rates has a relatively large impact on reducing transmission and preventing HAIs. This review therefore concentrates on HH interventions designed specifically for nurses.

Categorising and Evaluating HH Interventions

HH is a complex behaviour influenced by varying combinations of individual, social, and environmental factors.[11] Multifaceted intervention strategies combining multiple components have been found to be more effective in addressing low compliance rates as compared to strategies focused on simple interventions.[2, 12] However, it can be difficult to assess which intervention components within multifaceted strategies contributed to changes in the observed behaviour and to what extent. Understanding how individual components have contributed to changes in HHC may support the development of more effective strategies.

In recent years, within the public health systematic review literature, there has been an increased focus on categorising and assessing interventions based on either the Theory of Change or behavioural frameworks used.[13-17] Two recent systematic reviews— *Huis et al.*[2] and *Srigley et al.*[18]— selected hospital-based HH interventions informed by behaviour change frameworks. Each review classified behaviour change interventions in different ways. *Huis* used *Abraham & Michie's* (2008)[19] behaviour change technique (BCT)[*] taxonomy (which has since been updated)[20] while *Srigley* categorized interventions based on psychological theories of behaviour change. Both of these reviews identified successful strategies toward changing HH behaviour and, in doing so, have emphasized the importance of understanding how these strategies worked.

[*] Behaviour change techniques (BCTs) are intervention mechanisms that target a specific determinant of a behaviour in order to trigger behaviour change. The application of a chosen BCT as part of a wider HH strategy is hypothesised to alter a specified behaviour determinant which in turn will change related behaviours. For example, watching videos promoting the importance of HH as part of a wider HH strategy is hypothesised to impact the nurse's knowledge of the importance of practicing HH which in turn will lead to an increase in HHC.

Objectively evaluating complex interventions is challenging,[21] and various approaches such as Qualitative Comparative Analysis (QCA) and Intervention Component Analysis (ICA) have been recently employed in systematic reviews to understand the mechanisms through which different interventions attempt to change behaviour.[17, 22, 23] Here, we have adopted components of the ICA approach and created logic models to categorise and analyse interventions targeted at nurses.

METHODS

We report our methods in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[24] This systematic review is not registered.

Search Strategy

Electronic searches were performed on three databases: MEDLINE, CINAHL, and EMBASE. The search strategy incorporated search terms related to:

1. hand hygiene and hand washing,
2. interventions, campaigns and initiatives,
3. compliance and adherence,
4. hospital and healthcare setting,
5. nurse and nursing

We also manually searched reference lists from five previous reviews for eligible studies: *Gould et al.* (2008),[25] *Erasmus et al.* (2010),[1] *Huis et al.* (2012),[2] *Schweizer et al.* (2013),[12] and *Srigley et al.* (2015).[18] The search was first performed in August 2016 and then in October 2019. Search strings are included in Appendix 2-1.

Eligibility and Inclusion Criteria

Only studies conducted in HICs[†] as per the World Bank's 2016 definition and published in English were considered. Studies conducted between January 2002—when the CDC in the United States issued guidelines that defined ABHR as the standard of care for HH practices in healthcare settings— and October 2019, were eligible for inclusion. In addition, only studies meeting all the following inclusion criteria were included in the review (Table 2-1):

1. the evaluated intervention targeted nurses and/or nursing students caring for patients in a hospital setting
2. the evaluated intervention focused on HH behaviours in a healthcare setting
3. the study clearly defined the intervention and had a control or comparison group; eligible study designs included cohort, case-control, controlled before-and-after, interrupted time series, cluster randomised trial, and randomised controlled trial
4. the study reported HHC rates as an outcome; rates could be measured by either direct observation or through indirect methods like calculating product usage or using an electronic monitoring system that counts sink or ABHR dispenser use
5. the study received a methodological quality score of three or greater

The studies were empirically rated on their level of quality using a rating system developed by *Anderson and Sharpe* (1991)[26] and adapted by *Huis et al.* (2012)[2] to evaluate the impact of interventions on either HCWs or patients (Table 2-2). Studies

[†] We restricted our review to hospitals in high-income countries. The conditions of hospitals in low-income countries can be different than those to high-income countries, especially with respect to infection control measures and the infrastructure required for HH.

scoring less than three out of a possible seven points on the scale were considered of poor quality and excluded.

Article Selection

Two reviewers independently screened the titles and abstracts of citations generated by the electronic and manual searches to assess their eligibility for consideration. AW and MHS reviewed the citations in the initial search in August 2016 and JS and MHS reviewed the citations in the updated search in October 2019. Any differences in selection were first resolved by consensus or, where this was not possible, by adjudication by a third reviewer (RA). Next, two reviewers (RA and MHS) independently reviewed the full-text articles to determine if the methodological quality criteria were met. The full text articles were then reviewed for inclusion by one reviewer (MHS).

Data Extraction, Synthesis, and Analysis

A formal meta-analysis was not conducted due to the heterogeneity of the included studies across various parameters, including: content and delivery of the interventions, the moments during care for when HH performance was measured, and the methods for measuring the outcome variable and thus assessing compliance. Instead, the review combined qualitative and quantitative methods to analyse studies following the model of Intervention Component Analysis.[23] The ICA approach allows for the complete analysis of the individual components of each intervention without formal standard statistical technique to test the hypotheses. However, we only managed to implement certain aspects of the ICA approach. For example, one departure from the standard procedure was the filtering of studies based on the quality of their research design, which is standard practice in quantitative systematic reviews. The ICA approach does not involve the evaluation of the methodological quality of studies. In addition, we created logic models for each intervention using BCTs to categorize and analyse the intervention components. The ICA approach sidesteps the creation of logic models. By combining logic models and components of ICA we adopted a comprehensive approach that facilitated the articulation of the theoretical basis of the interventions and identification of BCTs. In this way, the present review combined quantitative and qualitative methods of analysis.

We examined how the interventions differed from one another using a two-step approach. The first step used the Effective Practice and Organization of Care (EPOC) Data Extraction Checklist to identify the following characteristics in each study: a) study design, b) description of intervention, c) target population, d) setting, e) results, f) outcome measures, and g) analysis. The second step involved inferring the BCTs, which informed the various activities in these complex interventions. We used the taxonomy of BCTs developed by *Michie et al*. (2013)[27] due to its standardised labels, clear definitions, and examples; also, this taxonomy is widely used among researchers, practitioners, and policy-makers. The taxonomy includes 93 BCTs clustered into the following 16 groups:

1. goals and planning
2. feedback and monitoring
3. social support
4. shaping knowledge
5. natural consequences
6. comparison of behavior
7. associations

8. repetition and substitution
9. comparison of outcomes
10. reward and threat
11. regulation
12. antecedents
13. identity
14. scheduled consequences
15. self-belief
16. covert learning

A selection of the most relevant BCTs regarding HHC is provided in Appendix 2-2. Two reviewers (MHS and RA) used the taxonomy to independently code the various intervention components in each study. Differences in coding were resolved by consensus. Following the coding, logic models were then inferred for each study by incorporating the nominated BCTs, activities and modes of delivery; this guided the development of the Theory of Change behind each intervention, which is based on the approaches used by *Govender et al.(*2015)[13] and *Kahwati et al.* (2016)[17]. To ensure that the models accurately reflected the Theory of Change hypothesised by the studies, the authors of each study were contacted and asked to review the logic model. Only *Stock* verified the Theory of Change; the other authors did not respond. Frequencies with which the BCT categories were implicated in the studies were then calculated and compared.

RESULTS

A total of 1214 articles were identified across three databases and from reference lists of previous reviews (Figure 2-1). After duplicates were removed, 513 records were screened of which 477 were excluded due to not being a journal article, not being conducted in a HIC, or not evaluating HHC rates as the main outcome. The full text of the remaining 36 articles were assessed for eligibility resulting in a total of 7 studies (10 articles)[‡] that met the inclusion criteria.[28-35] The three main reasons for exclusion of the other 26 articles were: 1) that the study did not evaluate an intervention (n=6), 2) the target population of the intervention included other HCWs in addition to nurses and did not allow for separate analysis (n=17), or 3) the methodological quality assessment score was below three (n=3).

Study Characteristics

The seven studies included in this review are as follows:

- *Fox et al.*, 2015[31]
- *Erasmus et al.*, 2010[28]
- *Stock et al.*, 2015[29]
- *Harne-Britner et al.*, 2011[30]
- *Huis et al.*, 2012[32, 33, 36]
- *Boyce et al.*, 2019[34]
- *Stella et al.*, 2019[35]

Characteristics of the included studies are presented in Table 2-3.

Study Descriptions

Three of the studies only evaluated one intervention while the other four studies reported on two or more interventions (Figure 2-2). The studies and their

[‡] There were a total of 10 articles included, however three of the articles described the same intervention (Huis et al.).

intervention(s) are described below, based on the authors' own descriptions. The Theories of Change (see Appendix 2-4) reflect the descriptions provided here.

Fox et al. (2015)[31] performed a pre-experimental (post-test only with a comparison group) study design comparing nurses' HHC rates and the rates of two common HAIs— central line-associated bloodstream infections (CLABSI) and catheter-associated urinary tract infection (CAUTI)— before and during the intervention. The study was conducted in a cardiovascular medical ICU in a 498-bed community hospital in the United States from December 2009 to February 2012. The study involved three phases: 1) a comparison 12-month period before protocol implementation, 2) a 10-week protocol-training period, and 3) a 12-month period during the protocol implementation. The innovative characteristic of this intervention was focusing attention on the patient's HH rather than on the HCW's HH practices. Nurses were required to wash the patient's hands three times a day: at 8am, 2pm, and 8pm. There was a 10-week protocol phase-in period in which training of the ICU staff was led by the study team. Nursing staff received verbal instructions and were monitored for proper return demonstration of the protocol in efforts to improve consistency of HH technique. In addition, the electronic medical record (EMR) triggered timely reminders to perform the patient hand hygiene protocol (PHHP). Nurses documented their own PHHP adherence on the EMR. During the execution phase, the primary ICU nurse introduced the PHHP to each patient and/or patient's family; a document explaining the protocol was added to each ICU patient's admission packet.

Nurses' HHC when entering patients' rooms increased from 35% to 66% during the study. Although there was an improvement, the difference was deemed not statistically significant. Nurses' HHC when exiting the patient's room also improved with an increase from 66% to 79%, but the results were not as remarkable.

Harne-Britner et al. (2011)[30] conducted a quasi-experimental (controlled before-after) study conducted among registered nurses and patient care assistants from three medical-surgical units at an urban hospital in the United States. It was conducted from April to October 2005. Both HHC and unit HAI rates were measured, with HH observations taken each month for 6 months (May to October 2005). The study was Participants in the control group received HH education by completing a self-study module on handwashing. The intervention groups completed the same module but also received positive reinforcement (a sticker-reward system that included individual and unit rewards) or additional information on the risks on HH non-compliance. These were grounded in Control Theory, Social Cognitive Theory, Behaviourist Theory, and Field Theory. These two interventions were evaluated against the standard minimal intervention comparator group, which received basic HH education via a self-study module. This study was therefore considered to be assessing three different interventions.

After one month of the intervention, the HHC among the positive reinforcement group increased by 15.5% (χ^2=4.27, P=0.039), but decreased in the risk of nonadherence group (6.4% decline) and the control group (3.2% decline). While the positive reinforcement intervention initially improved HHC, this effect was not sustained throughout the study. By the sixth month, there were no significant differences in HHC or HAI rates between the three groups. *Harne-Britner* concluded that both the education-alone and the education-paired-with-negative-behaviour interventions did not result in sustained improvement of HHC. However, the peer-recognition and unit-reward programs paired with education were effective in producing an immediate increase in HHC rates; *Harne-Britner* argued that these approached could be effective in promoting long-term HHC.

Stock et al. (2016)[29] assessed the feasibility of an innovative hands-on training session aimed at improving HHC through a before-after controlled cohort trial. The study was conducted from October 2012 to March 2014 in a large university hospital in Germany with 50 trained nurses from three medical and medical-surgical units (gynaecology, neurology, and nephrology). HHC rates were measured, with a baseline covering a 12-week span pre-intervention and follow-up covering a 12-week span post-intervention. Content and form of the educational intervention were developed based on the German Institute for Hygiene and Infection Control's current guidelines and the objective structured clinical examination (OSCE).[§] The hands-on training was organized into four separate parts, which were delivered over one and half days of consecutive training. The first part focused on providing the research team with a baseline assessment of the participants' hygiene skills while also giving participants the chance to reflect on their own hygiene and communication skills. Part two involved a learning session on communication skills related to promoting hygiene at the workplace. The session featured lectures, role-play, reflection, evaluation, quality management in hospital hygiene, and various methods to address barriers to hygiene when communication with peers and superiors. The third part centred on combining the theoretical with the practical in the form of simulation training. Participants practiced hygiene skills in different situations under the supervision of the infection control nurse. In the fourth and final part, the initial assessment was repeated to evaluate improvements in hygiene skills.

Overall HHC rates increased from 64.3% before the training to 79.2% after the training ($P \leq 0.0001$). *Stock* identified two biases that could have attributed to the high

[§] The OSCE is an exam where healthcare students examine and assess either real or simulated patients and are marked on their clinical skills performances.

compliance rates: 1) the Hawthorne effect (participants increased HHC because they were aware that they were being monitored) and 2) self-selection bias introduced by the "opt-in" design of the study. Despite the acknowledged possible biases, *Stock* concluded that monitoring, feedback, and implementation of teaching 'on the job' are effective tools in increasing HHC.

Erasmus et al. (2010) [28] explored the practicality and effects of action planning on HH behaviour of nurses in an ICU and surgical unit of a university teaching hospital in the Netherlands. This work was intended as a pilot study. A pre-post-test design, using the Health Action Process Approach,[37] was conducted from March to August 2008. HHC rates were measured at baseline and then at three-weeks post-intervention. The intervention consisted of a structured interview of around 30 minutes that covered the importance of HH, rated self-compliance, preferred methods of HH, and the possible barriers encountered in daily practice. Individualised action plans for performing HH were then made. In addition to action planning, participants had to anticipate and plan alternatives for moments when the situation did not lend itself to the facilitation of HH. No feedback was given regarding the correctness or quality of the participants' action plans.

HHC rates increased from 9.3% at baseline to 25.4% post intervention ($P<0.001$). Nurses were 3.3 times more likely to perform HH (Odds Ratio [OR]: 3,3; confidence interval [CI]: 1.7-6.5]) after the intervention. *Erasmus* acknowledged numerous limitations of the study such as the small number of participants and the short time span between intervention and follow-up. Although considered a pilot study, *Erasmus* argues that action planning could feasibly be used as a change strategy through bridging the intention-behaviour gap and thus leading to improved HHC in practice.

Yet, *Erasmus* recognizes that action planning is unlikely to have sufficient effects as a single intervention (the overall shift in compliance from 10% to 25% was far too low), and as such should be part of a multiple component intervention that addresses individual, social, environmental, and planning variables.

Huis et al. (2013) [32, 33, 36] tested whether a social cognitive theory-based team and leaders-directed strategy would be more effective in increasing HHC rates in nurses than a literature-based state-of-the-art strategy. A cluster randomised controlled trial was conducted between September 2008 and November 2009 in 67 nursing units of three hospitals in the Netherlands. Baseline data were collected right before intervention implementation. Interventions were delivered over a period of six months. Follow-up measurements were recorded directly after the strategy delivery and then at six months. The control arm received the 'state-of-the-art' strategy, which included: a) education for improving relevant knowledge and skills, b) reminders for supporting the actual performance of HH, c) feedback to provide insight into current behaviour and to reinforce improved behaviour, and d) providing for adequate products and facilities. The team and leaders-directed strategy included all elements of the 'state-of-the-art' strategy (a-d) in addition to: e) gaining active commitment and initiative of unit management, f) modelling by informal leaders at the unit, and g) setting norms and targets within the team. This was therefore considered as two separate interventions.

The HHC rates of the state-of-the-art group increased from 23% to 42% in the short term and then to 46% in the long run. The HHC in the team and leaders-directed group improved from 20% to 53% in the short term and remained at 53% in the long term. The difference between both strategies showed an Odds Ratio of 1.64 (95% CI 1.33-2.02; p<0.001) in favour of the team and leaders-directed strategy. *Huis* emphasize that their results support various behavioural science theories, which hold that social influence, team effectiveness, role modelling, and leadership are necessary to successfully change behaviour.

Boyce et al. (2019)[34] performed a retrospective, nonrandomised, observational, quasi-experimental study in a single 93-bed non-profit hospital in the United States from August 2015 through January 2018. The study evaluated the installation of an automated HH monitoring system (AHMS) and three defined interventions: 1) a Frontline ownership (FLO) initiative, 2) support by hospital leadership, and 3) implementation of a Toyota Kata methodology. The 'FLO initiative' involved an expert visiting the hospital on three separate occasions to assist in implementing FLO. The 'support by hospital leadership' intervention consisted of the hospital leadership sending a delegate to another hospital to learn about their successful multimodal HH campaign and to discuss methods for analysing AHHMS data and incorporating additional promotional activities. The third intervention, which adopted aspects of the Toyota Kata performance improvement methodology, encompassed mandatory trainings, staff members wearing a "sheriff" badge and reminding personnel to perform HH, daily reportings of HH rates during shift huddles, and coaching of HCWs when compliance rates decreased. The interventions were staggered across various hospital units.

Boyce found that installation of the AHHMS without supplementary activities did not yield sustained improvement in HHC rates. However, implementation of the three interventions resulted in a statistically significant 85% increase in HH performance rates ($P < .0001$). *Boyce* also looked at HAI rates and observed that the incidence density of non–C. difficile HAIs decreased by 56% (P = .0841), while C. difficile infections increased by 60% (P = .0533) driven by 2 of the 4 study units.

Stella et al. (2019)[35] studied the effect of two visual cues on HHC in a prospective, quasi-experimental study that utilised an interrupted time-series design. Intervention placards that depicted an image of eyes, a social norms message, or a control placard (image of mountains) were placed near soap and ABHR dispensers and alternated every 10 days. HH opportunities and compliance rates were assessed electronically over a 4-month study period. The preintervention baseline HHC rate was 70%. No statistically significant increase in HHC was observed as a result of either intervention.

BCTs Addressed

The HH intervention(s) from each study were broken down into their individual components and the BCTs utilised were coded accordingly (Table 2-4). Explanations for the coding of each study are given in Appendix 2-3 and the resulting Theories of Change are included in Appendix 2-4.

Every BCT grouping was used across all studies. However, the BCT groupings *goals and planning*, *feedback and monitoring*, *comparison of behaviour*, and *shaping knowledge* were the most commonly used among the majority of studies and were most frequently used within interventions (Table 2-5). As depicted in Figure 2-3, BCTs from all 16 groups were used by at least one study in our sample. The most widely used groupings across studies were *comparison of behaviour* (n=6 studies), *goals and planning* (n=5 studies), *feedback and monitoring* (n=5 studies), and *associations* (n=4 studies). When looking at BCTs across interventions, the BCT grouping that was most frequently used was *goals and planning,* which was coded 21 times across 6 studies, as seen in Figure 2-4. However, of the 21 coded components, 7 of those belonged to

Huis' team and leaders-directed strategy. The BCTs from other groupings that were more commonly used include: *feedback and monitoring* coded a total of 14 times across 9 interventions, *comparison of behaviour* coded 14 times across 8 interventions, and *shaping of knowledge* coded 12 times across 7 interventions.

These groupings were used in different ways. In regard to *comparison of behaviour*, *Stock* used these BCTs in the form of having nurses compare their own HH practices to the simulation training demonstrations, *Harne-Britner*'s positive reinforcement sticker system served as another way to compare behaviour, and *Stella's* social norm message placards prompted nurses to compare their behaviour to the HCWs on the placards. The g*oals and planning* grouping was used by *Erasmus*' in their action and coping planning activities, in *Boyce's* frontline ownership initiative where the hospital actively sought to create a solution for low HH rates, and in *Huis*' team and leaders-directed strategy which used analysis of the barriers and facilitators to HH in order to help nurses' with their own compliance. While *feedback and monitoring* was implemented in different ways, a common approach seen across interventions was reviewing HH rates with nurses during regularly scheduled meetings (as seen in *Harne-Britner's* positive reinforcement intervention, in both of *Huis'* interventions, and throughout *Boyce's* various strategies). The one grouping that consisted of the same BCT utilised across all studies and within interventions was *knowledge shaping*, in which instruction on how to perform HH was provided.

DISCUSSION

This review found that the BCT groupings *goals and planning*, *feedback and monitoring*, *comparison of behaviour*, and *shaping knowledge* were commonly utilised across a majority of studies. Moreover, BCTs from these groupings were also the most frequently used within the interventions. It should be noted that even though each BCT groupings was utilised across all studies, and while some groupings were significantly used, the actual techniques employed were limited. There were many techniques within each grouping that had not been addressed. For example, the *knowledge shaping* grouping is comprised of four techniques, yet all studies only incorporated the technique on instruction of behaviour (BCT 4.1: instruction on how to perform a behaviour). Thus, the relatively narrow range of actual techniques used within each grouping suggest that new campaigns could look to other, unused forms of promotion to achieve sustained improvements in HHC.

The three studies that produced statistically significant increases in HHC rates were *Stock, Huis,* and each of *Boyce's* strategies sans the initial AHHMS approach. The four BCT categories common amongst these three studies included *comparison of behaviour*, *shaping of knowledge*, *feedback and monitoring*, and *goals and planning* (although this last BCT grouping was only present in *Huis'* team and leaders-directed intervention).

These three studies were also among those that incorporated the most BCTs in each of their interventions. There has been discussion in the literature about the association between number of BCTs included and the effect on HHC rates. One review observed that the effect size of HH improvement increased when more BCTs were addressed;[2] another review did not see such a relationship between increase in effect size and number of BCTs included.[12] In this review, the three studies found to be associated with increased HHC each included more than five BCTs.

Unfortunately, due to the small number of studies which matched our inclusion criteria, the overlap between BCTs used in both effective and non-effective interventions, the small number of studies demonstrating a significant outcome, and the diversity of conditions of delivery and measurement, it simply isn't possible to identify which BCTs are associated with a higher probability of improving nurse HHC.

The present analysis, however, does expand upon what previous reviews, conducted between 2002 and 2012, found. Those studies identified successful HH interventions as multifaceted approaches that bundle education, reminders, feedback, and in some cases access to ABHR and the inclusion of administrative support. [2, 12] This review, looking at publications between 2002 and 2019, identified a shift in the components incorporated in recent HH interventions. While most of the reviewed interventions included the conventional components of education, reminders, and feedback, many of these interventions included two additional components that had previously been underutilized: in particular, *comparison of behaviour* both at the individual and hospital unit level and *goal setting* for setting goals to reach certain HHC rates and creating plans to reach such goals. The comparison of behaviour activities, which are now being included in these interventions, draws attention to others' performance, prompt nurses to imitate a certain behaviour, and highlight the social acceptance of HH. By having nurses devise and work towards a HH goal, the nurses become involved in a greater initiative—that they have decided upon— that establishes an expectation of the post-intervention outcome. Affiliation and self-empowerment serve as motivators for increasing HH practice. This shift in intervention components could be attributed to the date of publication of the considered research papers. Our inclusion criteria during the study selection process resulted in a predominance of studies published within the past ten years. In the present day, almost all hospitals in the United States and Europe provide ABHR at the point of patient care.[5, 38, 39] Ensuring that ABHR is readily accessible is no longer a main focus of current HH interventions in HIC hospital settings.

Limitations

Several limitations must be acknowledged regarding our analytic approach, search criteria, sample size, determining of effectiveness, and the inherit bias and difficulties that arise in coding.

Eligibility and Inclusion Criteria

In searching for articles, we were limited by the language and location of studies. Only papers in English were included due to the authors' own linguistic capacities. Thus, potential articles written in other languages were overlooked. Also, by only considering studies conducted in HIC, we excluded potential studies from low- to middle-income countries in highly resourced hospitals with infrastructure comparable to that in HIC.

Small Number of Papers

A rating system was used to evaluate relative methodological quality. Due to the lack of moderate to high-quality HH improvement studies, the review only considered seven studies. This review provides insight even if it reflects only a small number of papers because conclusions drawn from analysis of these papers are well founded as compared to papers of lower methodological quality.

Determining Effectiveness

We were unable to calculate effectiveness for most of the studies due to three main reasons: 1) not every study had a control group, 2) the studies defined HH opportunities in different ways, and 3) measurements of HHC pre- and post-intervention were taken at different times for each study. By comparing the effectiveness or relative differences for each intervention, we would have been able to determine if a relationship existed between effectiveness and number of BCTs used. The limitations mentioned above are a few examples of methodological weaknesses. In fact, multiple systematic reviews have recognized that there are severe design limitations in various HH studies.[2, 12, 25, 40]

CONCLUSION

The purpose of this review was to identify the mechanisms, and the corresponding BCTs used, by which recent HH interventions sought to improve HH behaviour amongst nursing personnel. We used Intervention Component Analysis to guide our processes and analytic strategy. The specific improvement activities for each intervention were identified and classified using *Michie's* BCTs taxonomy. This review underscores the importance of truly understanding how and why a change in behaviour—such as an increase in HH practice— is expected to happen in the particular context. Many studies cite behavioural frameworks yet fail to explain how the frameworks were operationalized and which BCTs were utilized. It can be argued that the real pitfall in these sorts of studies comes from the misunderstanding and mischaracterisation of hand hygiene behaviour. HH is a repetitive, automatic behaviour that is habit-forming.[18, 41] However, many studies create interventions that treat HH as if it were a deliberative action rather than a spontaneous behaviour involving non-thoughtful responses that are shaped by the behaviour setting. It is simply not enough for interventions to be grounded in behaviour change theory; interventions must employ behaviour change theories and utilise BCTs that are appropriate for the type of behaviour at hand.[18]

Previous reviews have indicated that successful HH interventions are multifaceted approaches that bundle education, reminders, feedback, and in some cases access to ABHR and the inclusion of administrative support. We identified a shift in types of techniques used in these more recent studies on HH interventions, as compared with studies from prior to the review period. These newer interventions did not focus on providing access to ABHR or trying to solely encourage administrative support. Instead, they had nurses create goals and plan how to best facilitate HH, compared both individuals' and the group's behaviour to others, and focused on providing feedback.

It has been difficult to draw inferences from complex interventions as to which aspects of the intervention were effective in creating the observed behaviour change, due to a number of limitations in the current literature. However, analysing interventions based on the BCTs employed offers insight into how the proposed mechanisms may have succeeded or failed in changing behaviour. We recommend that additional reviews be conducted in this manner once additional studies have been published.

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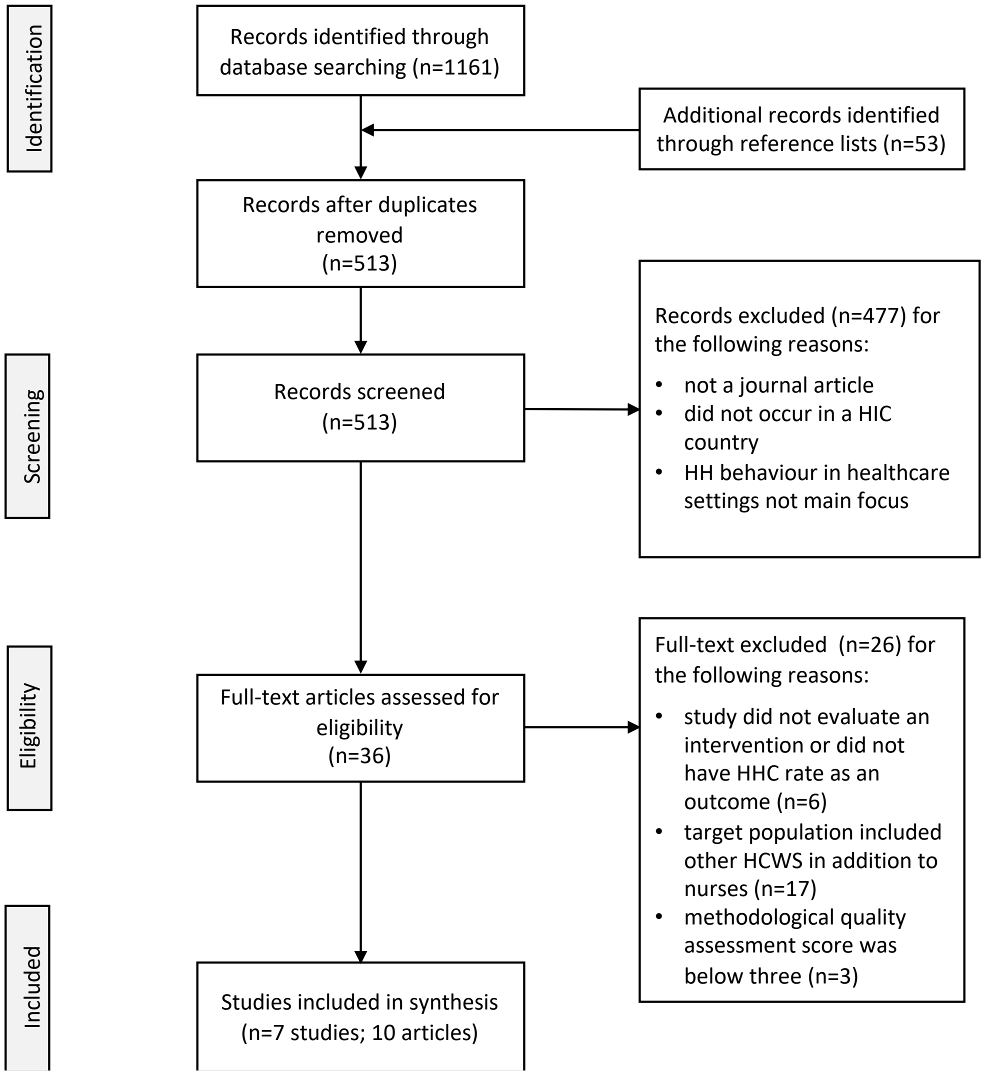
FIGURES

Figure 2-1: Flow diagram for study selection



The flow of information through the different phases of the systematic review are depicted including the number of records identified and then number included and excluded.

Figure 2-2: Summary of the studies included in the review

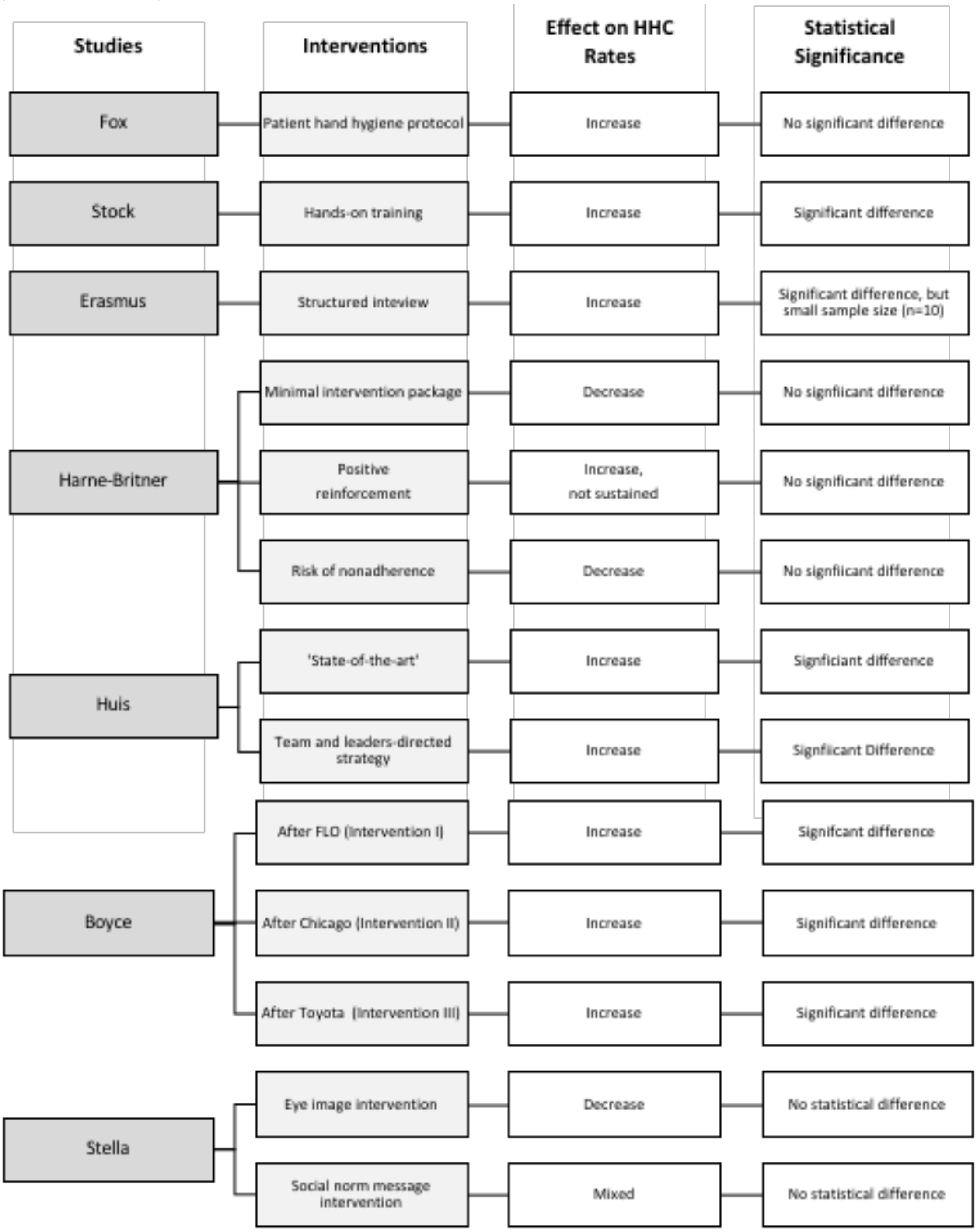


Figure 2- 3: BCT groupings across studies

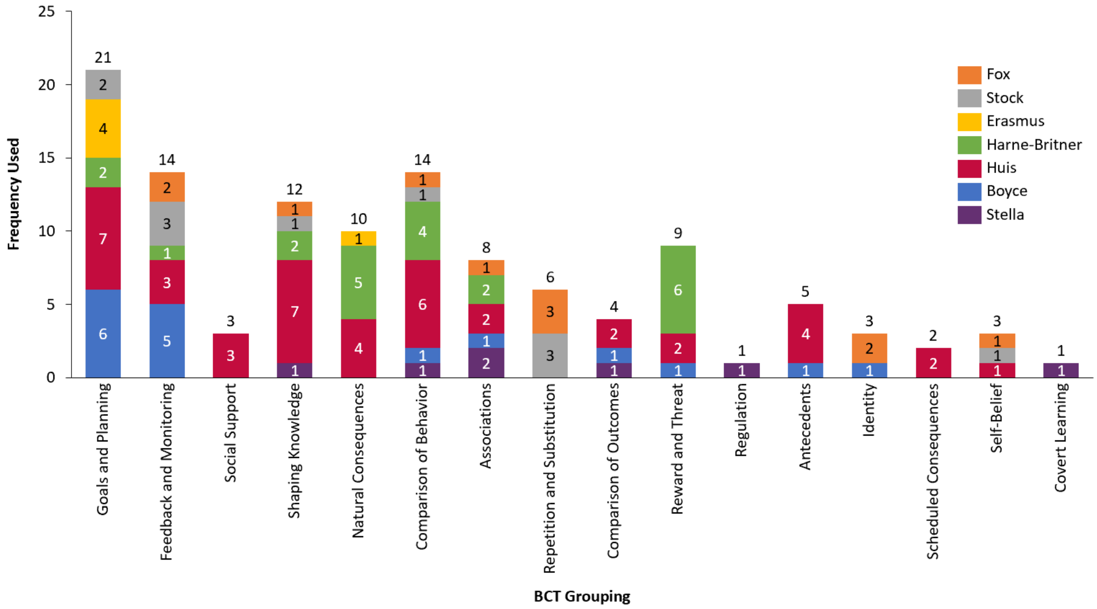
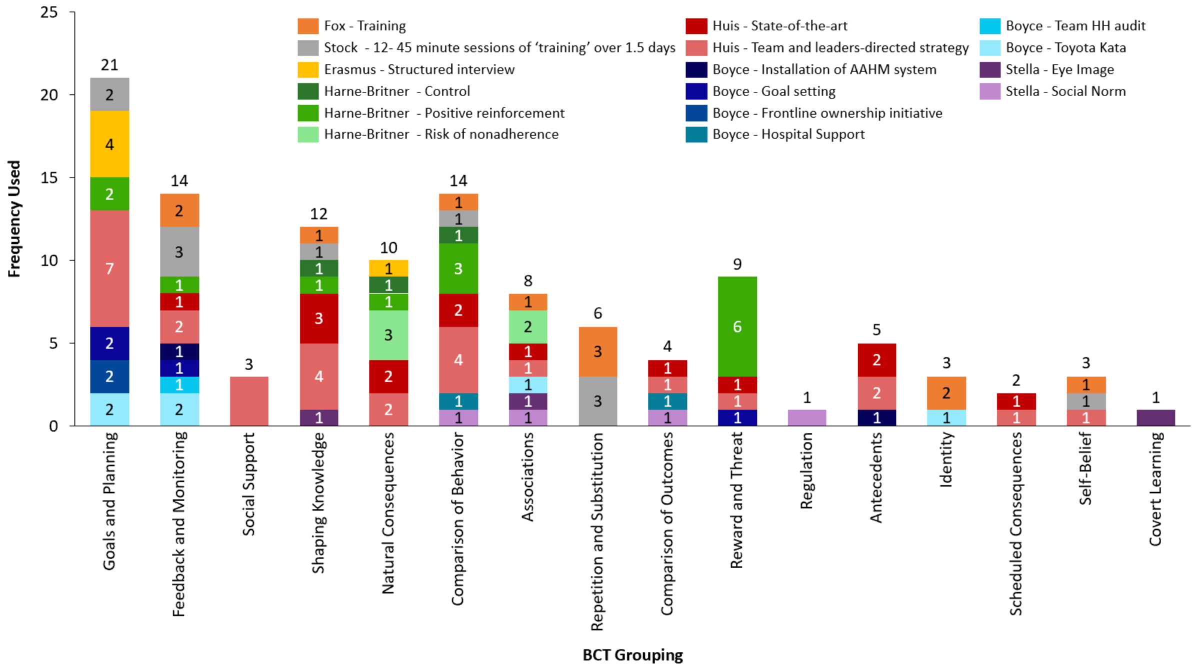


Figure 2- 4: BCT groupings across interventions



TABLES

Table 2- 1: Search criteria

	Inclusion	Exclusion
Date of Publication	1 January 2002-22 October 2019	Before 1 January 2002 After October 2019
Location or Context	Healthcare environments (e.g. ICU, medical wards, surgical units, inpatient units, entire facility) in high income countries	All other settings; low/middle income countries
Intervention	Various forms of HH interventions	
Outcome	Measurements of observed improvement in HHC	Studies that do not measure improvement in HHC
Study Design	Experimental: randomized-controlled trial (RCT) and non-RCT Experimental or quasi-experimental: pre-and-post intervention design with a control group; pre-and-post intervention design without a control group	Any other publications (e.g. outbreak reports, editorials)
Target Population	Nursing staff; nursing student	Any other HCW

Table 2-2: Methodological quality rating

Design of Study	
Experimental: randomized controlled trial (RCT), random allocation; case-controlled trial (CCT), quasi-random allocation; three data collection points before and after the intervention	1
Quasi-experimental: controlled before-and-after study; comparable control sites	1
Quasi-experimental: non-equivalent control sites	0
Single group before-and-after tests with baseline measurements	0
Content	
Intervention is clearly described	1
Sample size	
An *n* per group sufficient to detect a significant effect ($p<0.05$) with a power of 0.80 or reported calculation of power	1
An *n* per group insufficient to detect a significant effect ($p<0.05$) with a power of 0.80 or no reported calculation of power	0
Validity and reliability of instruments	
Unobtrusive observations, procedure described	2
Unobtrusive observations, procedure not described	1
Obtrusive observations, procedure described	1
Obtrusive observations, procedure not described	0
Test statistics	
Test statistics are described	1
Significance	
P value or confidence interval is given	1

Table 2-3: Study characteristics

Characteristic	References
Setting	
Intensive care unit (ICU)	Fox; Erasmus; Huis; Boyce
Medical unit	Stock; Huis
Surgical unit	Erasmus; Huis
Mixed medical-surgical unit	Stock; Harne-Britner; Boyce; Stella
Paediatric unit	Huis
Progressive care/step-down unit	Boyce; Stella
Sample Type (HCWs)	
Nurses only	Erasmus; Fox; Stock; Huis; Boyce
Nurses and nursing assistants	Harne-Britner; Stella
Sample Size (HCWs)	
<20	Erasmus
20-40	---
41-60	Stock
>60	Harne-Britner; Huis; Stella
Unknown	Fox; Boyce
Sample Size (Observations)	
<100	
100-500	Erasmus; Harne-Britner
501-1500	Stock
1501-2500	---
2501-5000	---
>5000	Huis; Boyce; Stella
Unknown	Fox
Behavioural Frameworks, Theories, and Approaches	
Behaviourist Theory	Harne-Britner
Change Theory	Harne-Britner
Field Theory	Harne-Britner
Health Action Process Approach	Erasmus
Social Cognitive Theory	Harne-Britner; Huis
Social Norms (Behavioural Economics)	Stella
Toyota Kata	Boyce
Not listed	Fox, Stock
Study Design	
Before-after	Stock; Fox; Erasmus
Case-control	Harne-Britner
Cluster randomized control	Huis
Quasi-experimental w/ interrupted time series	Boyce; Stella
Assessment of Compliance	
Direct observation	Stock; Fox; Erasmus; Harne-Britner; Huis
Electronic monitoring system	Boyce; Stella
Length of Study	
>6 months	---
6 months	Erasmus; Stella
12 months	---
14 months	Huis
15 months	Fox
16 months	Stock
>2 years	Boyce
Country	
Europe	Stock; Erasmus; Huis
North America	Fox; Harne-Britner; Boyce; Stella
Assigned Methodological Quality Score	
6	Erasmus; Harne-Britner; Boyce; Stella
7	Fox; Huis; Stock

Table 2- 4: Distribution of BCT codes by study and intervention

BCTS		Studies															
		Fox	*Stock*	*Erasmus*	*Harne-Britner*			*Huis*		*Boyce*						*Stella*	
					Control	Positive reinforcement	Risk of nonadherence	State-of-the-art	Team and leaders-directed strategy	Installation of AAHM system	Goal setting	Frontline ownership initiative	Hospital Support	Team HH audit	Toyota Kata	Eye Image	Social Norm
1.2	Problem solving		1	2					3			1					
1.3	Goal setting (outcome)					2					1						
1.4	Action planning			1					1			1					
1.6	Discrepancy between current behavior and goal		1	1					2						1		
1.7	Review outcome goal(s)										1						
1.9	Commitment								1						1		
2.2	Feedback on behaviour	1	1												1		
2.3	Self-monitoring of behaviour	1	1														
2.5	Monitoring of outcome(s) of behavior without feedback													1			
2.7	Feedback on outcome(s) of behavior		1			1		1	2	1	1				1		
3.2	Social support (practical)								3								
4.1	Instruction on how to perform the behavior	1	1		1	1		3	4							1	
5.1	Information about health consequences			1	1	1	2	2	2								
5.2	Salience of consequences						1										
6.1	Demonstration of the behavior	1	1		1	1		1	2								
6.2	Social comparison					1		1	1				1				1
6.3	Information about others' approval					1			1								
7.1	Prompts/cues	1					2	1	1						1	1	1
8.1	Behavioral practice/rehearsal	1	2														
8.3	Habit formation	1	1														
8.6	Generalisation of target behavior	1															
9.1	Credible source							1	1								1
9.3	Comparative imagining of future outcomes												1				
10.1	Material incentive (behavior)					2											
10.1	Material incentive (behavior)					2											
10.4	Social reward					1					1						
10.5	Social incentive					1											
10.6	Non-specific incentive							1	1								
10.8	Incentive (outcome)					2											
11.2	Reduce negative emotions																1
12.1	Restructuring the physical environment							1	1								
12.5	Adding objects to the environment							1	1	1							
13.1	Identification of self as role model														1		
13.2	Framing/reframing	1															
13.5	Identity associated with changed behavior	1															
14.6	Situation-specific reward							1	1								
15.2	Mental rehearsal of successful performance		1														
15.3	Focus on past success	1							1								
16.1	Imaginary punishment															1	

Table 2- 5: Distribution of BCT groupings by study and interventions

BCT Groupings	Studies															
	Fox	*Stock*	*Erasmus*	*Harne-Britner*			*Huis*		*Boyce*						*Stella*	
				Control	Positive reinforcement	Risk of nonadherence	State-of-the-art	Team and leaders-directed strategy	Installation of AAHM system	Goal setting	Frontline ownership initiative	Hospital Support	Team HH audit	Toyota Kata	Eye Image	Social Norm
Goals and Planning		2	4		2			7		2	2			2		
Feedback and Monitoring	2	3			1		1	2	1	1			1	2		
Social Support								3								
Shaping Knowledge	1	1		1	1		3	4							1	
Natural Consequences			1	1	1	3	2	2								
Comparison of Behavior	1	1		1	3		2	4				1				1
Associations	1					2	1	1						1	1	1
Repetition and Substitution	3	3														
Comparison of Outcomes							1	1				1				1
Reward and Threat					6		1	1		1						
Regulation																1
Antecedents							2	2	1							
Identity	2													1		
Scheduled Consequences							1	1								
Self-Belief	1	1						1								
Covert Learning															1	

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RESEARCH PAPER COVER SHEET

PLEASE NOTE THAT A COVER SHEET MUST BE COMPLETED FOR EACH RESEARCH PAPER INCLUDED IN A THESIS.

SECTION A – Student Details

Student	Madeline Sands
Principal Supervisor	Dr. Robert Aunger
Thesis Title	Infection Control in Our Hands: Developing and Evaluating a Novel Intervention to Improve the Hand Hygiene Behaviour of Nurses in Acute Care Hospital Units in the US

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

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SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Plos One
Please list the paper's authors in the intended authorship order:	Madeline Sands Robert Aunger
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Madeline Sands made substantial contributions to the conception and design of the formative research questionnaire; analysed and interpreted the data; and drafted the manuscript.

Student Signature: Madeline Sands **Date:** 5 October 2019

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Supervisor Signature: ______________________ **Date:** 15 October 2019

CHAPTER 3: FORMATIVE RESEARCH

Determinants of hand hygiene compliance among nurses in US hospitals: A formative research study

ABSTRACT

Background: Hand hygiene is the simplest and most effective measure for preventing healthcare-associated infections. Despite the simplicity of this procedure and advances made in infection control, hospital health care workers' compliance to hand hygiene recommendations is generally low. Nurses have the most frequent patient care interactions, and thus more opportunities to practice hand hygiene. As such, it is important to identify and understand determinants of nurses' reported compliance. Formative research was undertaken to assess the potential impact of several unexamined factors that could influence HH among nurses: professional role and status, social affiliation, social norms, and physical modifications to the work environment (as well as institutional factors such as safety climate).

Methods: A survey questionnaire was developed primarily to inform the creation of a behaviour change intervention. The survey looked at how these factors influence HH among nurses and sought to identify barriers and levers to hand hygiene. It was administered to a survey panel of acute care nurses, working in US hospitals, with a year or more of experience.

Results: Multivariate regression modelling suggested that reported hand hygiene compliance was most likely to be a function of a hospital management's communication openness, perceived performance by peers, increased interactions

with patients and other staff members, and the reduction in stress, busyness, and cognitive load associated with role performance.

Conclusion: A powerful, effective intervention on HH among nurses therefore could be directed at improving communication openness, considering the impact of perceived performance by peers, increasing interactions with patients and staff, and determining how to reduce the stress and cognitive load associated with role performance.

INTRODUCTION

Hand hygiene (HH) is the simplest and most effective measure for preventing healthcare-associated infections (HAIs).[1] Despite the simplicity of this procedure and advances made in infection control, hospital health care workers' compliance to hand hygiene recommendations is generally low.[2] Nurses have the most frequent patient care interactions, and thus more opportunities to practice HH.[3] As such, it is important to identify and understand determinants of nurses' reported compliance.

HH is a complex behaviour with a myriad of motivators and barriers.[1, 4] While the basic behavioural aspects surrounding HH practices in hospital settings have been widely researched, there remain gaps in the literature regarding effective psychological promotion of hand hygiene compliance (HHC).[4] Psychological frameworks have been shown to lead to behaviour change in a wide variety of contexts, especially in the behaviour of healthcare workers (HCWs).[5] Therefore, focusing on determinants of behaviour change and employing psychological behaviour change models can better inform HH improvement strategies.

Behaviour Centred Design (BCD) is a general approach to behaviour change that offers both a Theory of Change for behaviours in addition to a practical process for designing and evaluating interventions.[6] The BCD's Theory of Change incorporates concepts such as Reinforcement Learning Theory,[7] the evolution of behavioural control,[8] the evolved structure of human motivation,[9] and Behaviour Settings Theory. [6,10] The Behaviour Settings Theory explains the relationship between individuals and the environment—both physical and social.[10] Behaviour is a function of the setting within which it takes place. As such, *behaviour settings* are situations where people have learned what to expect from the environment and from other people's behaviours. Each setting has a purpose, a designated place, a set of objects, and a prescribed set of behaviours. Therefore, each person entering a setting expects others, who are also participants, to perform their designated roles.

BCD is associated with a checklist of factors that determine human behaviour, which can be used to direct empirical investigations prior to the design of public health interventions. This checklist includes environmental determinants such as the props and infrastructure that support performance of the behaviour, as well as the psychological characteristics and personal traits required.

The aim of this study was to use the BCD approach to identify determinants that impact the HHC of nurses in acute care hospital units. A combination of literature review and formative research were used to identify prospective strategies for a behaviour change intervention. We hypothesise that recognising what motivates and hinders a nurse from practicing HH will aid in the development of successful strategies seeking to improve nurses' HHC.

Background

Given the complexity of institutional settings for behaviour change, our data gathering strategy focussed on potentially important factors that have not yet been found to be significant. The literature search began with a background search to develop an understanding for the breadth of the body of literature. The iterative search process became more refined and developed as the review progressed. Once the volume and general scope of the HH field had been determined, parameters were set and search strings were developed [Appendix 3-1]. Search strings were developed for concepts encompassing behaviour change, hand hygiene compliance, healthcare workers, healthcare-associated infections, hand hygiene, and interventions. Medline, Web of Science, CINAHL, and Google Scholar databases were electronically searched selecting only for papers written in English. A total of 187 publications were identified this way; after filtering for papers published from January 2002- January 2015, there were 89 papers left to be reviewed. Additional papers and grey literature were identified by searching the references lists of the retrieved papers. We used the WHO's tables of factors (WHO Table I.2.1) as well as HH improvement interventions (WHO Table I.2.2) as a framework.[1]

Categorizing and Identifying Modifiable Factors Using BCD

The BCD Checklist itemises all the types of behavioural determinants identified by the BCD approach. Placing the factors from the literature known to influence HHC (Figure 3-1) into the BCD Checklist enabled us to see what categories of factors have potential for deeper investigation and could serve as the foundation for further research into HHC. This analysis showed that only a few of these categories have been investigated by intervention-based studies in the literature, and it is apparent that whole categories of factors have not yet been examined by the public health community. Types of potential factors that have been completely ignored thus far are listed without entries in Table 3-1. It should be noted that even some categories with entries below have not been fully investigated; additional factors could be identified and explored. If we restrict our attention to categories—either with or without entries—which can be readily changed by the types of mechanisms that are both acceptable and within the budget of an average hospital administration, we arrive at the following list of five categories: 1) *motivational psycholog*y, 2) *reactive psychology* (i.e. habit formation), 3) *modification of the relevant behaviour setting stage*, 4) *role change*, and *5) social norm manipulation*. These categories were the focus of this formative research.

Importance of this Formative Research

Formative research is a critical step in the development of health behaviour change interventions.[6, 11] The purpose of formative research is to assess individuals' beliefs, perceptions, behaviours, and the structure of the environment itself that may help or hinder program effectiveness. Typically, such research involves significant fieldwork in the relevant context. In the case of this study, the ability of the research team to obtain a comprehensive view of the factors associated with HHC was limited by the logistics of access to hospitals. It was neither possible to take nurses from the floor during their shift nor to engage in substantial observation of their practices without introducing bias into the data collection. Further, there are considerable variations and organization-specific intricacies when it comes to the institutional contexts of HHC, which needs to be understood and considered when creating interventions intended to be widely used. Thus, the decision was made to administer a survey to a large number of nurses, with a range of experiences, across the United States, gaining in breadth what was lacking in terms of depth in the investigation. This survey sought to assess the behavioural change potential of the factors identified by the analysis above.

METHODS

Sampling Procedure

An anonymous internet-based cross-sectional survey was administered between November to December 2015 by a global online sampling and digital data collection company called Dynata— formerly known as Research Now—to a survey panel of acute care nurses, working in various types of hospitals that are geographically distributed across the US, with at least a year or more of experience. There were 19,969 hospital nurses available to take the survey. With a confidence interval of 95% and a margin of error 5%, we calculated that we need a minimum of 377 completed surveys. Dynata screened and recruited participants, and it used an incentive scale based on set time increments. Incentive options allowed panellists to redeem from a range of gift cards, charitable contributions, and other products or services upon completing the survey.

Survey Design

The survey concentrated on the five unexamined but modifiable factors that are potential determinants of HHC: 1) motivation, 2) habit, 3) roles, 4) behaviour setting stage, and 5) norms. The survey questions, which drew upon various concepts and measurement tools from fields such as sociology and psychology, were designed to measure the degree to which these factors influence reported HHC. In doing so, a novel questionnaire was developed using techniques—such as vignettes and the self-reported habit index (SRHI)[12]— that have not been commonly or consistently used in HH questionnaires before. The movement of the respondent through the survey is depicted in Figure 3-2. The survey itself can be found in Appendix 3-2. The explanation of the theoretical underpinnings of the survey with their respective survey questions follow.

Role

The role of the nurses was explored through professional identity. Identities are the traits and characteristics, social relations, roles, and social group memberships that define an individual.[13] A professional identity is the sense of self that is associated with the enactment of a professional role.[14, 15] This identity gives members of a profession a definition of self-in-role and the goals, values, norms, and interaction patterns that are associated with their job.[16] This definition of identity is critical to how professionals interpret and behave in various work situations, with identity being both a product of situations and a determinant of behaviour within situations.[13,17] Identity is a) predicted to influence what individuals are motivated to do, b) encompasses how individuals think and makes sense of themselves and others, c) the actions the individuals take, and d) the individuals' feelings and abilities to control or regulate themselves.[18, 19]

By learning what qualities, skills, and traits nurses value, the perceived responsibilities of the professional role can be modified to include the responsibility of practicing HH. There is potential for HH to be integrated into the qualities that nurses perceive to be what a "good" or "ideal" nurse possesses. Respondents are therefore asked to choose five qualities or traits they wish they had exhibited more of during their most recent shift. The following qualities and traits were identified from the literature:[20-27]

Empathy	Reliability
Respect	Awareness
Confidence	Critical Thinking

Technical Competence	Stress Management
Leadership	Flexibility
Good Communication Skills	Physical Endurance
Mental Endurance	Patient Advocate
Friendliness	Resourcefulness
Patience	Responsiveness
Good judgment	Cooperativeness

Respondents were then asked to choose five statements they would least like to hear said about them as a nurse. The statements address undesirable qualities and traits or unfavourable working conditions identified in the literature.[20-27]

"I do not provide emotional support to my patients."
"I am unsure of myself as a nurse."
"I do not handle stress well."
"I am not as technically skilled as I should be."
"I am curt and short with the patients."
"I do not show leadership qualities."
"I do not communicate well with others."
"I neglected a patient."
"I am not dependable."
"I am not always aware of what is going on around me."
"I hurt a patient."
"I neglected a patient."
"I do not know my patient's wants or needs."
"I am not flexible and able to adapt."
"I am not a team player."

Norms

A social norm is a rule of behaviour that individuals conform to conditionally based on the beliefs that a) most people in their relevant network conform to this behaviour (this is referred to as an *empirical expectation*), b) they themselves believe that they should perform the behaviour (*normative personal belief*), and c) that most people in their relevant network believe they ought to conform to this behaviour as deviations from the norm could result in potential punishment (referred to as a *normative expectation*).[28] Social norms direct human action, however, norms are situationally contingent, meaning that a norm's salience and one's compliance to this norm are conditional upon the situation.[29] To understand and predict behaviour, it is important to know which social norms individuals find salient in particular contexts— that is, which norms are likely to be dependent on particular settings.[30, 31]

The normative system of nursing with respect to HH behaviour can be measured through learning about a) individual's preferences for 'proper' HH action, b) expectations of others' HH behaviour, and c) beliefs about the expectations others have of them in this regard. We sought to identify nurses' social norms regarding HH and whether the social norms have a causal influence on behaviour. Bicchieri (2014) devised a series of questions that diagnose, explain, and predict collective patterns of behaviour, which were adapted for the research purposes here.[28] This involves ascertaining several aspects of a normative system, including empirical expectations, normative beliefs, and normative expectations. To test empirical expectations, respondents were asked about their own beliefs regarding the prevalence of HH behaviour among their peers; respondents were asked to disclose how many nurses out of a group of ten would always practice HH at the various indications.

To test normative personal beliefs, respondents were also asked if they think they should practice HH at six various moments: 1) before entering a patient's room, 2) when exiting a patient's room, 3) after taking a patient's vitals, 4) after cleaning a patient's wound, 5) before charting in the nurse station, and 6) after talking with fellow nurses in the break room. Responses along a Likert scale from never to always were offered. To test normative expectations, respondents were asked if they believed that other nurses thought that they should use hand sanitizer or soap at the same moments provided above. Once again, the same Likert scale offered five response options.

Habit

Verplanken and Orbell (2003), drawing from previous literature, define habits "as learned sequences of acts that have become automatic responses to specific cues, and are functional in obtaining certain goals or end-states." [12] Habits have a history of repetition. The more frequently a behaviour is performed, the more likely it becomes habitual. The recurrence of a behaviour does not constitute habit, however. Habit is created "by frequently and satisfactorily pairing execution of an act in response to a specific cue" thus resulting in "a mental representation of an association between a goal and an action." [12] Encountering such a cue is expected to automatically trigger the habitual response. Thus, habits are psychological tendencies to respond automatically to environmental stimuli, acquired through repeated practice in particular contexts.[32, 33] Examples of contextual cues triggering habitual responses are the actions of automatically putting on a seatbelt (action) after getting into the car (contextual cue) or washing hands (action) after using the toilet (contextual cue).[34] Habit strength is a continuum. Habits that are considered to be of weak or moderate strength are performed with less frequency than strong habits.[35]

Participants were asked about the strength of their HH habits using the Self-Report Habit Index (SRHI) developed by Vernplanken et al. (1994).[36] The SRHI is a tool used either as a dependent variable or to determine or monitor habit strength without measuring behavioural frequency. It discriminates between behaviours varying in frequency and between daily vs. weekly habits. The index is based on features of habit: a) a history of repetition, b) automaticity, and c) expressing one's identity. Respondents answer the degree to which they felt the statement affected them using a five-point Likert scale (from strongly disagree to strongly agree). There is evidence that the SRHI can solicit accurate answers comparable to real behaviours.[37] The index in this case is phrased to ask respondents about practicing HH before entering and after exiting a patient's room.

Motivation

Motives are evolved psychological mechanisms that help individuals choose the appropriate goal-directed behavioural strategy in response to a situation.[38] An appropriate strategy would most likely lead to a satisfactory outcome in terms of the benefits accruing from that interaction with the environment.[9] A satisfactory outcome involves an experience that is rewarding—be it a sensory pleasure, a metabolic benefit for the body, or a change to one's place in the social world.

This research sought to identify what motivates people to practice HH. Thus, the objective of the motive questions was to determine if a person of higher status— such as a nurse manager or direct supervisor— or someone who is dependent on the nurse—such as a patient— is a likely motivator of HH. The BCD's motive mapping technique is used.[6] Motive mapping attempts to reduce psychological 'distance' by simulating the behavioural context using a narrative, and attempts to minimize the participant's reflection by focusing directly on the rewards from performance.

Participants responded to three scenarios asking about how feedback is likely to influence their own HH behaviour. In each of the scenarios, participants were told that they had taken a patient's vitals and immediately practiced HH upon exiting the room. At the end of each scenario, positive feedback regarding the practicing of HH was shared with the nurse by the nurse manger, a fellow nurse, and the patient. Respondents answered to what degree they felt this type of feedback (and from which people they received the feedback from) would most likely result in an increase in compliance in the future as compared to normal compliance. A five-point Likert scale measured responses.

Situational Constraints: Vignettes

Participants were asked to judge their likely compliance to HH in varying situations known as vignettes. Vignettes are closer to real-life judgment-making situations than relatively abstract questions that are typical of most surveys. Respondents were asked to reflect on whether they would practice HH in the following situations: 1) exiting a patient's room after taking the patient's vitals, 2) entering a patient's room before taking vitals, 3) exiting a patient's room after cleaning and bandaging the patient's diabetic foot wound, and 4) entering a patient's room before cleaning and bandaging the patient's foot wound. These situations were altered slightly for each follow-up question by introducing either a facilitator or a barrier to practicing HH, such as:

- Large patient load, which measures busyness
- Already wearing gloves, which measures the nurse's inclination to practice HH when wearing protective equipment
- Being observed by the infection prevention manager, which measures higher status social influence
- Being observed by a fellow nurse, which measures peer influence
- Trying to practice hand hygiene but the dispenser is empty, which measures perception of ease

- An interruption during patient care requiring the immediate assistance of the nurse, which measures interruption
- An emergency requiring CPR, which measures reaction to emergency

Through vignettes, we sought to determine the extent to which these factors impact HH behaviour. Responses were presented on a five-point Likert scale based on the likelihoods of behavioural response.

Institutional Factors: Safety Culture and Familiarity with Hand Hygiene

Nurse behaviour takes place within the context of hospital life. Hospitals can be considered institutions, which have an impact on the settings that occur within them. Therefore, this research sought to assess the *culture of safety* within the respondents' institutions. It has been widely accepted that the safety culture of a hospital affects HHC rates of its HCWs.[1, 39-41] To measure the safety culture of the hospitals where the respondents work, the research team selected and modified questions from the hospital survey on patient safety culture developed by the US Agency for Healthcare Research and Quality (AHRQ).[42] Questions were grouped according to the safety culture dimensions they were intended to measure. Groups included: rating overall perceptions of safety, frequency of event reporting, supervisor/manager expectations and actions, teamwork within units, closeness, communication openness, feedback and communication about error, non-punitive response to error, staffing, and hospital management support. Five-point Likert scales asking for agreement/disagreement and frequency were used.

Participants were also asked about their engagement and participation in past HH training and interventions, both as nursing students and as practicing professionals. In addition, participants were asked about their hospital's own HH programs. Questions were all phrased so that a yes/no response was appropriate.

Modification to Physical Setting

Finally, the research aimed to investigate various ways to disrupt a behaviour setting, specifically by identifying how the stage and arrangement of props of the setting surrounding the act of HH serve as constraints or opportunities to practicing HH. Respondents are presented with two photos—one of a hallway in a non-descript hospital and one of a patient's room— and then asked how both the hallway and the room could be altered to better facilitate HH. These questions allowed for open-ended responses.

Formatting the Survey

The survey was a self-administered online task. Each question was presented on its own webpage. Respondents were first asked a series of screener questions to determine if they were eligible: they had to be an acute care nurse, working in a US hospital, with a year or more of experience.

Those who were eligible were then presented with a series of photos related to the modification of the physical setting. These questions were asked first because the research team wanted responses that were not influenced by other questions in the survey. In addition, the photos served to ground the respondents in the survey by providing visual context. The vignettes immediately followed; the research team reasoned that the vignettes would likely solicit the most accurate responses about HH performance. As such, the vignettes were placed early in the survey so that the respondents were not biased or primed by subsequent specific queries. The professional identity questions were asked next as these questions centred on values.

Questions about norms were presented next and followed by questions on habit and motivation. The final questions focused on the safety culture of the hospital as well as the respondents’ history with HH interventions and programs.

Analysis of the Survey

Descriptive statistics were first used to characterize the sample. Univariate analyses were then conducted to determine which variables were associated with reported levels of HHC. Next, a multivariate regression of the variable of interest—*reported HH on exiting a patient room after taking vitals* — was conducted on *demographic*, *role*, *safety culture*, and *norm variables*. This variable of interest was chosen as it was asked in the form of a vignette, which is closer to real-life judgment-making situations and thus provided a better sense of compliance than asking respondents directly about their HHC. In addition, this specific vignette question was used as nurses are more likely to practice HH upon exiting a room, but less likely to practice HH after conducting a low-risk procedure.

An ordinary least squares regression of outcome on predictors was inappropriate for a model with this number of predictors and with only 500 observations; it would not have been possible to assign significance to many variables. Consequently, we performed a bidirectional stepwise procedure for building the model, using the Akaike Information Criterion (AIC) as the model-building criterion for adding or removing variables; any variable that, when removed, changed the model AIC by ≤ 1 was discarded.

RESULTS

Study Population

A total of 540 surveys were completed. Table 3-2 summarizes selected characteristics of the participants. The median age was 49 (range: 24-70). In a typical workday, more than two-thirds of the respondents (68%) reported spending 80% or more of their time performing direct patient care. Familiarity with HH practices was indicated by 459 (85%) of respondents, who reported that HH was emphasized during professional training to be a nurse. Furthermore, the clear majority of respondents (456, or 84%) had participated in a hospital-led hand hygiene initiative before.

Summary variables were standardized before analysis. Variables included *habit*, *safety culture*, *norms*, *motivation*, *role*, *hand hygiene familiarity*, and *demographics*. Means were taken across Likert scale questions per the prescribed groupings. Sums were calculated across yes/no variables and demographic variables were encoded with a binary number system.

Univariate Analysis

The results for each of the five main potential determinants of HHC have been provided in their respective tables and figures enumerated below. Major findings have been summarized for *norms*, *habit*, and *motives*. Additional figures are provided in Appendix 3-3 as detailed below.

Vignettes

The results for every question in this section of the survey are included in Table 3-3. The most salient findings were that nurses were more likely to practice HH upon exiting a patient's room than entering, and that when the procedure was perceived as being high-risk—such as cleaning and bandaging a wound—there was an increased likelihood of practicing HH. Most notably, 90.7% (n=490) of nurse respondents reported being likely to practice HH upon exiting a patient's room after cleaning and bandaging the diabetic foot wound.

Norms

The results for empirical expectations, normative personal beliefs, and normative expectations have been presented in Table 3-4. Regarding *empirical expectations*, respondents felt that most nurses practiced HH before entering a patient's room, when exiting a patient's room, after taking a patient's vitals, and after cleaning a patient's wound. Concerning *normative personal beliefs*, for each moment apart from charting or talking with colleagues, most respondents claimed that HH should always be practiced. Of the 540 respondents, 81.7% (n=441) of respondents said it should always be practiced before entering a patient's room, 90.4% (n=488) when exiting a patient's room, 75.6% (n=408) after taking patient's vitals, and 98.7% (n=533) after cleaning a patient's wound. With *normative expectations*, over 50% of respondents claimed that most other nurses always think that one should practice HH before entering a patient's room, when exiting a patient's room, after taking a patient's vitals, and after cleaning a patient's wound. Refer to figures in Appendix 3-3 for graphical representation of the results.

Habit

Respondents answered the SRHI about practicing HH before entering a patient's room and after exiting a patient's room. Responses were made on five-point Likert scales anchored by the terms strongly agree to strongly disagree and were coded such that high values indicated strong habits (1= strongly disagreeing and 5= strongly agreeing). The means of the questions were calculated, and these in turn became the habit strength scores. Regarding HH upon entering a room, 59.1% (n=319) of respondents had a score of 4.5 or over (Figure 3-3). In the case of exiting, 68.0% (n=367) of respondents had a habit strength score of 4.5 and over (Figure 3-4).

Motives

Regarding feedback, 50.7% (n=274) of participants indicated that receiving positive re-enforcement from a nurse manager would not impact their HH behaviour in the future. When receiving feedback from a peer, 55.4% (n=299) of participants did not think it would impact future HH behaviour. Feedback from patients resulted in 59.3% (n=320) of respondents saying that their future HH behaviour would be positively impacted. Results are listed in Table 3-5.

Safety Culture

The results for each question in this section of the survey are included in Table 3-6.

Multivariate Regression

Presented in Table 3-7 are the results from the bidirectional stepwise procedure. Included in the table are only the variables which met the selection criteria. Values are provided for the Estimate, Standard Error, T-value, and Pr(>|t|) coefficients derived from the model output using R-studio. Coefficients were assigned to each predictor; the sign on the coefficient (positive or negative) provides the direction of the effect. The coefficients are explained below:

- The coefficient Estimate gives the size of the effect for each independent (predictor) variable on the dependent variable (or variable of interest). The Estimate indicates how likely the variable is expected to increase when that independent variable increases by one while holding all the other independent variables constant. It should be noted that the Intercept is the expected value of the variable of interest when we consider the other variables in the dataset.

- The Standard Error is the average value that the coefficient estimates vary from the actual average of our interest variable.
- The t-value is the coefficient Estimate divided by its Standard Error. is from 0; the father from 0, the more likely we are to reject the null hypothesis.
- The Pr(>|t|) coefficient corresponds to the probability of observing a value equal to or greater than t; a small p-value (typically of 5% or less), indicates that the observed relationship between the predictor variable and the variable of interest is due to chance.

DISCUSSION

Univariate Analysis

Vignettes

The reported higher likelihood of practicing HH upon performing a high-risk procedure as compared to a low-risk procedure aligns with the literature which shows that HHC is greater when involving higher-risk tasks.[2, 43, 44] In addition, nurses reported being more likely to practice HH upon exiting a patient's room than entering, which is interpreted as nurses practicing HH as a form of self-protection.[44]

Role

Nurses work in close relationships with patients who are vulnerable and largely dependent on the nurse for care.[45] Nurses work with one another and on inter-professional healthcare teams to deliver care and provide support. Fagermoen's (1997) proposed theoretical model for professional identity of nurses maintains that nurses' perceptions of the 'professional self' focuses on both *other-oriented* and *self-*

oriented values.[45] *Other-oriented values* encompass the nurse's actions on behalf of the patient's well-being and the interactions with patients in providing care. *Self-oriented work values* include work performance and collaboration with other professionals. While *self-oriented work values* directly impact the self, these values also affect the care delivered. For instance, better stress management can lead to a nurse feeling more confident, capable, and in control, which can then lead to better care delivered.

When asked which values the participants wish they had exhibited more of during their last shift, the traits most widely selected were those of *self-oriented values* such as stress management, patience, good communication, and physical and mental endurance. These in turn impact *other-oriented values* to a degree since work performance directly influences the kind of care delivered. *Other-oriented values* are the foundation of nursing care and an integral part of the nurses' relationships with patients. Areas of improvement could be seen in how nurses engage in the work-setting and the actualization of the *other-oriented values*. When asked what the nurses would least like to hear said about them, the top responses were about the inadequacy in the delivery of care. This again demonstrates how integral *other-oriented values* are to the discipline of nursing.

It should be noted that nurses were asked about values in the general sense; these questions did not ask about the qualities and traits associated with the act of practicing HH. By not directly asking about perceptions of traits and values associated with HH, we were able to collect a general sense of what the respondents perceived to be an "ideal" nurse. This meant, however, that we had to extrapolate from our findings how HH could be integrated into the qualities that were perceived to be "good."

Norms

There was agreement amongst participants as to when to practice HH—upon entering and exiting a patients' room and after performing a procedure such as vitals or cleaning a wound. It is apparent that participants believed these to be norms, and believed others to hold the same norms in addition to conforming to these norms. This suggests that HH indications are well understood and agreed upon by nurses.

Habit

Our findings question the utility of self-report habit measures. The habit scores in this questionnaire were high and without variance. The SRHI— unlike most other survey tools that aim to measure habit— focuses on measuring automaticity of behaviour rather than frequency. Thus it is a self-report index that characterises habit as a subjective experience of automaticity. This leads to significant limitations regarding the SRHI as discussed in Gardner's (2014) literature review on the effects of the habit construct in health-related research. Gardner calls attention to the fact that: 1) self-reports of behaviour are prone to inaccuracy, 2) that the SRHI instrument does not actually measure cues, and 3) that some of the items are more consistent with frequency of action rather than automaticity.[46]

In addressing self-reported behaviour measurements, we believe that the SRHI tool used in this questionnaire may have been susceptible to respondents wanting to appear consistent or to provide socially desirable answers. While the SRHI instrument uses multiple items (incorporating various questions regarding the behaviour of HH) thus making it less vulnerable to such threats as compared to a single-item instrument, self-report of any kind has the potential to lead to inaccurate responses. Moreover, people cannot always reliably reflect on habits because habits can proceed outside of awareness.[34] Hagger et al. (2015) claim that the SRHI is problematic in that individuals are unlikely to have access or awareness of the cues and associated responses that give rise to habitual action.[47] In the case of this questionnaire, it may be unrealistic to expect the respondents to be attentive to actions undertaken with minimal deliberative input, which may be the action of practicing HH upon entering and exiting a patient's room. Some habitual actions may proceed less mindfully than others.[48]

Motives

Over half of participants indicated that receiving feedback from a patient or a colleague would likely lead to an increase in future HH action. There is evidence that HH behaviour of HCWs is positively influenced by the presence and proximity of peers.[49, 50] Regarding patients, patient involvement in supporting their own safety has been widely discussed.[51-53] Patient involvement in HH—such as praising HCWs for practicing HH or reminding HCWs to wash their hands— and its impact on HH behaviour has not been extensively studied,[53] but our results show that it would be acceptable to HCWs for patients to recognise nurses for practicing HH.

Multivariate Regression

The variable of interest (or the dependent variable) was the reported HHC upon exiting a patient's room after taking their vitals. This question had the most variance in responses. The regression analysis shows that reported HHC is a function of specific variables at all possible levels: the hospital, unit, and individual. At the hospital level, increased *openness of communication*—which was asked about in the safety culture portion of the survey— led to a higher reporting of HHC. There is evidence that features of a hospital's safety climate are related to how well standard precautions and safety practices, such as HH, are adhered to.[54-56] *Communication openness* is a component of a hospital's patient safety culture and is defined as the extent to which the staff freely speak up if they see something that may negatively affect a patient and/or question those with more authority.[40, 57] A core tenet behind *communication openness* is that all have a responsibility to speak out when certain actions, objects, or processes pose danger to the safety of the patient and others, and those who speak out should be able to do so without fear of being reprimanded. It could be surmised that those who are comfortable enough to speak out about threats to patient safety would also act on their own accord to protect patient safety by practicing HH at the proper indications.

At the unit level, the type of hospital unit played a role in the HHC reported— overall, participants who work in an emergency department reported lower HHC rates. This could be attributed to the fact that nurses must respond to various unpredictable situations that could be life-threatening to the patient, and the patient's need for immediate attention and care is put first before practicing HH. Practicing HH in an emergency could be perceived as dilatory. This could also be because the emergency department is an environment with a high density of invasive procedures that require glove usage, and there is evidence that glove usage is inversely correlated with adequate HH.[1, 58, 59]

An interesting finding was that nurses who indicated having a higher proportion of shift time allocated to interaction with patients and with fellow healthcare professionals reported higher HHC. More time spent with a patient could lead to more opportunities to practice HH and thus more events completed. Additionally, more time spent with other HCWs could result in a nurse feeling the ‘watching eyes’ effect. It could also result in the nurse bonding with the patient and is thus more cognisant of practicing HH to ensure the patient’s safety.

At the individual level, one’s personal ability to manage subjectively important aspects of the professional role— such as stress management, communication skills, and being confident in one’s self as a nurse—leads to increased reporting of HHC. All the individual-level variables in the analysis could be defined as *other-oriented* to a degree as presumably successful stress management can lead to providing better care. The significant individual variables show *other-oriented* values involving care and communication as being of highest professional importance to nurses, and this orientation fosters better HH.

It has been noted in the literature that poor working conditions, increased levels of stress, and insufficient communication have a direct negative impact on the quality of nursing and have severe consequences for patients.[60-63] In addition, low HHC can result from fatigue or burnout. As a nurses’ shift progresses, HHC declines towards the end of the shift.[64] Continuous long shifts can lead to nurse burnout which in turn has been associated with increased HAI levels.[65] Thus, nurses who feel in control, confident in their abilities, supported, and have lower stress levels can better focus on and execute safety procedures such as HH.

Limitations

Surveys administered to HCWs are relatively inexpensive and allow for HCWs to focus and reflect on their own practices. However, self-report of infection prevention can be flawed, especially as reported HH practices and actual HH practice can differ significantly.[56, 66, 67] In using vignettes, we may have reduced socially desirable responses by allowing participants to report their HH practice and the practices of others through the vignette character(s) and situations.[67, 68] This may have reduced the potential for disparity between reported and actual behaviour. Additionally, generalizability of the findings may be limited by certain characteristics of the sample, achieved through online data recruitment. This limitation was addressed by administering the survey online, which allowed for us to collect responses from a wide variety of participants located in different regions and hospitals of the United States with varying degrees of experience and specialisation.

CONCLUSION

Formative research was undertaken to assess the potential impact of several unexamined factors that could influence HH among nurses: *professional role and status*, *social affiliation*, *social norms*, and *physical modifications to the work environment*, as well as *institutional factors* (like safety climate). A survey questionnaire looked at how these factors influence nurses' reported HHC and also sought to identify barriers and levers to HH. Multivariate regression modelling suggested that HHC was most likely to be a function of a hospital management's 'openness', perceived performance by peers, increased interactions with patients and other staff members, and the reduction in stress, busyness, and cognitive load associated with role performance. Thus, a powerful and effective intervention focusing on nurses' HHC should address improving communication openness, consider the impact of perceived performance by peers, increase interactions with patients and staff, and determine how to reduce the stress and cognitive load associated with role performance.

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FIGURES

Figure 3- 1: Known hand hygiene compliance factors

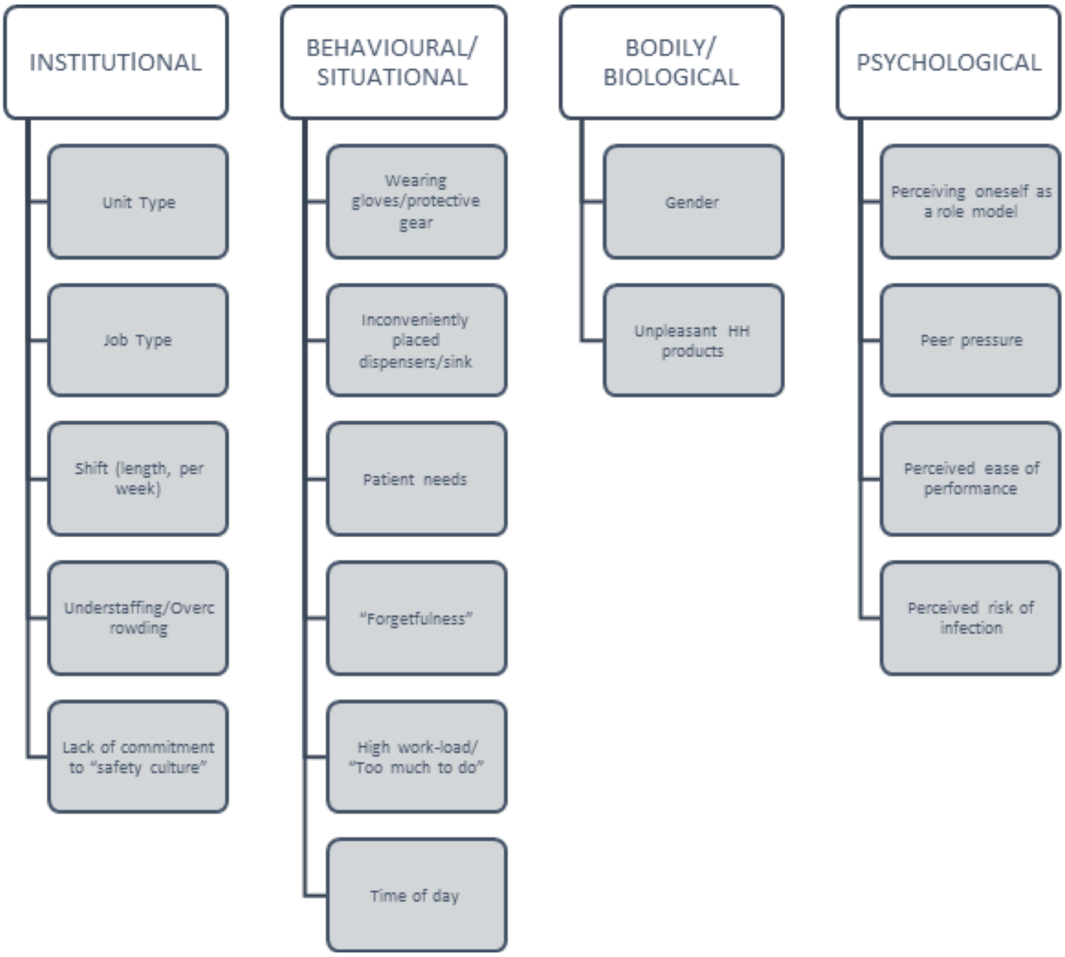


Figure 3- 2: Survey Flow

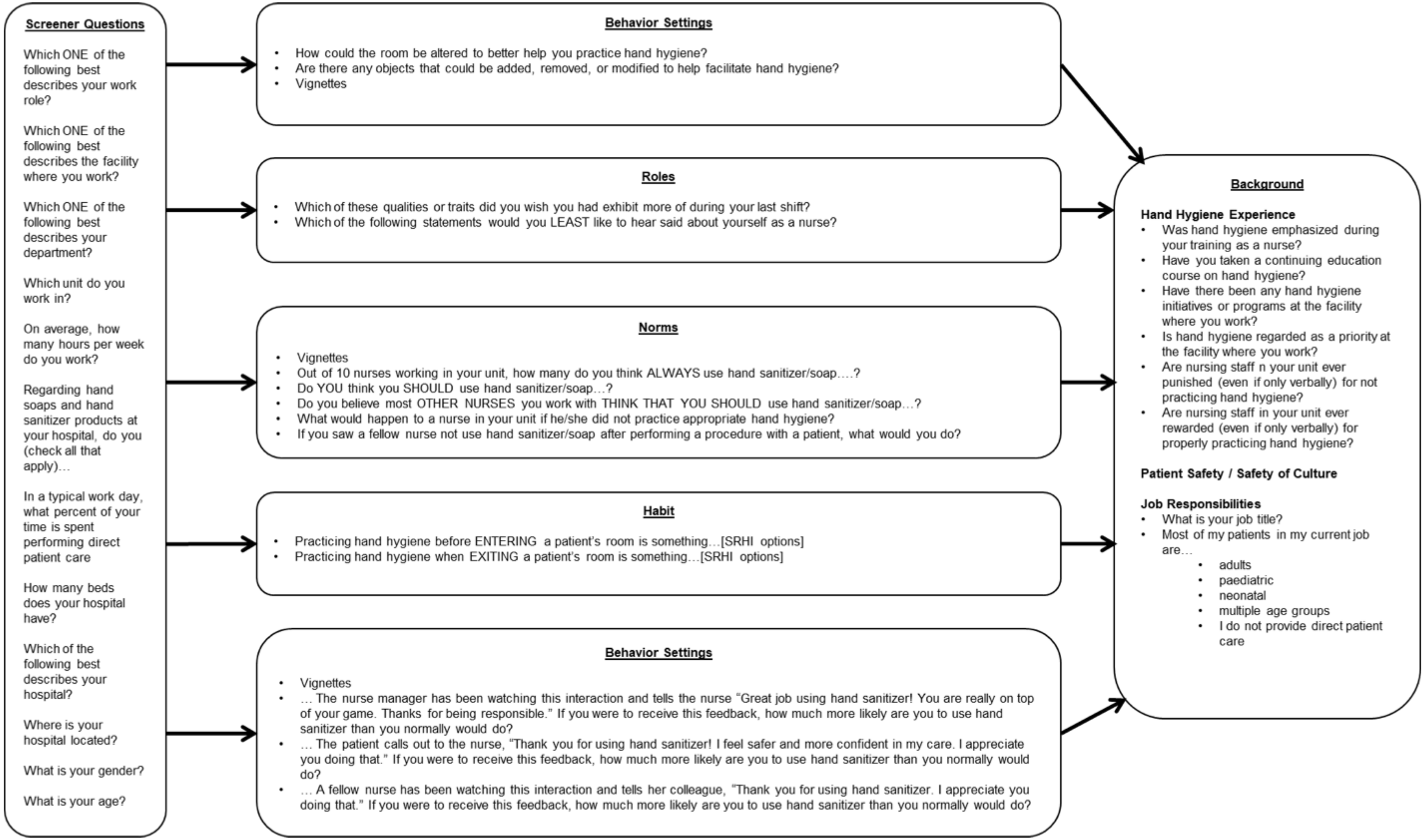
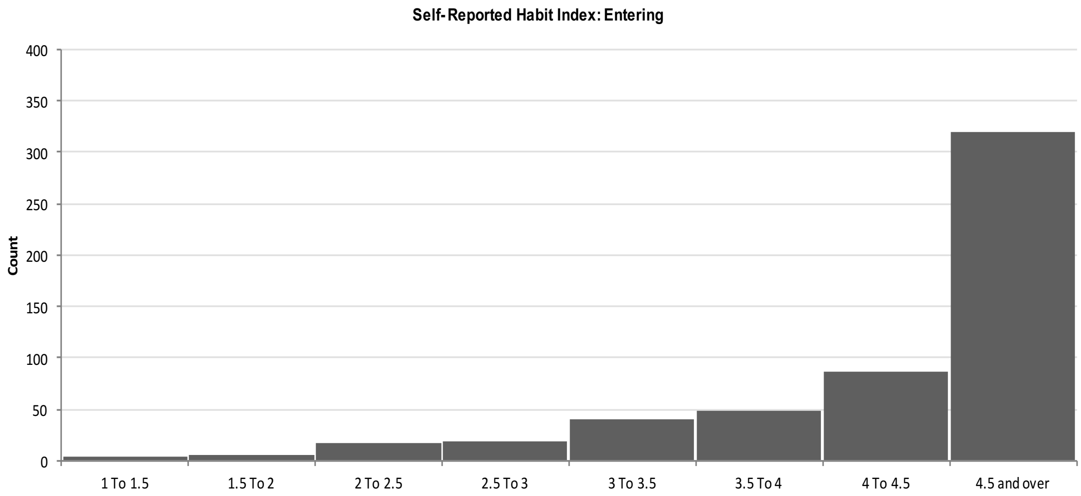
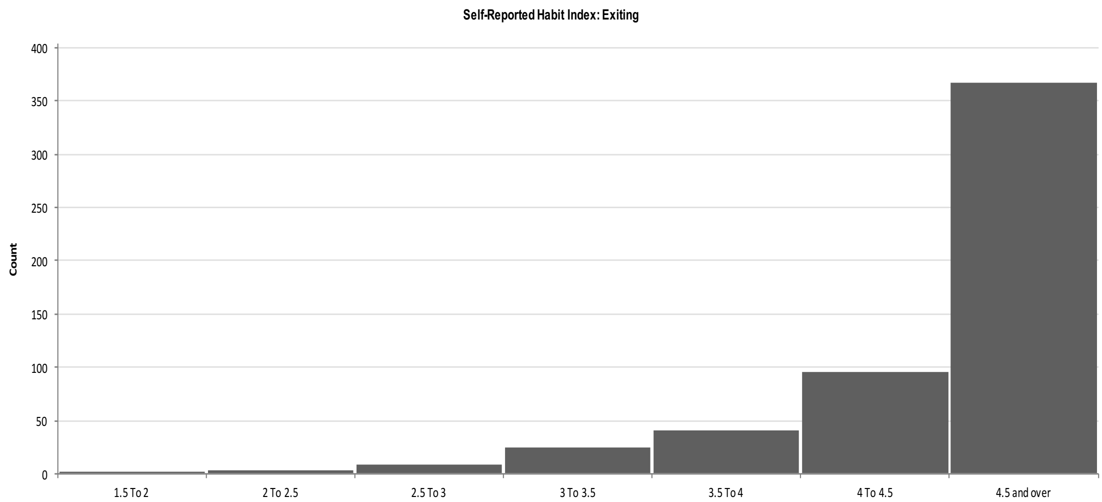


Figure 3- 3: Self-Reported Habit Index— Entering



Respondents answered the degree to which they felt the statement affected them regarding hand hygiene upon entering a patient's room.

Figure 3- 4: **Self-Reported Habit Index— Exiting**



Respondents answered the degree to which they felt the statement affected them regarding hand hygiene upon exiting a patient's room.

TABLES

Table 3- 1: Factors and behaviour change strategies examined in the literature

CATEGORY	SUB-CATEGORY	FACTORS IN THE LITERATURE	BEHAVIOUR CHANGE STRATEGIES IN THE LITERATURE
Brains	*Executive*	• *Identity*: doctor, nurse, nurse assistant • *Knowledge/Belief*: lack of knowledge of hand hygiene recommendations, disagreement with regulations, skepticism about efficacy of hand hygiene	• Emphasize self-protection • Provide knowledge of hand hygiene techniques/ regulations • Feedback on performance
	Motivate	• Fear of 'dirt'	—
	Reactive	—	—
Body	*Traits*	• Male	—
	Physiology	• Hand hygiene agent, such as alcohol-based hand rub, causes irritation/dryness	—
	Senses	—	—
Behaviour Setting	*Stage*	—	—
	Roles	• Relationship with patient/patient needs • Lack of others as role models	—
	Routine	• High number of hand hygiene opportunities • Too busy	• Reminders
	Script	• Forgetfulness • Distraction/ Interruption • Discretionary refusal	—
	Norms	—	—
	Props	• Automated sink • Sink location • Lack of soap • Wearing gloves • Dispensers conveniently located	• Improved access to ABHR
Environment	*Physical*	—	—
	Biological	• Activities with high/low risk of cross-contamination	—
	Social	• Work in intensive care or acute care settings • Understaffing	• Social influence
Context	*Programmatic*	—	—
	Political	• Lack of institutional priority for hand hygiene compliance • Lack of sanctions for non-compliance • Lack of safety climate	—
	Economic	—	—
	Social	—	—

Table 3- 2: Characteristics of survey participants

Variable	N Response (out of 540)	Percent (%)
Gender		
Female	490	90.74
Male	50	9.26
Geographic Location in the United States		
New England	27	5.00
Middle Atlantic	75	13.89
East North Central	102	18.89
West North Central	43	7.96
South Atlantic	88	16.29
East South Central	24	4.44
West South Central	44	8.15
Mountain	54	10.0
Pacific	83	15.37
Age		
20-29 y	46	8.52
30-39 y	124	22.96
40-49 y	104	19.26
50-59 y	183	33.89
≥ 60-69y	83	15.37
Professional Status		
Staff nurse	467	86.48
Nurse manager	10	1.85
Assistant nurse manager	13	2.41
Nursing director	3	0.56
Advanced practice nurse	28	5.19
Other	19	3.52
Medical Specialty		
Medical/surgical unit (Med/surg)	129	23.89
Intensive care unit (ICU)	108	20.00
Cardiac unit	51	9.44
Emergency	105	19.44
Other (NICU, PACU, Radiology, Oncology, Obstetric)	147	27.22
Hospital Type		
Teaching	305	56.48
Non-Teaching	235	43.52
Urban	407	75.37
Rural	133	24.63
System-affiliated	425	78.70
Independent	115	21.30
Hours Worked Per Week		
30-35 h	62	11.48
36-40 h	411	76.11
41-45 h	22	4.07
46-50 h	35	6.48
≥ 51-65 h	10	1.85

Table 3- 3: Responses to vignettes

Vitals-Vignette – Exit You are a nurse in Normal Hospital. You need to take the vitals for Mrs. Jones in room 2. You enter the room, say hello, explain the procedure, take Mrs. Jones' vitals, ask if she needs anything else, and then you head towards the door to leave.				
Question	**Response**	**N responses**	**Percent (%)**	**Corresponding Figure in Appendix 3-3**
Base Vignette Exiting Practicing HH upon exiting the patient's room.	Not at all likely	2	0.37	Figure 3A-1
	Slightly likely	7	1.30	
	Moderately likely	32	5.93	
	Very likely	124	22.96	
	Extremely likely	375	69.44	
Busyness Practicing HH when leaving the patient's room with other demanding tasks on the mind	Much less likely	11	2.04	Figure 3A-2
	Somewhat less likely	71	13.15	
	No difference	357	66.11	
	Somewhat more likely	33	6.11	
	Much more likely	68	12.59	
Gloves Practicing HH after taking off gloves	Much less likely	8	1.48	Figure 3A-2
	Somewhat less likely	53	9.81	
	No difference	354	65.56	
	Somewhat more likely	44	8.15	
	Much more likely	81	15.00	
Peer Influence Practicing HH when seeing a fellow nurse outside the patient's room	Much less likely	0	0	Figure 3A-2
	Somewhat less likely	11	2.04	
	No difference	365	67.59	
	Somewhat more likely	86	15.93	
	Much more likely	78	14.44	
Higher Status Social Influence Practicing HH when seeing the hospital's Infection Prevention Director outside the patient's room	Much less likely	0	0	Figure 3A-2
	Somewhat less likely	0	0	
	No difference	257	47.59	
	Somewhat more likely	70	12.96	
	Much more likely	213	39.44	
Higher Status Modelling Practicing HH when leaving the patient's room even though the Nurse Manager did not practice HH	Much less likely	2	0.37	Figure 3A-2
	Somewhat less likely	9	1.67	
	No difference	351	65.00	
	Somewhat more likely	69	12.78	
	Much more likely	109	20.19	
Empty Dispenser Practicing HH when there is an empty ABHR dispenser	Much less likely	38	7.04	Figure 3A-2
	Somewhat less likely	162	30.00	
	No difference	248	45.93	
	Somewhat more likely	37	6.85	
	Much more likely	55	10.19	
Interruption	Much less likely	30	5.56	Figure 3A-2

Practicing HH when interrupted upon leaving a patient's room	Somewhat less likely	117	21.67	
	No difference	296	54.81	
	Somewhat more likely	35	6.48	
	Much more likely	62	11.48	
Emergency Practicing HH when exiting the patient's room to attend to an emergency	Much less likely	118	21.85	Figure 3A-2
	Somewhat less likely	162	30.00	
	No difference	188	34.81	
	Somewhat more likely	30	5.56	
	Much more likely	42	7.78	
Vitals-Vignette – Entry Now instead of exiting Mrs. Jones's room, you are entering her room to take her vitals.				
Question	**Response**	**N responses**	**Percent (%)**	**Corresponding Figure in Appendix 3-3**
Base Vignette Entry Practicing HH before entering patient's room	Not at all likely	6.	1.11	Figure 3A-1
	Slightly likely	30.	5.56	
	Moderately likely	64.	11.85	
	Very likely	132.	24.44	
	Extremely likely	308.	57.04	
Patient's request Practicing HH upon patient's request	Much less likely	1	0.19	Figure 3A-3
	Somewhat less likely	0	0	
	No difference	230	42.59	
	Somewhat more likely	37	6.85	
	Much more likely	272	50.37	
Empty Dispenser Practicing HH when there is an empty ABHR dispenser	Much less likely	37	6.85	Figure 3A-3
	Somewhat less likely	145	26.85	
	No difference	270	50.00	
	Somewhat more likely	34	6.30	
	Much more likely	54	10.00	
Gloves Practicing HH before putting on gloves	Much less likely	47	8.70	Figure 3A-3
	Somewhat less likely	134	24.81	
	No difference	285	52.78	
	Somewhat more likely	27	5.00	
	Much more likely	47	8.70	
Cleaning Wound- Vignette – Exit You are a nurse at Normal Hospital. You are cleaning and bandaging Mr. Robinson's diabetic foot. After finishing the procedure, you take off your gloves, and then say goodbye to Mr. Robinson.				
Question	**Response**	**N responses**	**Percent (%)**	**Corresponding Figure in Appendix 3-3**
Base Vignette Exit How likely are you to practice hand hygiene upon exiting the room?	Not at all likely	0	0	Figure 3A-1
	Slightly likely	4	0.74	
	Moderately likely	4	0.74	
	Very likely	42	7.78	
	Extremely likely	490	90.74	
Busyness Practicing HH when leaving the patient's room with other	Much less likely	1	0.19	Figure 3A-4
	Somewhat less likely	11	2.04	
	No difference	382	70.74	

demanding tasks on the mind	Somewhat more likely	36	6.67	
	Much more likely	110	20.37	
Peer Influence Practicing HH when seeing a fellow nurse outside the patient's room	Much less likely	0	0.	Figure 3A-4
	Somewhat less likely	3	0.56	
	No difference	389	72.04	
	Somewhat more likely	53	9.81	
	Much more likely	95	17.59	
Higher Status Social Influence Practicing HH when seeing the hospital's Infection Prevention Director outside the patient's room	Much less likely	0	0	Figure 3A-4
	Somewhat less likely	1	0.19	
	No difference	316	58.52	
	Somewhat more likely	51	9.44	
	Much more likely	172	31.85	
Higher Status Modelling Practicing HH when leaving the patient's room even though the Nurse Manager did not practice HH	Much less likely	1	0.19	Figure 3A-4
	Somewhat less likely	5	0.93	
	No difference	384	71.11	
	Somewhat more likely	44	8.15	
	Much more likely	106	19.63	
Empty Dispenser Practicing HH when there is an empty ABHR dispenser	Much less likely	6	1.11	Figure 3A-4
	Somewhat less likely	70	12.96	
	No difference	347	64.26	
	Somewhat more likely	32	5.93	
	Much more likely	85	15.74	
Interruption Practicing HH when interrupted upon leaving a patient's room	Much less likely	4	0.74	Figure 3A-4
	Somewhat less likely	75	13.89	
	No difference	351	65.00	
	Somewhat more likely	34	6.30	
	Much more likely	76	14.07	
Emergency Practicing HH when exiting the patient's room to attend to an emergency	Much less likely	57	10.56	Figure 3A-4
	Somewhat less likely	125	23.15	
	No difference	260	48.15	
	Somewhat more likely	32	5.93	
	Much more likely	66	12.22	
Cleaning Wound- Vignette – Enter Now instead of *exiting* Mr. Robinson's room, you are entering his room to clean and reapply his bandages. After reading each scenario, please answer the following questions.				
Question	**Response**	**N responses**	**Percent (%)**	**Corresponding Figure in Appendix 3-3**
Base Vignette Entry Practicing HH before entering patient's room	Not at all likely	4	0.74	Figure 3A-1
	Slightly likely	18	3.33	
	Moderately likely	48	8.89	
	Very likely	116	21.48	
	Extremely likely	354	65.56	
Patient's request Practicing HH upon patient's request	Much less likely	4	0.74	Figure 3A-5
	Somewhat less likely	18	3.33	

	No difference	48	8.89	
	Somewhat more likely	116	21.48	
	Much more likely	354	65.56	
Empty Dispenser Practicing HH when there is an empty ABHR dispenser	Much less likely	3	0.56	Figure 3A-5
	Somewhat less likely	2	0.37	
	No difference	264	48.89	
	Somewhat more likely	45	8.33	
	Much more likely	226	41.85	
Gloves Practicing HH before putting on gloves	Much less likely	18	3.33	Figure 3A-5
	Somewhat less likely	110	20.37	
	No difference	299	55.37	
	Somewhat more likely	40	7.41	
	Much more likely	73	13.52	

Table 3- 4: Responses to norm questions

Empirical Expectations Number of nurses out of 10 that always practice hand hygiene:				
Questions	**Response**	**N response**	**Percent (%)**	**Corresponding Figure in Appendix 3-3**
before entering a patient's room?	0	7	1.29	Figure 3A-8
	1	9	1.67	
	2	27	5.00	
	3	23	4.26	
	4	14	2.59	
	5	91	16.85	
	6	32	5.93	
	7	52	9.63	
	8	128	23.70	
	9	82	15.19	
	10	75	13.89	
when exiting a patient's room?	0	4	0.74	Figure 3A-8
	1	1	0.19	
	2	10	1.85	
	3	6	1.11	
	4	10	1.85	
	5	45	8.33	
	6	36	6.67	
	7	52	9.63	
	8	146	27.04	
	9	116	21.48	
	10	114	21.11	
after taking a patient's vitals?	0	14	2.59	Figure 3A-8
	1	11	2.037	
	2	37	6.85	
	3	18	3.33	
	4	23	4.26	
	5	101	18.70	

	6	43	7.96	
	7	46	8.52	
	8	103	19.07	
	9	65	12.04	
	10	79	14.63	
after cleaning a patient's wound?	0	2	0.37	Figure 3A-8
	1	2	0.37	
	2	2	0.37	
	3	2	0.37	
	4	0	0.	
	5	10	1.85	
	6	4	0.74	
	7	9	1.67	
	8	39	7.22	
	9	96	17.78	
	10	374	69.26	
before charting in the nurse station?	0	53	9.82	Figure 3A-8
	1	22	4.07	
	2	48	8.89	
	3	17	3.15	
	4	31	5.74	
	5	108	20.00	
	6	39	7.22	
	7	47	8.70	
	8	77	14.26	
	9	45	8.33	
	10	53	9.82	
after talking to a colleague in the hallway?	0	156	28.89	Figure 3A-8
	1	40	7.41	
	2	67	12.41	
	3	31	5.74	
	4	25	4.63	
	5	89	16.48	
	6	22	4.07	
	7	24	4.44	
	8	38	7.04	
	9	19	3.52	
	10	29	5.37	

Normative Personal Beliefs
Do you think you should practice hand hygiene:

Questions	**Response**	**N response**	**Percent (%)**	**Corresponding Figure in Appendix 3-3**
before entering a patient's room?	Never	0	0	Figure 3A-9
	Seldom	11	2.04	
	About half the time	12	2.22	
	Usually	76	14.07	
	Always	441	81.67	
when exiting a patient's room?	Never	0	0	Figure 3A-9
	Seldom	2	0.37	
	About half the time	8	1.48	
	Usually	42	7.78	

	Always	488	90.37	
after taking a patient's vitals?	Never	3	0.56	Figure 3A-9
	Seldom	13	2.41	
	About half the time	33	6.11	
	Usually	83	15.37	
	Always	408	75.56	
after cleaning a patient's wound?	Never	0	0	Figure 3A-9
	Seldom	0	0	
	About half the time	2	0.37	
	Usually	5	0.93	
	Always	533	98.70	
before charting in the nurse station?	Never	23	4.26	Figure 3A-9
	Seldom	57	10.56	
	About half the time	71	13.15	
	Usually	150	27.78	
	Always	239	44.26	
Normative Expectations Do you believe that most other nurses think that you should practice hand hygiene:				
Questions	**Response**	**N response**	**Percent (%)**	**Corresponding Figure in Appendix 3-3**
before entering a patient's room?	Never	2	0.37	Figure 3A-10
	Seldom	13	2.407	
	About half the time	51	9.444	
	Usually	136	25.185	
	Always	338	62.593	
when exiting a patient's room?	Never	1	0.185	Figure 3A-10
	Seldom	1	0.185	
	About half the time	32	5.926	
	Usually	101	18.704	
	Always	405	75.	
after taking a patient's vitals?	Never	9	1.667	Figure 3A-10
	Seldom	30	5.556	
	About half the time	78	14.444	
	Usually	148	27.407	
	Always	275	50.926	
after cleaning a patient's wound?	Never	0	0.	Figure 3A-10
	Seldom	1	0.185	
	About half the time	8	1.481	
	Usually	43	7.963	
	Always	488	90.37	
before charting in the nurse station?	Never	37	6.852	Figure 3A-10
	Seldom	92	17.037	
	About half the time	126	23.333	
	Usually	140	25.926	
	Always	145	26.852	
	Never	82	15.185	Figure 3A-10

after talking with fellow nurses in the break room?	Seldom	146	27.037	
	About half the time	116	21.481	
	Usually	86	15.926	
	Always	110	20.37	

Table 3- 5: Responses to motives questions

MOTIVATION				
Questions	**Response**	**N response**	**%**	**Corresponding Figure in Appendix 3-3**
Feedback from nurse manager	Much Less Likely	2	0.37	Figure 3A-11
	Somewhat Less Likely	1	0.19	
	No Difference	274	50.74	
	Somewhat More Likely	114	21.11	
	Much More Likely	149	27.59	
Feedback from patient	Much Less Likely	1	0.19	Figure 3A-11
	Somewhat Less Likely	0	0.00	
	No Difference	299	40.56	
	Somewhat More Likely	111	22.59	
	Much More Likely	129	36.67	
Feedback from colleague	Much Less Likely	1	0.19	Figure 3A-11
	Somewhat Less Likely	0	0.00	
	No Difference	299	55.37	
	Somewhat More Likely	111	20.56	
	Much More Likely	129	23.89	

Table 3- 6: Responses to questions about safety culture

Rating Overall Perceptions of Safety			
Questions	**Response**	**N response**	**Percent (%)**
Patient safety is never sacrificed to get more work done.	Strongly disagree	33	6.00
	Disagree	131	24.2
	Neither agree nor disagree	96	17.8
	Agree	168	31.1
	Strongly Agree	112	20.7
Our procedures and systems are good at preventing errors from happening.	Strongly disagree	10	1.9
	Disagree	50	9.3
	Neither agree nor disagree	73	14.6
	Agree	285	52.8
	Strongly Agree	122	22.6

When a mistake is made that could harm the patient, but does not, how often is this reported?	Always	89	16.5
	Usually	234	43.3
	Half the time	155	28.7
	Seldom	59	10.9
	Never	3	0.56
Supervisor and Manager Expectations and Action			
Questions	**Response**	**N response**	**Percent (%)**
My supervisor/manager overlooks patient safety problems that repeatedly happen.	Strongly disagree	100	18.5
	Disagree	194	35.9
	Neither agree nor disagree	68	12.4
	Agree	111	20.6
	Strongly Agree	67	12.4
My supervisor/manager seriously considers staff suggestions for improving patient safety.	Strongly disagree	16	2.96
	Disagree	56	10.4
	Neither agree nor disagree	99	18.3
	Agree	252	46.7
	Strongly Agree	117	21.7
My supervisor/manager says a good word when observing a job done according to established patient safety procedures.	Strongly disagree	25	4.6
	Disagree	67	12.4
	Neither agree nor disagree	129	23.9
	Agree	219	40.6
	Strongly Agree	100	18.5
Teamwork Within Units			
Questions	**Response**	**N response**	**Percent (%)**
Nurses in our unit help each other out regularly.	Strongly disagree	6	1.1
	Disagree	15	2.8
	Neither agree nor disagree	22	4.1
	Agree	244	45.2
	Strongly Agree	253	46.9
I can depend on getting help from other nurses.	Strongly disagree	5	0.92
	Disagree	25	4.6
	Neither agree nor disagree	38	7.0
	Agree	254	47.0
	Strongly Agree	218	40.5
In this unit, people treat each other with respect.	Strongly disagree	8	1.5
	Disagree	24	4.4
	Neither agree nor disagree	46	8.5
	Agree	293	54.3
	Strongly Agree	169	31.3
Closeness			
Questions	**Response**	**N response**	**Percent (%)**
Some of my closest friends are my work colleagues.	Strongly disagree	18	3.3
	Disagree	66	12.2
	Neither agree nor disagree	111	20.6
	Agree	207	38.3

	Strongly Agree	138	25.6
Communication Openness			
Questions	**Response**	**N response**	**Percent (%)**
Staff will freely speak up if they see something that may negatively affect patient care.	Always	117	21.7
	Usually	284	52.6
	Half the time	107	19.8
	Seldom	28	5.2
	Never	4	0.7
Staff feel free to question the decisions or actions of those with more authority.	Strongly disagree	20	3.7
	Disagree	103	19.1
	Neither agree nor disagree	134	24.8
	Agree	202	37.4
	Strongly Agree	81	15.0
Staff are afraid to ask questions when something does not seem right.	Strongly disagree	48	8.9
	Disagree	241	44.6
	Neither agree nor disagree	134	24.8
	Agree	84	15.6
	Strongly Agree	33	6.1
Feedback and Communication About Error			
Questions	**Response**	**N response**	**Percent (%)**
In this unit, we discuss ways to prevent errors from happening again.	Always	117	21.7
	Usually	284	52.6
	Half the time	107	19.8
	Seldom	28	5.2
	Never	4	0.74
Staffing			
Questions	**Response**	**N response**	**Percent (%)**
We sometimes work in "crisis mode" trying to do too much, too quickly.	Strongly disagree	5	0.93
	Disagree	48	8.9
	Neither agree nor disagree	67	12.4
	Agree	289	53.5
	Strongly Agree	131	24.3
Hospital management seems interested in patient safety only after an adverse event happens	Strongly disagree	40	7.4
	Disagree	136	25.2
	Neither agree nor disagree	110	20.4
	Agree	164	30.4
	Strongly Agree	90	16.7

Table 3- 7: Stepwise regression model results

	Estimate	Standard Error	T value	Pr(>|t|)
INTERCEPT	3.228	0.511	6.315	5.84E-10
HOSPITAL LEVEL FACTORS				
Openness of communication	0.117	0.049	2.388	0.017
UNIT LEVEL FACTORS				
Type of Unit: Emergency Department	-0.213	0.086	-2.496	0.013
Hours worked per week	-0.013	0.005	-2.467	0.014
Percent of time for patient care	0.102	0.040	2.520	0.012
Percent of time spent interacting with patient	0.004	0.002	2.366	0.018
Percent of time spent on professional interactions	0.019	0.005	3.747	0.0002
INDIVIDUAL LEVEL FACTORS				
Which quality did you wish you had exhibited more during your last shift?				
Good communication skills	-0.120	0.061	-1.975	0.049
Stress management	0.135	0.058	2.334	0.020
Which quality would you least like to hear during your last shift?				
Unsure of self as nurse	-0.128	0.060	-2.138	0.033
NORMS				
Out of 10 nurses working in your unit, how many do you think always use hand sanitizer or soap…				
after talking to colleague in hallway	0.041	0.010	1.970	0.049
after cleaning a patient's wound	-0.071	0.024	-2.935	0.003
after taking patient's vitals	0.041	0.014	2.823	0.005
when exiting a patient's room	0.073	0.020	3.684	0.0003

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SECTION A – Student Details

Student	Madeline Sands
Principal Supervisor	Dr. Robert Aunger
Thesis Title	Infection Control in Our Hands: Developing and Evaluating a Novel Intervention to Improve the Hand Hygiene Behaviour of Nurses in Acute Care Hospital Units in the US

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

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SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Implementation Science
Please list the paper's authors in the intended authorship order:	Madeline Sands Robert Aunger
Stage of publication	**Submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Madeline Sands documented the intervention design process, identified the theoretical underpinnings of the intervention, and created a Theory of Change. The candidate also drafted the manuscript.

Student Signature: [redacted] **Date:** 5 October 2019

Supervisor Signature: **Date:** 15 October 2019

CHAPTER 4: INTERVENTION DESIGN

Development of a behaviour change intervention using a theory-based approach, Behaviour Centred Design, to increase nurses' hand hygiene compliance in US hospitals

ABSTRACT

Background: A behaviour change campaign is unlikely to be effective if its intervention is not carefully designed. While numerous frameworks are widely used to develop and evaluate interventions, the steps detailing how to create an intervention are not as clear because the process of linking behaviour analysis to the intervention design is seldom discussed. We document the application of a novel approach called Behaviour Centred Design (BCD) to the development of an intervention to improve hand hygiene (HH) rates among nurses in hospital units in the United States.

Methods: Intervention development is divided into the first three steps of the BCD approach: Assess, Build, and Create. The Assess step centres on understanding the target behaviour. The Build step expands the knowledge of the target behaviour and population through formative research which leads to a creative brief that explains the focus of the intervention. In the Create step, the creative brief guides the intervention design.

Results: Drawing from the main findings of the Asses and Build steps, a focal insight was developed positing that nurses can rediscover the meaning and purpose of their role as a nurse and thus as a caregiver by practicing HH; in the process of cleaning their hands, nurses are living up to their ideal nurse-self. The focal insight was linked

linguistically into a Theory and Change. The outcome was a simple intervention, called the *Mainspring Intervention*, which consisted of three major parts: a self-affirmation exercise to reduce defensiveness, a message that challenged nurses' perceptions about their HH practice, and an implementation intention activity to help nurses link HH behaviour to a cue.

Conclusions: We detailed the creation of an original HH intervention that used the BCD approach. The intervention is relatively simple compared to most HH initiatives in the literature, both in terms of having relatively few components to the intervention and relatively easy field implementation. This intervention will allow us to test how specific psychological processes contribute to the problem of low HH rates, how our proposed intervention changes these processes in the hospital setting, and how the expected change in nurses' cognition transforms over time because of the intervention.

Contributions to the literature:

- We describe and document the novel BCD approach to intervention development, and in so doing, set forth systematic procedures for designing and refining techniques to be utilised in behaviour change interventions regarding healthcare workers in hospital settings.
- We detail how to identify and develop creative insights into actual intervention materials through linking behaviour analysis to the design of an intervention.
- The final product was the creation of an original HH behaviour change intervention, called a 'wise' intervention, which has not previously been used— to our knowledge— to improve healthcare workers' hand hygiene behaviour.

INTRODUCTION

A behaviour change campaign is unlikely to be effective if its intervention is not carefully designed. There are five extensively used behaviour change approaches in the literature that all incorporate structured intervention development processes: the Behaviour Change Wheel (BCW) framework[1], the Risks, Attitudes, Norms, Abilities, and Self-regulation (RANAS) approach,[2] the Medical Research Council (MRC) framework,[3] Intervention Mapping,[4] and the PRECEDE-PROCEED model.[5] While each approach is grounded in a different theory or philosophy, there are similarities in how researchers are guided through the various stages of intervention development, such as agreeing on a problem, researching that problem, implementing a solution, and evaluating its effectiveness. However, steps detailing how to identify and develop creative insights into actual intervention materials are not as clear because the process of linking behaviour analysis to the design of an intervention is seldom discussed.

In designing an intervention to target the hand hygiene (HH) behaviour of nurses in acute care units, we used a novel approach called Behaviour Centred Design (BCD), which is a framework that provides guidance not only with respect to the overall intervention development process, but also for the creative design of interventions themselves. BCD presents a systematic way to develop a program through five steps (Figure 4-1).[6] The first step—Assess— is concerned with setting out the scope of the intervention and identifying what is known about the target behaviour. This serves as the basis for the following step—Build— which seeks to fill knowledge gaps essential in the development of the Theory of Change. Determining the Theory of Change allows for the formation of potential intervention themes, components, scope, and sequences which are necessary for generating the intervention itself in the Create step. The intervention is subsequently implemented in the Deliver step and assessed in the Evaluation step. Intervention design occurs throughout the Assess, Build, and Create steps. The basic premise behind BCD's design process is that the settings where the target behaviour occurs must be disrupted to force revaluation of the desired behavioural option, which then causes people to perform that behaviour. Thus, interventions are tasked with creating surprising new stimuli that run counter to the brain's predictions about the consequences of performing the target behaviour. By doing so, the brain is forced to reconsider its expectations of the value of performing different options, resulting in a trial of the target behaviour.

In this paper, we describe the process of designing an intervention to improve hand hygiene compliance (HHC) among nurses in US hospitals. Healthcare associated infections (HAIs) are a global patient safety concern with an estimated 1.4 million people suffering from HAIs at any given moment. [7, 8] There are nearly 2 million HAIs and 100,000 HAI-related deaths occurring annually in the United Sates.[8-10] HAIs are associated with an increased attributable mortality, length of stay, and health care costs incurred by patients and healthcare facilities.[11] While HAIs pose a significant threat to patients, health care workers (HCWs) are also at risk of becoming infected while administering patient care. The causes of HAIs vary, but all can be attributed to health systems and processes of care provision. HH is recognized as the single most important measure for preventing the spread of HAIs.[8, 12, 13]

To reduce HAIs, improvement in compliance with HH guidelines is needed. Observed compliance rates among HCWs have been regarded by public health officials, health organizations, and researchers alike as being poor.[14-20] Over the past several decades, numerous campaigns promoting HH have been launched.[14] However, improving HHC and sustaining this behavioural change remains a significant challenge due to the complexities of the healthcare environment and to the difficulty of changing behaviour.[8, 14, 21, 22]

The process of designing a behaviour change intervention is inherently difficult, made even more so when placed within the healthcare setting. Hospitals are complex and dynamic institutions, especially in acute and intensive care units where seriously ill and unstable patients are cared for, invasive procedures are performed, and the sense of urgency is apparent. Moreover, behaviour change interventions focusing on HCWs must work within the constraints of complex organizational and policy contexts. Successful and sustainable interventions need to address individuals' behaviours in addition to the underlying norms, rules, and culture of the hospital at large. The targeted behaviour must become embedded in routine medical practices that are anything but routine in actual practice. Thus, promoting HHC in nurses is considered a particularly challenging context within which to implement an intervention design process. Nevertheless, the public health importance of this behaviour warrants attention.

The purpose of this paper is to describe, document, and explicate the applied BCD intervention development framework using this case study, and in so doing, set forth systematic procedures for designing and refining proven techniques to be utilized in behaviour change interventions for HCWs in hospital settings. This paper focuses on linking BCD's Assess and Build steps with the Create step, thereby illustrating the process behind the design and development of the intervention that is not as clearly documented with other approaches.

METHODS

The development of the intervention is divided into three steps: Assess, Build, and Create. Each of these steps has a unique process and is dependent on preceding steps. Here, we describe the processes that are undertaken for each step; the Results of each step follow in the subsequent section, with Discussion afterwards.

Assess

The Assess step is separated into two phases: background review and framing. The background review seeks to understand the target behaviour of HH in its context. The purpose of the framing process is to define what is within the scope of the intervention and within the means of the behaviour change practitioners.

Background Review

A systematic review is completed to assemble existing knowledge on HH interventions targeting nurses in hospitals. The findings should provide insight into the current state of nursing HH interventions by describing how interventions have changed, detailing what present-day interventions look like, and identifying areas for improvement in intervention design.

Framing Process

Here stakeholders and experts participate in a framing workshop to discuss the target behaviour and factors identified from the general survey of the literature, to agree on the aim of the intervention, and to outline the various constraints surrounding the intervention design. These stakeholders and experts will become the core group guiding the research project. The workshop ends with a framing statement that serves as the foundation on which the rest of the project is built (Figure 4-2). By defining the scope of the project and compiling an extensive evidence base, the team can pinpoint what still needs to be learned and tests for potential levers of change in the Build step.

Build

This stage expands the knowledge of the target behaviour and population. This involves conducting formative research that seeks to address the questions left unanswered during the framing process and literature reviews while also exploring hypotheses developed in the Assess stage.

Formative Research

Formative research is conducted with the objective to evaluate the behavioural change potential of factors identified from the Assess stage.

Design Workshop

Next, a Design Workshop is held. A team is collected together with a variety of backgrounds, expertise, and degrees of familiarity with the problem at hand. This includes the core group that participated in the framing process workshop as well as members from academia, marketing, and the target population. At this workshop, the findings from the formative research are presented and then converted into a Theory of Change for the intervention using BCD's creative design process. The design process is described as a sequence of nine phases, starting with analysing the findings from the field and concluding with a creative brief that explains the single focus of the intervention (Figure 4-3).

The first phase involves summarizing the salient findings from formative research, which is done by listing the important points from existing knowledge and the formative research findings on index cards. These are then put on the wall for consideration. The findings are clustered together by the entire team per a common element, and then appropriately named as a ‘theme’. Numerous themes are typically generated, so an elimination test is performed to keep only the relevant and significant themes. The remaining themes are then placed by the assembled group in a grid per their level of impact and changeability (Figure 4-4). The themes that have low-impact or low-changeability are immediately ruled out; only high-impact and high-changeability themes are considered further. The group uses the themes as guides to discuss ideas of how to prompt HH. In the next phase, these ideas were developed into platforms—or central concepts— that would be able to support the intervention. The platforms are assessed on their ability to cause a sustainable change in behaviour and their likelihood to be successfully implemented; this results in additional clustering exercise. The most promising platforms are selected, and the group further refines the focus. The group discusses how to link the platforms together. Once linked together into a focal insight, which is an enlightening deep truth about the behaviour and its causes,[6] intervention implementation ideas are discussed. From this discussion, the components of the intervention are developed. A Theory of Change is devised and a creative brief is written to summarize the findings and highlight the behavioural insight that will serve as the core behaviour change principle behind the intervention.

Create

The creative brief is given to a special creative team to develop the intervention. In the Create stage, the focal insight is expanded into the suite of materials that make up the intervention. These materials should initiate the change mechanisms postulated in the Theory of Change.

RESULTS

We now present the substantive results from the steps just described, as they occurred in this project. Greatest emphasis is placed on describing the execution and reported findings and insights from the design process (in the Build step) and the translation of the insights into intervention components (Create step). It should be noted that the results for the systematic review and the formative research are presented in other papers; however, the salient findings for each are briefly discussed below.[23, 24]

Assess: Establish Evidence Base

The systematic literature review produced three major findings.[23] First, the most recent HH interventions predominantly use education, reminders, and feedback as behaviour change mechanisms; they tend to incorporate information about the negative consequences arising from missed HH opportunities, they compare individual's and hospital unit's HH behaviour to other individuals and units, and they all set goals for increased HHC rates. The second major finding was that recent HH interventions use relatively few behaviour change techniques. Finally, most recent studies indicate that their interventions are grounded in behaviour change theory, yet little explanation is provided as to how the intervention implementation activities lead to behaviour change. It became apparent that there was a divide between the behavioural frameworks cited by the studies and how those constructs were operationalized. The findings from the background review provided a broad basis of knowledge, but also identified areas in which further investigation was required.

A Framing Workshop was held in November 2016 in the United States with stakeholders and experts. The stakeholders included employees of the Project Funder.

Nurses and Infectious Disease directors from local hospitals were present to provide insight and expertise on HH behaviour. The research team—primarily RA and MHS—were present to lead the Framing Workshop, to discuss the theories of behaviour change, and to review the factors that influenced HH behaviour identified from the general survey of the literature. This became the core group that guided the rest of the research project. It was during the Framing Workshop that we agreed on the aim of the intervention and outlined the various constraints surrounding the intervention design. The workshop ended with a framing statement (Figure 4-2).

The core group decided the target population should be nurses in acute care units in US hospitals. As discussed previously, different types of HCWs have different HHC rates and respond differently to HH campaigns. As nurses are on the frontline of healthcare delivery, the core group decided to create an intervention tailored specifically to nurses. We chose to focus on hospitals in the United States because the Project Funder was based there and had planned to commercialise the intervention in the States if proven to be successful. In addition, we chose acute care units for two reasons: 1) acute care units provide rapid, active, time-sensitive treatment to patients who have a severe injury or illness, an urgent medical condition, or are recovering from surgery; thus, with the primary purpose to improve the health of such serious cases, HH is extremely important, and 2) it was for this reason that most hospitals with the Project Funder's electronic compliance monitoring (ECM) system had installed it in their acute care units. The aim of the intervention was decided to increase a hospital unit's HHC rates by 50% over its baseline rates, which aligns with increases observed in other HH trials specific to nurses in hospitals.[25] Then the group identified hypotheses to explore in the formative research, which included:

- **Adding salience:** Would making evident the link between increased HHC rates and reduced HAI rates be a motivator?
- **Adding value:** Could we associate practicing HH with other values?
- **Linking to identity:** Could practicing HH be associated with being a "good nurse"?
- **Ritualizing the practice:** Would it be possible to ritualize the practice of HH and make it special?
- **Habit formation:** How could we reduce behavioural performance cost?

It was decided that the formative research would focus on investigating professional roles, status affiliation, social norms, motivation, physical manipulation of the hospital unit, and habit formation.

Build: Formative Research and Design Workshop

The formative research sought to further assess the relevance and behavioural change potential of factors identified from the literature and discussed during the Framing Workshop. Using as a web-based survey administered online to 500 nurses throughout the United States, the formative research determined that performing HH and complying with the recommendations were most likely a function of a hospital management's communication 'openness', perceived performance by peers, increased interactions with patients and other staff members, and the reduction in stress, busyness, and cognitive load associated with role performance.[24] Also, it was noted that nurses were more likely to practice HH: a) after performing a perceived higher-risk task like dressing a patient's wound as compared to performing a low-risk task such as taking vitals and b) upon exiting a patient's room as compared to entering a patient's room.[24]

Once the formative research had been analysed, a Design Workshop was held in the United States throughout February 2016 to develop a creative insight and brief. The formative research findings were presented, then clustered into groups collectively by the workshop participants, and evaluated on their level of impact and changeability (Figure 4-5). Examples from each of the categories have been described below for clarity:

- High Impact and High Changeability: From the formative research, we found that nurses feeling supported by hospital administration and authorities led to an increase in self-reported HH practice.[24] Thus, promoting a sense of support and unity is achievable and has the potential to lead to increased HHC rates.
- High Impact and Low Changeability: HCWs often cite that using alcohol-based hand rub (ABHR) has negative effects on their hands (such as drying of the skin).[16] It would neither be feasible nor in our area of expertise to create a new ABHR formula even if doing so would lead to increased usage.
- Low Impact and High Changeability: Changing a nurse's lack of knowledge regarding HH could be easily changed by providing a form of education. However, educating nurses about the importance of HH does result in noticeable changes in HHC.[23]
- Low Impact and Low Changeability: Being busy, having their hands full, or having other pressing matters that need immediate attention all impact nurses' HH behaviours.[16] However, these situations cannot be easily changed given the dynamics of the healthcare setting. In addition, while these are serious barriers to practicing HH, it could be argued that they are not the most

consistent barriers. As such, our efforts are better spent focusing on factors that have high impact and high changeability.

The themes considered to be most impactful and with the highest changeability were identified through group consensus—with two-thirds of the group having to be in agreement (Figure 4-6). The themes considered to be most impactful with the highest changeability were:

- Nurse's emotional connection with the patient
- Nurse feeling a sense of control
- Nurse feeling supported by hospital administration and authorities
- Nurse's professional imperative to practice HH
- Humanizing the patient
- Nurse's fear of causing the patient harm
- Nurse's want to protect their own family from illness
- Not relating to rates (need better feedback regarding HHC)
- Identity of a nurse

To further help identify a key insight, the themes were collapsed and combined into four insights associated with different types of behavioural determinants (as established by BCD): executive control, motives, social environment, and behaviour settings. Each of these insights are explained in detail in the following.

Executive Control

Executive control is a broad term that describes higher-order cognitive processes such as memory, planning, problem solving, multitasking, inhibition, mental flexibility, and verbal reasoning.[26] The themes relating to 'sense of control' and 'identity' were placed in this platform.

Sense of Control. Best practice care routines can easily be disrupted in acute care units resulting in relatively manageable and orderly shifts becoming chaotic and unruly. The workflow of nursing care delivery is constantly changing. During a shift filled with unpredictability, we speculate that nurses can gain a sense of control by practicing HH. The act of HH itself does not depend on others in the unit, and it has a substantial positive effect on patient outcomes. Thus, we predict that practicing HH gives nurses a sense of control where otherwise there is none.

Identity. In terms of identity, individuals are thought to be more likely to perform a behaviour that reflects the beliefs they have about themselves.[27-29] Self-identity and nested beliefs can change from engaging with a behaviour. Thus, it is hypothesised that a nurse who practices HH regularly can develop the identity or self-representation of being a good and diligent nurse.

Motives

Motives are evolved psychological mechanisms that lead to goal-directed behaviour.[6, 30] Performing a behaviour that produces a satisfactory outcome creates a rewarding experience, which prompts the individual to repeat the rewarding behaviour. Motives can be used to instigate behaviour change by modifying the target behaviour's value. In the case of HH, relevant and emotional messages that tie the behaviour to patient outcomes, family values, and the role of a good nurse are hypothesised to motivate nurses to perform HH. Attaching motives and rewards to the performance of a target behaviour can lead to the establishment of new behavioural patterns. Two motives that could potentially be linked to HH are disgust and nurture.

Disgust. This motive evolved to facilitate disease-avoidance behaviour thus protecting individuals against contamination. From the literature reviews in

Chapters 1 and 2, we found that disgust of contamination was an important driver of hygiene behaviour and has been harnessed to increase handwashing in various interventions.[6, 31] In fact, other researchers have specifically studied disgust and dirt as key drivers in nurses' infection control behaviours.[32, 33] Disgust can motivate nurses to practice HH for the obvious reason of reducing the nurses' own perceptions of personal risk. As nurses are surrounded by disease and engage with people who are sick, practicing HH is speculated to be a way to make what would be perceived as a disgusting incident during the work day less disagreeable.

Nurture. Nurture drives caring and protective behaviours, and it attempts to influence the social world in favour of one's in-group or kin. From the formative research in Chapter 3, we identified 'other-oriented values' as significantly important to nurses; these values encompass the nurse's actions on behalf of the patient's well-being and the interactions with patients in providing care, which could be considered nurturing. This motive can influence the practice of HH in two different ways. First, practicing HH is a way to protect one's own family or immediate community from communicable diseases. We hypothesise that nurses are motivated to wash their hands to safeguard hospital pathogens from being introduced into their own homes. Second, patients are people and by practicing HH the nurse is taking care of the person. By not practicing HH, the patient is put at risk. Thus, we further hypothesise that humanising the patient allows for the nurture connection to be made.

Social Environment

A major element of the social environment of a hospital is its 'culture of safety', which encompasses four main features: 1) acknowledgement of the high-risk nature of the hospital's activities and the determination to achieve consistently safe operations, 2) a blame-free environment where individuals are able to report errors or near misses without fear of reprimand or punishment, 3) encouragement of collaboration across ranks and disciplines to seek solutions to patient safety problems, and 4) hospital commitment of resources to address safety concerns.[34, 35] Two key components that can be used to increase the performance of HH are communication openness between all HCWs in the hospital unit and direct feedback from administration and supervisors. Institutional support that includes positive and constructive feedback can also accentuate the importance and necessity of practicing HH.

Behaviour Settings

Behaviour is also a function of the setting within which it takes place. The behaviour settings concept explains the relationship between individuals and the environment—both physical and social.[36] Behaviour settings are situations where people have learned what to expect from the environment and from other people's behaviours. Each setting has a purpose, a designated place, a set of objects, and a prescribed set of behaviours. Each person entering a setting expects others, who are also contemporaneous participants, to perform their (implicitly) designated roles. A sustainable way of changing HH behaviour is by changing some element of its behaviour setting. In this case, role and norms are relevant aspects.

Role. Safeguarding patients is a professional imperative of nursing. By reemphasizing the role of nursing and what it entails, connecting the performance of HH to positive patient outcomes can possibly highlight how practicing HH is a vital part of being a nurse.

Norms. By making HH performance imperative, there is a drive to practice HH. We hypothesise that by emphasising the notion that others care and are watching to see if HH is performed will prompt nurses to be more aware of practicing HH.

These various platforms were then linked together through facilitated engagement with the workshop members, resulting in the focal insight:

"It's under my control to reactivate [my commitment to] my professional code [of conduct] by caring for patients as persons via HHC to produce good patient outcomes and personal satisfaction."

This insight provided a single conceptual framework within which the intervention could be further developed. Essentially, nurses can be prompted to see HH as an opportunity to redefine their perceptions of patients as people to whom they are duty-bound to receive their care and protection. We postulate that by consistently practicing HH, nurses can rediscover the meaning and purpose of their role as a nurse and thus a caregiver—it is something good that nurses can do for themselves, their families and immediate communities, and for their patients. In the process of cleaning their hands, nurses will also feel good because they are living up to their ideal nurse-self. The explication of the focal insight is provided in Figure 4-7.

The focal insight was then linked linguistically into a Theory of Change (Figure 4-8) and subsequently translated into a creative brief. The brief, aiming to provide a succinct overview of the focal insight and strategy, rephrased the insight to help the creative team understand and address the challenge (Figure 4-9).

Create: Creative Process

In response to this brief, the creative team produced a simple intervention, called the Mainspring Intervention, that concentrated on a single approach: the threat to professional identity from non-compliance. Given the tight project budget, the short timeline for project completion, and the various constraints posed by hospitals— such as hospital regulations against altering the units or the inability to “pull nurses off the floor” for a considerable amount of time— the creative team decided that a simple intervention would be easier to implement, would be less resource-intensive, and would allow for easier evaluation. This paper used the Template for Intervention Description and Replication (TIDieR) Checklist to ensure complete description of the intervention [Appendix 4-1].

The intervention was field-tested twice using focus groups of practicing nurses. Refinements to the intervention centred on wording and tone of the material being presented. Since the message regarding HHC could make participants uncomfortable, we included an exercise beforehand to reduce defensiveness and increase openness. The first focus group identified feeling offended and became defensive when reading the HH message. The wording of the intervention’s message was revised and delivered to a second focus group, which found it satisfactory and engaging.

Description of the Intervention

The revised intervention consisted of three major parts: a self-affirmation exercise to reduce defensiveness, a message that challenged nurses’ perceptions about their HH practice, and an implementation intention activity. The self-affirmation exercise was a brief writing task that asked nurses to answer questions about values important to them. The message about HH introduced evidence that nurses were less likely to perform HH at room entry than at room exit, suggesting that nurses could improve their HHC by focusing on “foaming-in” when entering a room. The implementation intention exercise prompted nurses to identify various features of the physical environment encountered regularly at room entry that could serve as cues to perform the target behaviour. This feature was used in the expressed implementation intention: “*When I see [object], I will think ‘foam in!*’”

Mechanisms of the Intervention

The first part of the intervention sought to reduce defensiveness using a values exercise, which was derived from self-affirmation theory. By reducing defensiveness, we hypothesised that nurses would be more open to receiving a message that challenged their professional identity and threatened their self-integrity. The message created awareness of a deficiency in HH behaviour but then provided constructive coaching by suggesting how to correct it. We posited that after the message was received, nurses would be motivated to achieve their professional best by performing HH more frequently at room entry. To ensure that this intention was translated into action, the intervention employed the implementation intention strategy to link the behaviour to a cue in the environment. This cue-behaviour link would theoretically elicit an automatic response.

Theoretical Underpinnings of the Intervention

The behaviour change mechanisms were derived from self-affirmation theory and the implementation intention strategy.

Self-Affirmation Theory. Threating health information can sometimes produce defensiveness and resistance against the threat.[37] Self-affirmation theory proposes that individuals are motivated by a desire to maintain one’s worth and self-image as moral, adaptive, and capable.[38-40] Threatening health information creates dissonance with this image, which results in defensive responses as individuals seek to protect their self-integrity. To restore the integrity of the self, individuals may deny the potential risk and refuse to perform the adaptive behaviour. Potential opportunities for learning and growth are thus missed.

However, self-affirmation has been shown to reduce defensive processing of health risk information.[37, 41-44] Affirming the self before receiving threatening health messages reduces bias, promotes increased acceptance of the personal relevance of the message, and can affect risk perceptions over a short-term. In this intervention, self-affirmation took the form of having participants write about self-defining values, which helped individuals protect their self-integrity and self-worth through the affirmation of alternative sources of self-identity and by reminding people what is important to them. Self-affirmation interventions have been shown to successfully influence a number of health-promoting behaviours.[43]

Implementation Intention Strategy. This strategy links intentions to the desired goal-directed behaviour and subsequently to the attainment of those goals.[45-48] Implementation intentions are specific, concrete plans phrased in the following manner: “When situation X rises, I will perform response Y.” Thus, future critical situations are linked explicitly to goal-directed responses; when predefined situational cues are encountered, a goal-directed response occurs automatically. The intention-to-behaviour process works in the following way: an individual forms a plan that involves a specific situation—the “if” part of the statement. This situation then becomes mentally represented. When the situation arises, the chosen goal-directed behaviour—the "then" part of the plan—will be performed automatically and without conscious effort. Such automatization of behaviour in response to this cue removes deliberation on the part of the individual. Cognitive resources are made available for other mental process tasks while also avoiding goal-threatening or competing goals. Implementation intentions have been widely used in health promotion interventions and initiatives. They are among the best predictors of behaviour and behaviour change.[49-51]

Taken together, use of these mechanisms can be considered an example of a 'wise' intervention, which are psychologically precise interventions with brief implementations that aim is to alter self-reinforcing processes.[52] These seek to alter the psychological process that has developed over time and allow for the recurrent behaviour. Wise interventions are most likely to cause long-term gains in inherently recursive contexts in which positive experiences facilitate later positive outcomes.[52]

Behavioural Change Techniques

We used Michie et al.'s (2013) taxonomy of behaviour change techniques (BCTs) to define how our intervention's Theory of Change was hypothesised to work via this 'wise' intervention structure.[53] Thirteen BCTs were utilized. Techniques were taken from across seven different categories of techniques, including goals and planning, natural consequences, associations, repetition and substitution, regulation, identity, and self-belief (Figure 4-10). As the intervention centres on the use of threat to professional identity, most BCTs fell within the identity category. In the values affirmation exercise, nurses were asked to write about cherished values as a means of affirming their identity (BCT 13.4). Then the messaging or educational component raised awareness of the discrepancy in nurses' HH practices when entering and exiting a patient's room. Information about the health consequences of not practicing HH upon entry were emphasized (BCT 5.1). The health message drew attention to the incongruity between the nurses' current HH practice and the required practice, and sought to reframe the behaviour as being a fundamental component of nurse professionalism and code of conduct (BCT 13.3). This discomfort sought to prompt nurses to feel motivated to achieve their personal best. Practicing HH before entering a patient's room would reaffirm their identity by reducing the cognitive dissonance between their ideal self-image and their day-to-day practice as a nurse (BCT 13.5). The cue-linking activity followed to help the nurses to explicitly identify the goal of practicing HH before entry and to create an action plan (BCTs 1.1 and 1.4). Nurses were asked to think of practicing HH and the environment near the patient's room (BCT 15.2). The action plan had nurses link practicing HH to a cue in the environment that would lead to automaticity (BCTs 7.1 and 15.2). Making the behaviour automatic would reduce the deliberation and hesitation to perform HH thereby conserving mental resources (BCT 11.3). Afterwards, nurses were encouraged to say to themselves *"As soon as I see [insert name of object] I will tell myself 'clean your hands!'"* (BCT 1.9). The intervention ended by asking nurses over the next several days to use the object they selected as a reminder to clean their hands (BCTs 8.1 and 8.3).

Intervention Materials and Proposed Delivery

The intervention is presented to participants in two separate parts in one day. The intervention is a self-guided activity and takes less than thirty minutes to complete. It is divided into two sections: the first part is the values affirmation activity and the second is the HH messaging with the implementation cue activity. Participants must complete the affirmation activity before being presented with the HH messaging.

Given the constraints of "taking nurses off the floor" to participate, the intervention can be administered either in-person in the hospital unit or online. How the intervention is administered is at the hospital administration's discretion. For the in-person delivery, the two parts of the survey are presented on separate sheets of paper. Respondents only receive the second page from the facilitator dependent on the completion of the values affirmation on the first page. When administered online, respondents complete the first exercise before being allowed to continue to the following activity. The intervention materials are provided in Appendix 4-2.

The facilitator oversees the delivery of the intervention in-person and ensures that the procedures are adhered to. The prompts for the facilitator are provided in Appendix 4-3. The facilitator does not need expertise or background in the topic of HH, and minimal training is required for the delivery of the intervention.

DISCUSSION

This project not only used a novel approach to designing and creating an intervention, but the final product was the creation of an original HH behaviour change intervention. To our knowledge, a 'wise' intervention has not previously been used to improve HH behaviour in HCWs.

The BCD Approach to Design

The BCD approach incorporates process steps that are rooted in design thinking for how to create an intervention. Many frameworks provide steps on how to distil prior knowledge and formative research findings into themes. Translating these themes into intervention components is not often discussed. The BCD approach provides a method for developing intervention components and thus creating practical, creative solutions. Ideas are “built up” through multiple brainstorming phases, which include input and participation from a wide variety of sources. What is unique about the process is that behaviour can be designed through an iterative collaborative effort between the target population and the intervention designers.[6]

The BCD approach is also flexible. In this case study, the process for developing the intervention deviated in several ways from the normal BCD process. The first deviation was seen in the formative research stage. BCD champions the use of a variety of data collection methods, specifically methods that are ‘near’—situationally and psychologically—to the behaviour that the intervention is trying to change. Such methods include observation or imaginative techniques for drawing informants into a virtual experience. This project only used a web-based survey to learn about the target population and the target behaviour due to time, resources, and budget constraints. The findings from formative research were based on the literature reviews and the survey, and therefore were limited in comparison to fieldwork. As such, the development of the intervention relied heavily on the Design Workshop. In turn, the Design Workshop depended almost entirely on experts in the healthcare field (such as active and inactive nurses and those who were company employees with ties to healthcare).

A second deviation from standard practice occurred in the Create step. BCD stresses the importance of using a creative agency, often with several reverts to refine the creative direction and to build out the intervention itself. Due to budget constraints, the project did not work with a creative agency, but rather used an in-house marketing team. Even though our design and create processes diverged from the usual BCD processes, the approach allowed for such adaptability to occur. The framework was shown to be able to accommodate different techniques and approaches so long as the main principles of each step were adhered to.

The Intervention

In this project, the entire development process was grounded in theory from the BCD design approach. BCD is founded in both behavioural science and design thinking practice and is based on a number of fundamental theories such as reinforcement learning, role theory, behaviour settings, and evolutionary psychology.[6] The intervention itself was underpinned by self-affirmation theory and intention implementation strategy. In addition, the behaviour change techniques in the intervention were pre-identified. This is the one of the first times that a HH intervention has been grounded in theory from inception to development and has specifically described the mechanisms of change behind its Theory of Change. Another distinct feature of the intervention was the use of the values affirmation activity and implementation intention exercise in the context of a HH intervention. The values affirmation activity has mainly been employed in educational settings to reduce the achievement gaps faced by minority students and women in science, technology, engineering, and mathematics courses.[54-57] Implementation intention exercises have previously been used in a wide-variety of health contexts ranging from promoting exercise[49] to prompting people to eat more fruit, but have been underutilized in changing the HH behaviour of HCWs.[58-60]

The intervention incorporated reading-and-writing exercises to change nurses' cognitive processes directly. The activities encouraged the nurses to respond to ongoing, unpredictable work experiences in more adaptive ways to strengthen their professional identities. Most interventions focus on introducing a new experience to people's lives. The change that occurs to the psychology of the person is indirect.

Moreover, if the cornerstone of the intervention is introducing a new experience, the intervention can be vulnerable if that experience changes. This intervention encouraged nurses to see themselves as being in control of their own professional identity through the repeated practice of HH, rather than just relying on a specific experience to induce and then sustain change.

Given the constraints and restrictions, the creative team did its best to faithfully translate the proposed components into an actual program with materials. The values affirmation exercise was included to reduce defensive processing of health risk information. It was also intended to guide nurses through a reflection on their own personal values and principles, which would then—it was hypothesised—lead into nurses considering their own professional code. By having nurses engage with internal discussions about values, the creative team assumed that nurses would receive the health message, be surprised, and in re-evaluating their behaviour would realise that practicing HH upon entering a patient's room would be an easy way for them to realign with their professional code. By using cues to direct behaviour, we would help nurses translate intentions into actions, thus allowing them to take simple actions that would produce good patient outcomes and would therefore lead to their own personal satisfaction. The creative team included the intended components, although the messaging of trying to have nurses reactive their commitment to the professional code by caring for patients via HHC to produce good patient outcomes was not as overt as we had expected it to be.

CONCLUSION

HH is widely accepted as the most important measure for the prevention of HAIs, but HHC rates are typically low. Numerous efforts have been made to increase HH among

HCWs, and yet these initiatives have been unable to bring about sustained changes in behaviour. This paper detailed the creation of an original HH intervention that used the BCD approach, and we discussed the intervention design process, starting from the identification of the evidence base to the creation of the final intervention materials. What emerged from the development process was a 'wise' intervention, a simple intervention based on a specific psychological theory. The mechanisms, and the corresponding BCTs, behind the hypothesised Theory of Change were identified and explained, demonstrating how the constructs of the behavioural framework were operationalised. The intervention designed was relatively simple compared to most HH initiatives in the literature, both in terms of having relatively few components and relatively easy field implementation. This intervention will allow us to test: a) how specific psychological processes contribute to the problem of low HH rates, b) how our proposed intervention may change these processes in the hospital setting, and c) how the expected change in nurses' cognition transforms over time as a result of the intervention. Being so specific about how the intervention works, and basing the theory of change on strong theoretical and empirical grounds, should increase the likelihood of it being effective at sustainably increasing nurses' HHC.

ADHERENCE TO REPORTING GUIDELINES

The TIDieR (Template for Intervention Description and Replication) Checklist was used to ensure that the original intervention discussed in this paper was described in sufficient detail [Appendix 4-1].

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We are grateful to Jeff Quinn and Sharon Guten for their support and assistance throughout each stage of the intervention design process.

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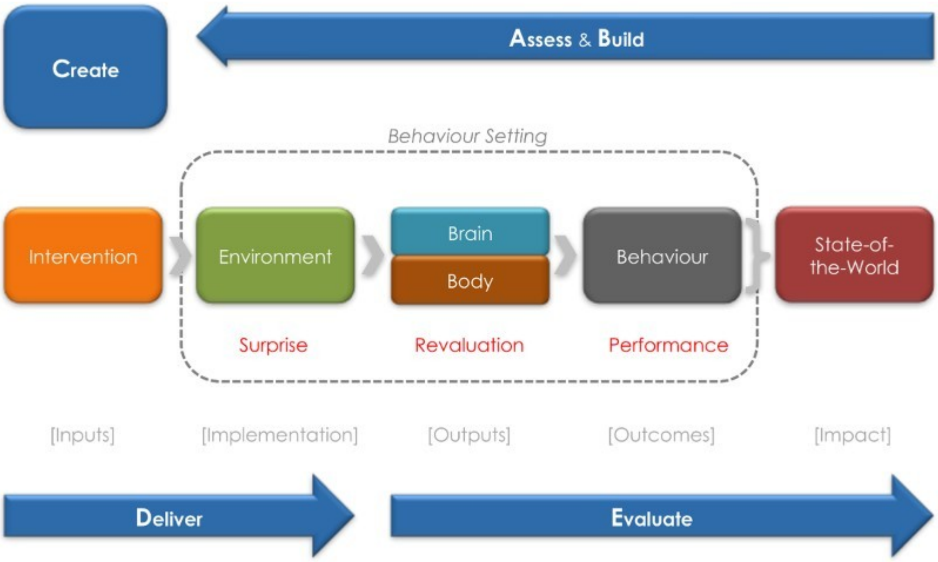
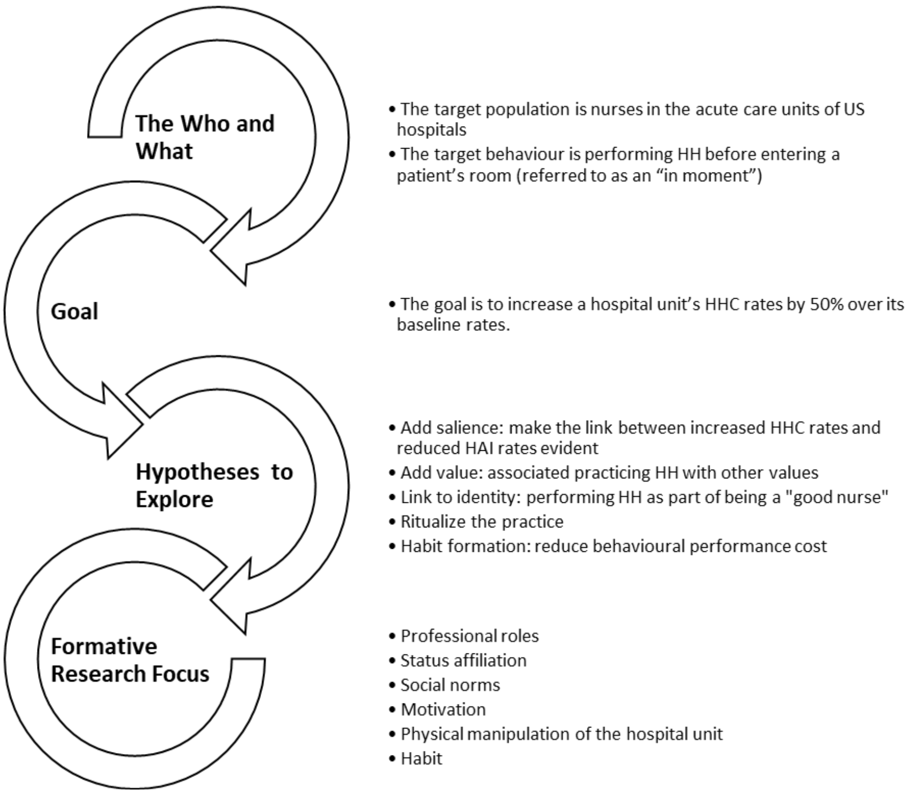
FIGURES

Figure 4- 1: Five steps of Behaviour Centred Design (BCD)



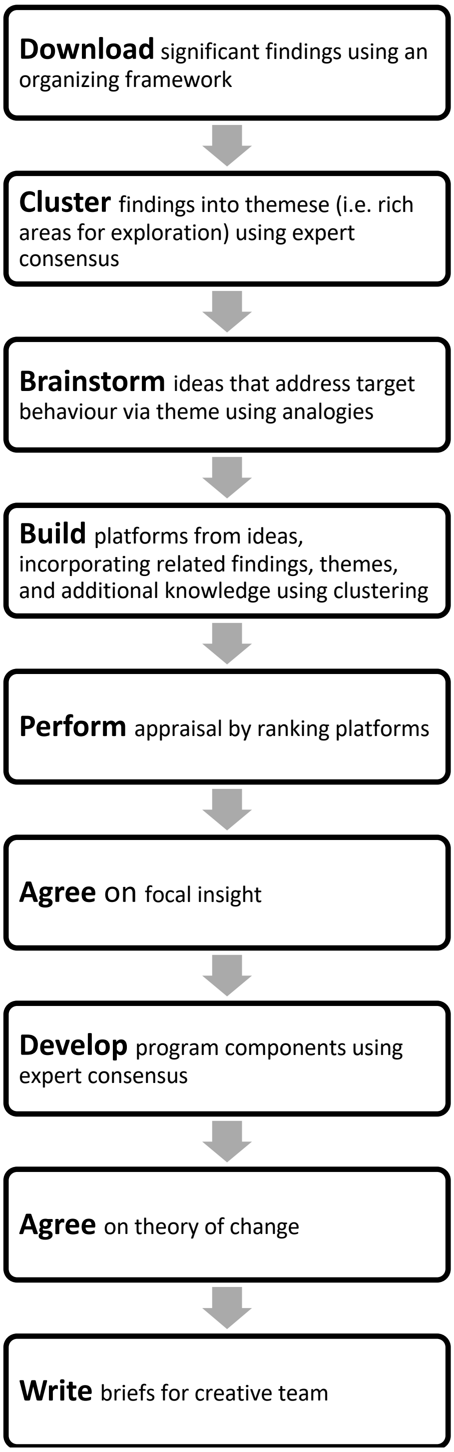
Reprinted from Aunger and Curtis, 2016.[6] BCD presents a systematic way to develop a program through five steps.

Figure 4- 2: Insight and focus from framing workshop



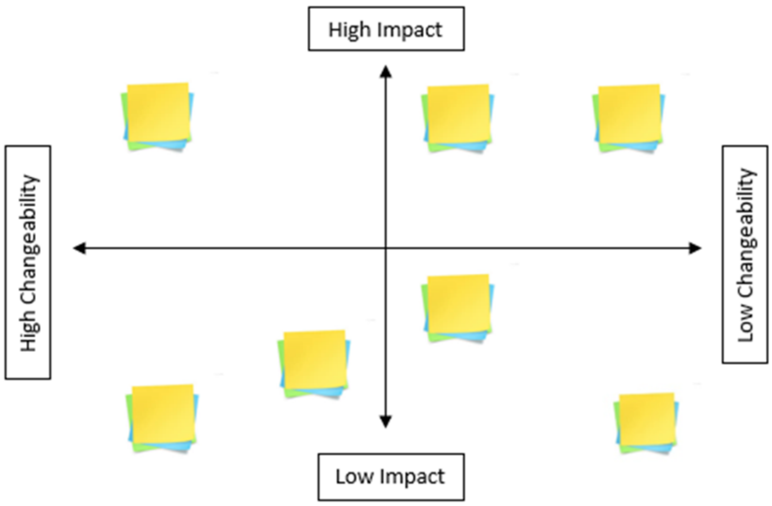
The workshop ends with a framing statement that serves as the foundation on which the rest of the project is built.

Figure 4- 3: BCD's design process for producing a focal insight



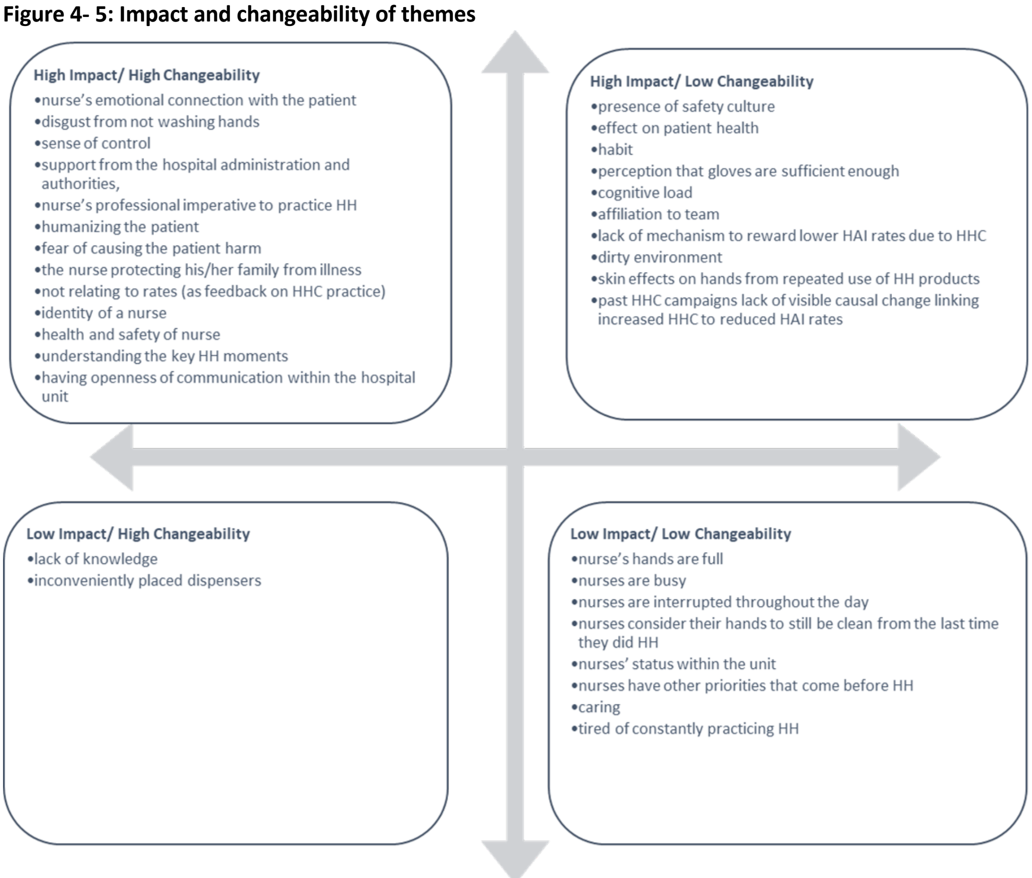
The design process can be described as a sequence of nine phases, which starts from analysing the findings from the field and concludes with a creative brief that explains the single focus of the intervention.

Figure 4- 4: Grid to measure impact and changeability



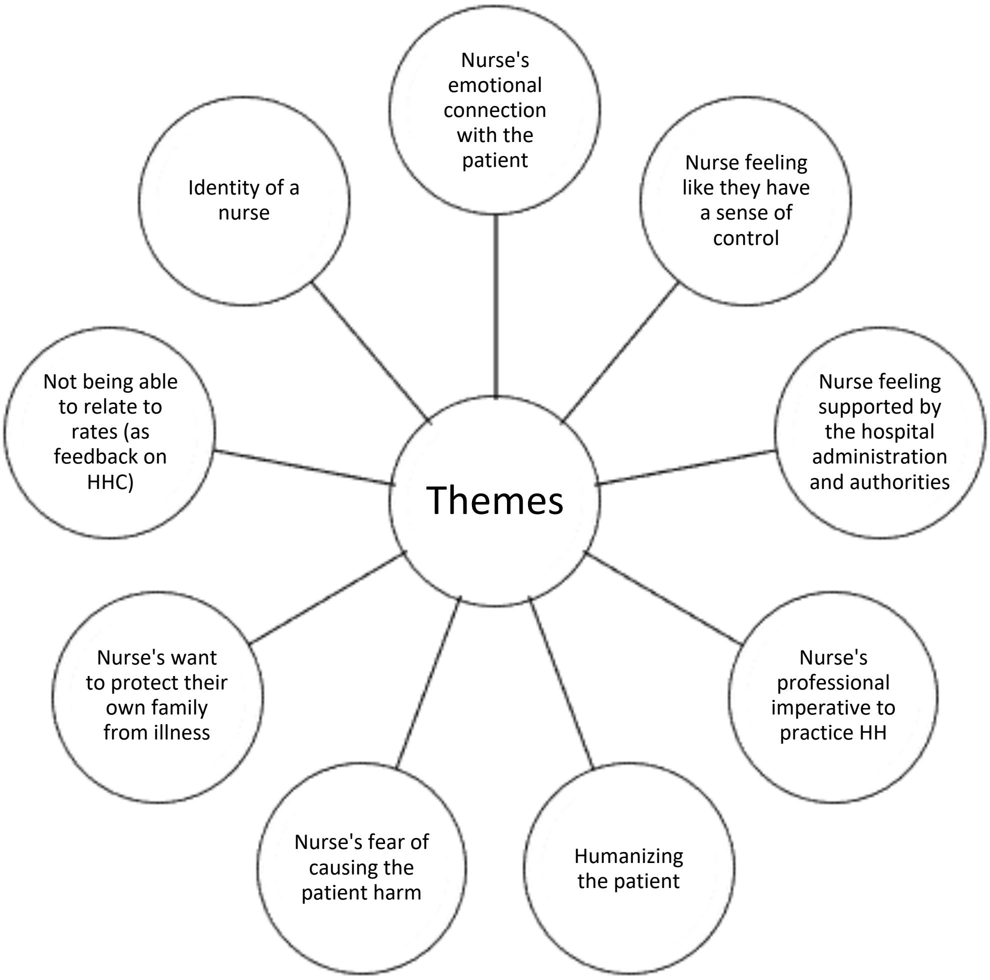
The remaining themes are then placed by the assembled group in a grid per their level of impact and changeability.

Figure 4- 5: Impact and changeability of themes



The formative research findings were presented, then clustered into groups, and evaluated on their level of impact and changeability.

Figure 4- 6: Most promising themes



The themes considered to be most impactful with the highest changeability were identified.

Figure 4- 7: Explication of the focal insight

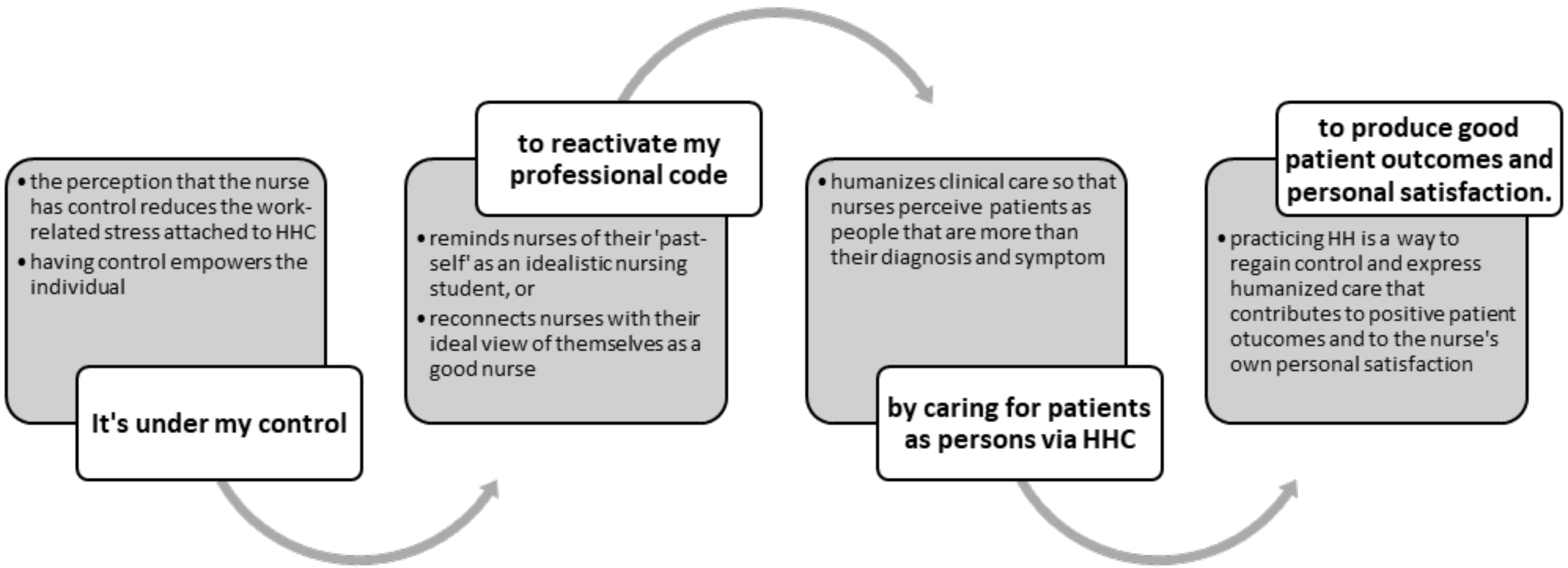
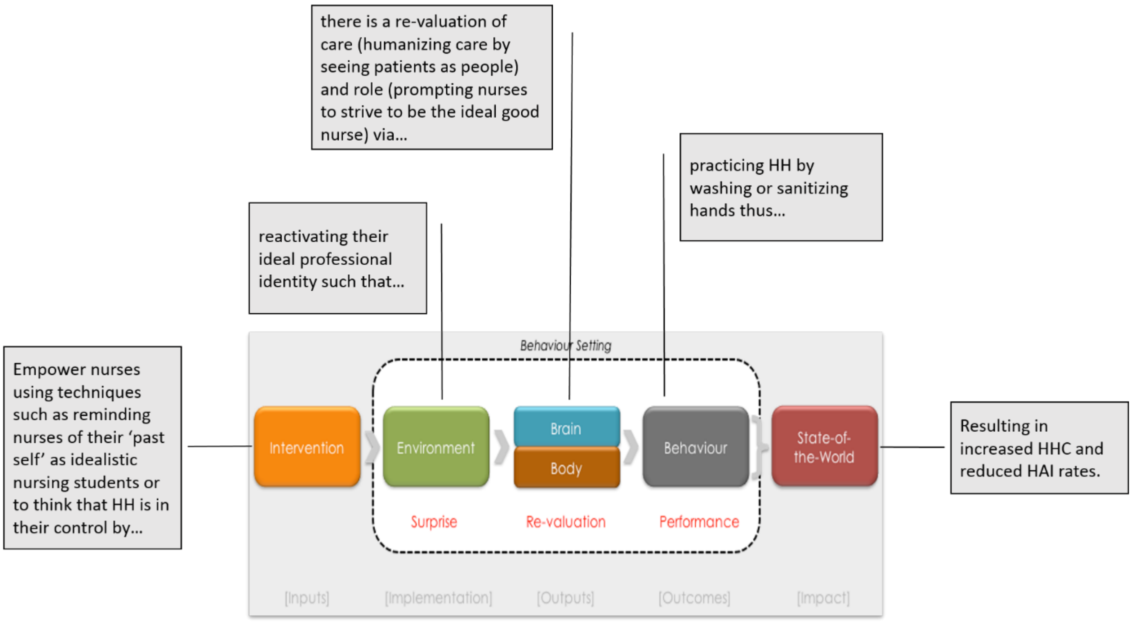
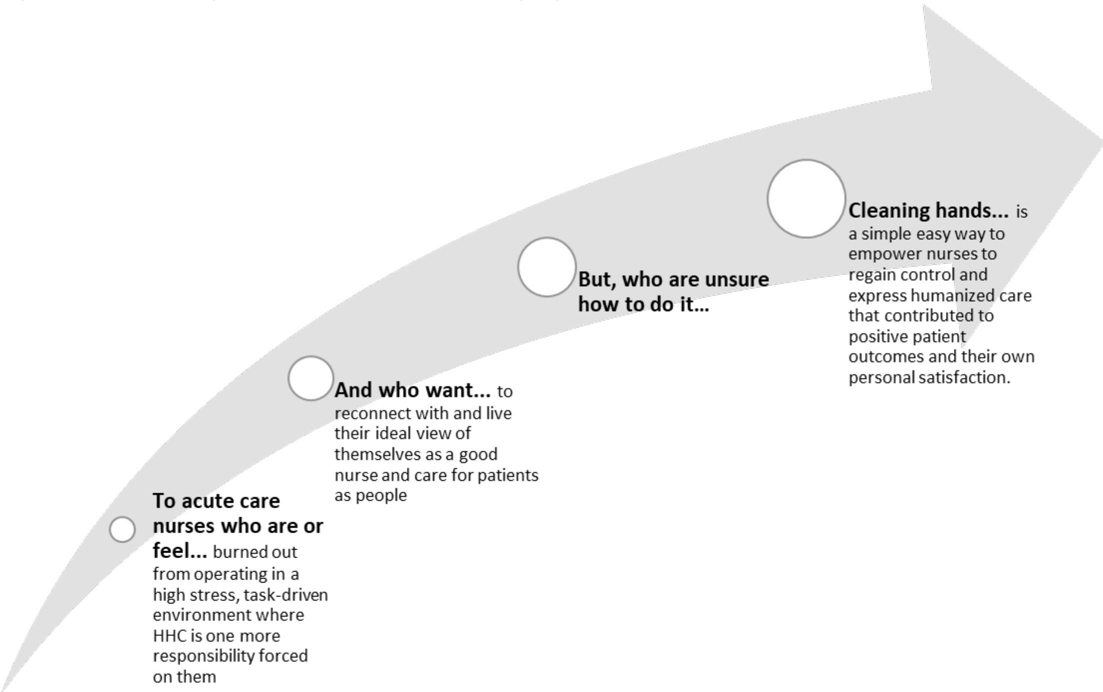


Figure 4- 8:Focal insight translated into a Theory of Change



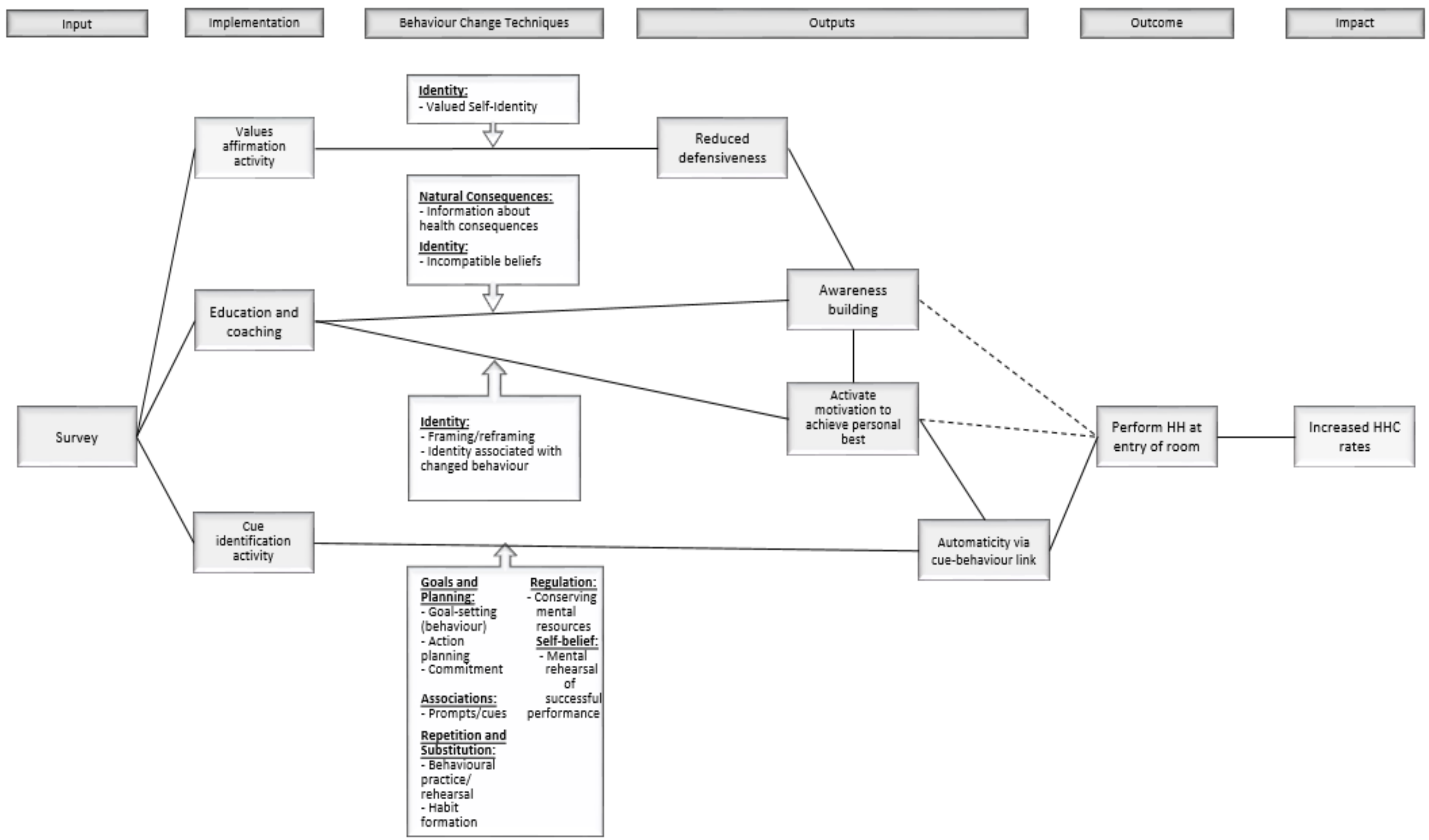
The focal insight was linked linguistically into a theory of change.

Figure 4- 9: Focal insight translated into creative language



The creative brief, aiming to provide a succinct overview of the focal insight and strategy, rephrased the insight to help the creative team understand and address the challenge.

Figure 4- 10: Mechanisms of change and their corresponding BCTs



Thirteen BCTs were utilized. Techniques were taken from across seven different categories of technique, including goals and planning, natural consequences, associations, repetition and substitution, regulation, identity, and self-belief.

CHAPTER 5: STUDY PROTOCOL

Evaluating a Hand Hygiene Intervention Designed for Nurses in Acute Care Units in U.S. Hospitals: A protocol and methods report for the *Mainspring* study

BACKGROUND

Healthcare-Associated Infections and Hand Hygiene

Healthcare-associated infections (HAIs) are a serious and persistent problem. There are nearly 2 million HAIs and 100,000 HAI-related deaths occurring annually in the United Sates.[1-3] Hand hygiene (HH) is considered the most important measure in preventing HAIs, with substantial evidence supporting the association between increased hand hygiene compliance (HHC) with reduced HAI rates.[4-10]

Current HH initiatives deemed to be successful in increasing HHC rates are multimodal approaches that bundle education, reminders, feedback, and in some cases, access to alcohol-based hand rub (ABHR) and the inclusion of hospital administrative support.[11, 12] These interventions are complex, with several interacting components, which are demanding on the research team and intervention implementers. They also require a substantial amount of time and resources from the hospital, the unit, and the individual nurses alike, which is not always practical. In addition, researchers do not always make clear the theoretical underpinnings of the intervention, thus making it difficult to link the intervention to causal change. Even when studies do cite behavioural frameworks, the interventions tend to default to standard multimodal programmes utilizing audit, feedback, education, and positive reinforcement in addition to education, reminders, and availability of HH products.[13] Interventions based on psychological frameworks of behaviour change that clearly describe and operationalize constructs have the potential to predict HH behaviour and inform interventions to improve HHC.

Most initiatives fail to approach HH as a repetitive, automatic behaviour that can be habit-forming.[13, 14] As such, studies treat HH as a deliberate action rather than a spontaneous behaviour involving non-thoughtful behavioural responses. Thus, there are behaviour change mechanisms that have not been examined by the public health community regarding improving HHC.

Hand Hygiene Compliance Rates and Acute Care Nurses

Acute care nurses have an important position within the healthcare system as they work directly with patients who require immediate and serious care. While interdisciplinary collaboration in acute care— especially in intensive care units (ICUs)— is routine practice within the healthcare delivery team, acute care nurses have the most direct contact with patients.[15] Nurses have reported that 85-88% of their time is spent on direct patient care.[16] Moreover, rates of HHC have been shown to vary amongst the different healthcare professions, with nurses having the highest HHC as compared to other healthcare workers (HCWs) such as doctors.[17] In addition, nurses tend to show significant improvement in their HHC rates post-intervention as compared to other healthcare professionals.[17-19] This supports the idea that a ”one-size-fits-all” strategy to hospital-wide education and quality improvement interventions may not be effective for all healthcare workers.[19] Targeting physicians or other HCWs would also require strategies other than those employed in the intervention for nurses.

The Mainspring Intervention

The intervention sought to focus on the identity threat mechanism.[20, 21] In the planned intervention, nurses were presented with evidence indicating that they were not conforming to professional expectations about their behaviour with respect to HH. Consequently, this new information would hypothetically introduce a significant discrepancy between desired identity (as being a good hand washer) and newly perceived identity (as a poor hand washer). We assumed that the nurses would naturally try to repair their professional identity after this threat by bringing their behaviour more closely into conformity with professional standards ('the self-integrity motive'). We predicted that the nurses would experience defensiveness in response to the threat to their self-image and therefore would try to find ways to reject or avoid the new evidence. In doing so, they would try to re-establish the good standing of their self-image without engaging in any effort to modify their behaviour. It was important for nurses to accept the implicit self-critique and attempt to address it by changing their behaviour. Thus, we sought to reduce defensiveness through the values affirmation exercise, which we hypothesised would allow for nurses to be more accepting of the polarizing information shared regarding poor HHC rates before entering a patient's room. Being open to receiving this information meant that the nurses' misconceptions regarding HHC could be corrected and a process of discovery could occur. We then asked nurses to confirm their level of intention to increase their HHC. We did so by assisting them in forming an implementation intention to support practicing HH at a higher rate. By linking HH performance to contextual cues, we predicted that nurses would be more likely to implement their intention to practice HH. Sands et al. (2019) detailed the development of this intervention.[22] For further information, refer to the intervention materials for nurses in Appendix 4-2 and the delivery protocol for the facilitator in Appendix 4-3.

AIMS, OBJECTIVES, AND HYPOTHESIS

The aim of this study was to test an intervention strategy in acute care hospital units to improve nurses' HHC and to compare the short-term and sustained effects of this novel strategy. The *Mainspring* study sought to increase the HHC rates in each of the hospital units by 50% over the units' respective baseline HHC rate for a 3-month period.[**][††]

The objectives of this project were: 1) to develop an original intervention that improved nurses' HHC compliance, 2) to analyse the effects of the intervention, and 3) to gain insight into determinants of success or failure of the strategy.

Our hypothesis was that the intervention— which used activities such as values affirmation, tailored education coaching and cue identification— would be effective in increasing the HHC rates of nurses by empowering the individual to reactivate their commitment to their professional code of nursing. By practicing HHC, nurses care for patients as persons and as such produce good patient outcomes and personal satisfaction.

[**] The relative increase of 50% was decided upon by the core research group during the framing workshop of the intervention development phase (refer to Chapter 4). The Project Funder (GOJO Industries Inc.) insisted upon a 50% increase over the baseline rate with the reasoning that: a) the increase would be unit specific; if a unit had a lower baseline HHC rate than the other units, we would expect to see a greater increase than a unit with a much higher baseline rate and b) in the HH intervention packages they delivered as a company to hospitals, they had the goal of 50% increase over the baseline rate; thus, we would keep the expected value consistent.

[††] We compared this possible effect size to that of ten other studies that evaluated interventions to improve HHC of nurses in hospitals. The findings have been presented in Table 5-1.

METHODS

The outcome measurement was the percentage of opportunities at which HH was performed by the nurses. An opportunity was defined as the moment when the nurse entered or exited a room. An event occurred when the nurse had practiced HH—either by hand washing with soap and water or by disinfecting using ABHR— when an opportunity had presented itself.[‡‡]

Study Design

The study adopted a multiple baseline design, which has been recognized as a useful experimental design for studying behaviour change.[23-25] It is a form of time-series design that allows for the same groups to be compared over time by repeated measuring and analysing of data. One population group (or hospital unit in our case) can be used with its baseline measure acting as the control comparison. The interventions are staggered across time and hospital units, with each hospital unit deliberately receiving the intervention at a different point in time. Running multiple time-series in numerous hospital units will increase confidence that the intervention is responsible for the change in outcome.

Setting

Two hospitals—Hospital A and Hospital B— were used in this study. The hospitals nominated at least two acute care units to participate in this study. After completing baseline measurements in the reference period of six months, units were randomly assigned start dates for the intervention.

[‡‡] In ICUs in US hospitals, patients are nursed in individual rooms (i.e. no rooms with >1 person). Therefore, defining HH in terms of entering and exiting a room is a reasonable and simple measure.

Hospitals were recruited by the Project Funder based on the initial specific inclusion criteria agreed upon by the research team: hospitals must a) be located in the same geographical region of the United States, b) have the same electronic compliance monitoring (ECM) technology installed for at least six months prior to the intervention, c) both be medical-surgical hospitals that have acute care units willing to participate, and d) have not participated in a HH intervention for at least six months prior to the start of the baseline data collection.

Participants

The intervention was only delivered to nurses working in the selected units. The hospitals themselves were tasked with overseeing nurse recruitment. The research team expected the intervention's Facilitator to work alongside the Hospital Administrators and Nurse Managers to lead recruitment efforts.

As we were using an ECM system without personal badges, we were unable to discriminate between individuals such as nurses, physicians, environmental service technicians, or visiting family members. The basic assumption, however, was that nurses, having the most interaction with patients, constituted the majority of the entries and exits of patients' rooms and thus dispenser uses.

Controlling for Threats to Validity

Threats to Internal Validity

Exposure to disease trends and current events. As the data collection in the units was conducted simultaneously, the participants experienced the same flu season during the data collection time period.

Selection of Hospitals. Hospitals were recruited based on the specific inclusion criteria listed above. With the criteria, the research team sought to ensure that the hospitals are as comparable in likeness as possible.

Instrumentation. The main method of measurement was the Project Funder's ECM system, which collected data in real-time continuously throughout the day. The data was backed-up to the Project Funder's external server.

Design Contamination. We defined contamination as being nurses, who primarily worked in the other units that had not yet received the intervention, being made aware of the intervention prematurely. To avoid contamination, interventions were introduced in units of the same hospital that did not use nurses from other units; each of the units provided a specific type of care. Both hospitals assured the research team that nurses from the units selected to participate would not work as "float nurses" in the other selected units given the vast difference in specialty of care provided and the units would not share any "float nurses" between them. Moreover, the units in Hospital A were located on different floors of the same building while the units in Hospital B were located in separate buildings. This also reduced the possibility of contamination.

Threats to External Validity

Effects of Selection*.* As the research team only considered two hospitals (of which only acute units in each were used), the results are not generalizable. However, results could guide whether an additional larger-scale study should be pursued.

Effects of Setting. The two hospitals were in the same geographical region of the United States. The United States is a large and diverse country, and the various geographical regions have their own customs. By being in the same geographical region, the research team could account for similar customs. In addition, being in the same region of the US allowed for the research team to control for diseases endemic to the region or for outbreaks that occurred within the region, all of which could affect HH behaviour of nurses.

Effects of History. While the study itself began in March 2016, data already collected by the dispensers were analysed to determine the effects of history and seasonal trends. By looking at data from 2015, the research team was able to determine a baseline that was more reflective of the hospital units' actual HHC rate. By determining how HHC rates were affected during the flu season, the research team was able to analyse whether fluctuations in compliance rates were due to the intervention working or due to these other factors.

Data Collection

Outcome Evaluation

HHC in this project was measured through an ECM system, which was comprised of soap and ABHR dispensers fitted with sensors that communicated with sensors above the patient room doorways. A module in the dispenser recognised, tracked, and transmitted near real-time HH activity data continuously throughout the day (Figure 5-1). Stable baseline data were collected for a minimum period of six months (26 weeks) for each unit with a follow-up period of 6-months post-intervention.

Process Evaluation

We conducted a process evaluation to identify the key components of the intervention that were effective and to identify under what conditions the intervention succeeded or failed. The process evaluation investigated how the intervention influenced the behavioural outcomes.

Our process evaluation incorporated the use of questionnaires and non-participant observation. Questionnaires were administered to the nurses and to the intervention’s Facilitator following the delivery of the intervention; nurses received the questionnaire 4-6 weeks after delivery in their units and the Facilitator received the questionnaire immediately following delivery. The non-participant observation was conducted during the actual delivery of the intervention. The questionnaire for the nurses and the Facilitator are provided in Appendix 5-1 and Appendix 5-2, respectively. Nurses were purposively sampled most likely in the same method as the intervention.

Statistical Analysis

Analysis of the outcome evaluation data was divided into a primary analysis using standard interrupted time series (ITS) analysis techniques, and a supplementary method of analysis, statistical process control (SPC), to ensure that the differences in outcome could be assigned to the role of the intervention. The process evaluation data used mixed methods. The analysis for each evaluation is expanded upon as follows:

Outcome Evaluation

Interrupted time series analysis (ITS). Using RStudio, the ITS analysis estimated changes in level and trend of HHC following the implementation of the intervention. This method controlled for the baseline level and trend when estimating expected changes in the rate due to the intervention.[26] We specifically used segmented regression analysis to estimate the mean HHC rates per week in the post-intervention period.[27] The time-series regression equation for this model was:

$$\Upsilon_t = \beta_0 + \beta_1 \times \mathrm{time}_t + \beta_2 \times \mathrm{intervention}_t + \beta_3 \times \ \mathrm{time\ after\ intervention}_t + e_t$$

Where:

Υ_t	the outcome (mean HHC rate per week)
time	indicates the number of weeks from the start of the series (1-xx)
intervention	dummy variable taking the values 0 in the pre-intervention segment and 1 in the post-intervention segment
time after intervention	0 in the pre-intervention segments and counts the weeks in the post-intervention segments at time t (1-yy)
β_0	estimates the base level of the outcome (HHC rate) at the beginning of the series
β_1	estimates the base trend, which is the change in outcome per week in the pre-intervention segment
β_2	estimates the change in level of HHC rates in the post-intervention segment
β_3	estimates the change in trend in HHC rates in the post-intervention segments
e_t	estimates the error; standard errors will be clustered at unit-level

Statistical process control (SPC). SPC charts were used to determine whether changes in processes produced by the intervention were making a real difference in outcomes. Repeated measures of the same parameter—such as an ECM system with various dispensers collecting repeated measures of HHC in hospitals— could yield slightly different results even if there was no fundamental change.[28] This inherent variability could be due to various factors with one example being imperfections in the compliance measurement process. SPC allows for the identification of the naturally occurring variability within the process. These methods combine time series analysis methods with graphical presentation of data to detect changes and trends. By establishing statistical limits and testing for data that deviate from predictions, the research team could examine whether changes in HHC rates were within expected variability of the system or if the rates were outside what was expected. SPC provided statistical evidence of a change. As the outcome was a dichotomous event (a Bernoulli trial), a *p*-control chart was most appropriate and will be created for each of the hospital units. More information about SPC is provided in Appendix 5-3.

Process Evaluation

We used mixed methods and mixed analytic strategies to explain the process evaluation data. Descriptive statistics were calculated. Where sample size allowed for multivariate statics, such analytic strategies were applied. Regarding the open-ended Facilitator questionnaire and the non-participant observation, content analysis and interpretive analysis were conducted as per the approaches presented in Bernard (2011).[29]

Sample Size for Outcome Evaluation

To conduct segmented regression analysis, there needs to be an adequate number of time points before and after the intervention. For a long time series, the Cochrane's EPOC Group requires that at least 20 observation points be collected in the pre-intervention.[30] The Centre for Clinical Epidemiology and Biostatistics at the University of Newcastle recommends 12 data points before and 12 data points after an intervention;[27, 31] however, Wagner et al. (2002) highlights that this number is not based on estimates of power and so recommends 24 monthly measures to allow for the analyst to adequately evaluate seasonal variation (such as that of the flu season).[27] To ensure an acceptable level of variability of the estimate at each time point, there must be an adequate number of observations at each data point of the time series. A minimum of 100 observations is advised.[27]

The research team conducted its own power calculations and graphed the findings accordingly. The calculations were based on monitored HH events, opportunities, and calculated compliance rates for two hospitals with the same ECM system as those we will be recruiting for this study. Simulations were conducted to estimate the power of segmented logistic regression models when the main intervention effect size was 25%, 50%, and 75% and the interaction between time and intervention were -0.0025, -0.005, and -0.0075, respectively. We conducted 5000 simulations for each scenario and estimated that for all numbers of time points we examined, we had 85-99% power to detect these effects (alpha - .05). The graphs and corresponding data are presented in Appendix 5-4. It should be noted that the power calculations were based on the number of observations the research team needed to collect in order to have significant findings. We did not calculate power calculations on the basis of primary outcome (HHC).

ETHICAL CONSIDERATION

The intervention delivery and data acquisition, apart from the nonparticipant observation, were performed by the Facilitator (who is a paid employee of the Project Funder). The Project Funder is a privately held company that manufactures HH and skin care products. It had written a letter to LSHTM's Ethics Committee stating that it would follow professional marketing ethics guidelines during all data collection procedures [Appendix 5-5]. Furthermore, all participants in intervention studies remained anonymous as did the identity of the participating hospitals and their specific locations. In addition, the Project Funder submitted this project to the respective Institutional Review Boards of the recruited hospitals for this study. The LSHTM Ethics Committee approved this project; the reference number is 14411 [Appendix 5-6].

DISCUSSION

Results from our study add to the general HH intervention body of knowledge through the evaluation of new approaches to changing behaviour. Instead of creating a complex-intervention based on the standard multimodal approaches, we evaluated a simple intervention that sought to change behaviour by employing the identity threat mechanism. Various theories and techniques such as values affirmation, education-coaching, and implementation intentions were used to incite behaviour change.

Methodological Strengths and Limitations

The purpose of any experimental design is to determine whether the independent variable of interest affects the dependent variable. Confidence in our conclusions regarding the cause-effect relationship between the independent and dependent variables is a function of our ability to reject other variables as contributors to the effect observed; this is a matter of internal validity. Our multiple baseline design controls for common internal threats to validity.

History

Our design controlled for historical events—events that co-occurred with the intervention— that took place across all units in the same region. For example, the occurrence of the flu season could have affected all units in the region. Thus, if the HHC rates of a unit changed when the intervention was introduced while those units that remained in the baseline phase did not see a change in the HHC rates, we could be confident that the change is not due to concurrent events that would affect the other units. There was the possibility that events could occur within a hospital or within a unit that accounted for the effect in that hospital or unit. This possibility was addressed in the replication of the intervention in subsequent units and in another hospital.

Testing and Instrumentation

The use of repeated and ongoing measurement usually establishes unique challenges regarding instrumentation and testing in multiple baseline design studies. However, the same ECM system was used to collect data across all the units involved in the study. Furthermore, the placement of the ECM system was consistent, as all sensors were placed above the doorway of the patient's room and in dispensers in the immediate vicinity of the doorway (inside and outside the room). The ECM systems were installed in all participating units for a minimum of 3-months prior to the beginning of data collection, allowing for the nurses to become comfortable with the new technology. Thus, the nurses' behaviour and HH performance should not have been affected by new technology at the start of pre-intervention data collection (i.e. avoiding "installation" Hawthorne effect). The process of assessment should not have affected the measure.

Instability

Instability is the variability in the repeated time series. When measures are highly variable, it can be difficult to detect the effects of an intervention. However, much of the variability in a time series is systematic and predictable.[32] Trend and cycles can be controlled statistically using methods such as modelling. However, uncontrolled variability poses a threat. This variability can result from the unreliability of the measurement or from the fact that the process itself is inherently unstable. Such sources of instability were identified in the process evaluation and were addressed accordingly in the analysis. Moreover, the use of SPC allowed us to identify whether the change in the pattern of observed data was within the limits, and thus contributed to the inherent variability of the system rather than to the intervention itself.

Statistical Regression

Statistical regression is the tendency of extreme scores to regress toward the mean with each measurement occasion. If a baseline HHC measure is extremely high (or extremely low), we might conclude that the intervention produced a change that was most likely due to regression toward the mean. Stable baseline data collected over 6-months eliminated regression to the mean as a plausible explanation. Also, using SPC allowed for the research team to identify if the change was outside two standard deviations and could be an effect of the intervention.

Selection

Selection effects refer to pre-existing differences between cases in group designs and can threaten internal validity as such selection effects may account for what appears to be effects of experimental condition. While this study included numerous units across two hospitals, there was no treatment or control groups. To account for this, we compared the relative performance of each unit against its baseline HHC rates as well against one another. Subsequent replication of the effect of the intervention in the other units provided further evidence and support.[32]

In all, the assessment and evaluation of experimental control and internal validity depended substantially on the study's ability to collect and establish a robust data set within and across the data series. As the ECM system collected continuous real-time data, and as the research team collected at least 6-months of data prior to implementation of the intervention and 6-months post-intervention, the data was expected to be robust, within and across all hospital units.

Possible Challenges

We predicted that several challenges would arise through the research project. There was a diverse group of research partners, stakeholders, and participants involved in this project that include the Project Funder, the Facilitator, the research team, hospital administrators, Nurse Managers, and nurses. Coordinating cooperation amongst stakeholders was difficult, and ensuring that everyone agreed and adhered to set arrangements and schedules was onerous. While we ideally planned to stagger the implementation of the interventions in each unit by one month, we were aware that hospitals are rapidly changing, uncertain, and complex environments and that our delivery and implementation would require flexibility.

CONCLUSION

This study aimed to develop a strong yet simple intervention that changed the HH behaviour of nurses and increased HHC rates. We hope that our findings will justify more extensive tests of replicability, efficacy, and generalizability using RCTs.

ACKNOWLEDGEMENTS

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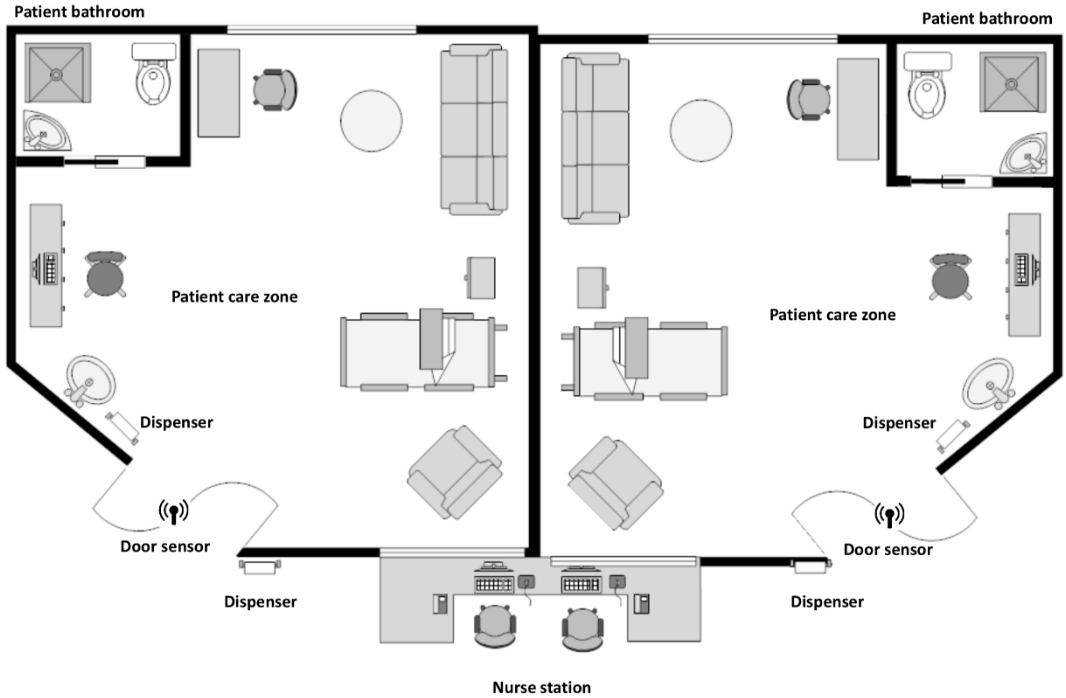
FIGURES

Figure 5- 1: Visual representation of the ECM system



Sensors are in the doorway and in ABHR and soap dispensers immediately inside and outside a patient's room.

TABLES

Table 5- 1: Comparison of changes in HHC rates in other studies

Study	Design		HHC Rates (%)			
			Pre-intervention (baseline)	**Post-intervention**	**Overall change**	**Percent change over baseline**
Huis et al. (2013)[33]	Cluster Randomized Trial	State-of-the-art group	23	46	23	100
		Teams-and-leaders-directed group	20	53	33	165
Erasmus et al. (2010)[34]	Pre-Post Test		9.3	25.4	16.1	173
Stock et al. (2016)[35]	Controlled Before and After		64.3	79.2	14.9	23.17
Fox et al. (2015)[36]	Pre-experimental (Post-test only)	Entering patient room	35	66	31	88.57
		Exiting patient room	66	79	13	19.7
Gould & Chamberlain (1997)[37]	Controlled Before and After		54	58	4	7.4
Huang et al. (2002)[38]	Randomized Control Trial	Before patient contact	51	86	35	68.6
		After patient contact	75	91	16	21.3
Dubbert et al. (1990)[39]	Interrupted Time Series		81	94	13	13.5

The studies were identified from the systematic review conducted for this thesis (refer to Chapter 2) and also from a systematic review by Doronina et al. (2017) which looked at the effectiveness of interventions on HHC of nurses in hospitals.[40] When comparing the ten studies, the mean percentage change over baseline was 68.02% and the median was 46%. Thus, our target effect of 50% improvement over the baseline rate for each hospital unit, while a lofty goal, was not improbable.

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RESEARCH PAPER COVER SHEET

PLEASE NOTE THAT A COVER SHEET MUST BE COMPLETED FOR EACH RESEARCH PAPER INCLUDED IN A THESIS.

SECTION A – Student Details

Student	Madeline Sands
Principal Supervisor	Dr. Robert Aunger
Thesis Title	Infection Control in Our Hands: Developing and Evaluating a Novel Intervention to Improve the Hand Hygiene Behaviour of Nurses in Acute Care Hospital Units in the US

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

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SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Journal of Advanced Nursing
Please list the paper's authors in the intended authorship order:	Ben Tidwell Madeline Sands Robert Aunger
Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Madeline Sands made substantial contributions to the conception and design of the study, contributed to the interpretation of results, and drafted the manuscript. .

Student Signature: [redacted] **Date:** 5 October 2019

Supervisor Signature: [redacted] **Date:** 15 October 2019

CHAPTER 6: OUTCOME EVALUATION

A 'wise' intervention to increase hand hygiene compliance of nurses in acute care units in US hospitals: A multiple baseline interrupted time-series analysis

ABSTRACT

AIMS: The aim of this study—called the *Mainspring* study— was to test an intervention strategy in acute care hospital units to improve nurses' hand hygiene compliance (HHC) and to compare the short-term and sustained effects of this novel strategy. The objectives are: 1) to develop an original intervention that improves nurses' HHC, 2) to analyse the effects of the intervention, and 3) to identify the determinants of success or failure of the strategy.

DESIGN: The setting for the *Mainspring* study involved two medical-surgical teaching hospitals located in the United States, named Hospital A and Hospital B to maintain anonymity. All participating hospital units provided acute care, with each having a different specialty of care. The study adopted a multiple baseline design. The delivery of the intervention was staggered across time and unit for each hospital, with at least a month in between each implementation session. The hospital units were randomly assigned start dates. The study ran for nine months, with the first hospital unit receiving the intervention in August 2016 and the last hospital unit receiving the intervention in April 2017. The outcome measure was the proportion of opportunities in which HH was undertaken over the course of a week in each unit. An opportunity occurred whenever an individual entered or exited a patient room. Data was collected using an electronic compliance monitoring system with sensors placed in doorways and corresponding soap and alcohol-based hand rub dispensers.

METHODS: To identify the effect of the intervention— if any—on HHC rates, interrupted time series (ITS) analysis using a quasi-Poisson regression model was performed. Statistical process control (SPC) charts were created for each unit to determine if the effects were due to naturally occurring variance or a result of unnatural variation stemming from events, such as the intervention, not inherent in the regular process.

RESULTS: The overall aggregate result from the intervention shows a statistically significant increase in HHC rates that was sustained for at least 3-months post-intervention. However, the patterns by unit were varied and in multiple cases were not statistically significant once temporal trends were considered. Other factors outside of the intervention, such as the type of unit, the involvement of the Nurse Manager, and the use of incentives could have impacted the results. Moreover, the SPC analysis showed that much of the increase in rates could also be due to naturally occurring variance.

CONCLUSION: In all, these analyses suggest that the aggregate impact should not be taken as evidence of intervention effectiveness; the null effects in some units were simply due to unmeasured confounders. This study therefore cannot be considered to have provided a strong foundation for use of this particular ‘wise’ intervention targeting professional identity at scale, despite its relatively small financial, logistical and psychological cost. However, given these potential benefits, such interventions should be further studied and tested.

IMPACT: The study sought to address the problem of low HHC rates in healthcare settings. To sustainably increase the HHC rates of nurses, we developed a ‘wise’

intervention that sought to reanimate nurses' sense of professional identity and responsibility, thus influencing the likelihood they would practice hand hygiene at expected moments. While the aggregate results showed a statistically significant increase in HHC rates, the patterns at the unit level were varied and in multiple cases were not statistically significant once temporal trends were considered. These findings will appeal to researchers, healthcare workers, and policy-makers interested in creating novel behaviour change interventions regarding hand hygiene in healthcare settings.

INTRODUCTION

Healthcare-associated infections (HAIs) are a major threat globally to patient safety, often resulting in complications of care to millions of patients.[1] The causes of HAIs can be attributed to the health systems and processes of care provision as well as to behavioural practices.[2] Hand hygiene (HH) is recognized as the single most important measure for preventing the spread of HAIs with substantial evidence supporting the association between increased hand hygiene compliance (HHC) and reduced HAI rates.[3-9]

Although there have been many attempts to increase HHC amongst health care workers (HCWs), in the great majority of cases these efforts have led to initial increases in HHC rates but have not produced sustained behavioural changes without an ongoing multifaceted approach.[6, 8, 10-13] The present study sought to increase HCW's—most specifically nurses'—HHC rates by informing the development and performing an evaluation of an innovative HH intervention. The focus of this evaluation was on the assessment of the intervention's impact on HHC and the intervention's relevance to healthcare settings. Behaviour Centred Design (BCD) was used to uncover novel avenues to change behaviour, as well as to guide the intervention development process itself.[14, 15]

BACKGROUND

Mainspring Study Intervention

The intervention centred on the use of threat to professional identity to prompt change.[16] The intervention's main health message explained that nurses were less likely to perform HH at room entry than at room exit, and drew attention to the incongruity between the nurses' current HH practice and their required practice. This message was intended to surprise the nurses. To decrease defensiveness and, in turn, increase openness to the message, a values affirmation exercise was included as the first part of the intervention. This made it an example of a 'wise' intervention, a brief intervention that seeks to disrupt a recursive process, and thus facilitates a positive experience that leads to later positive outcomes.[17] The full description of the intervention is provided in Appendix 6-1 and follows the Template for Intervention Description and Replication (TIDieR) Checklist to ensure complete description of the intervention.[18]

THE STUDY

Aims and Objectives

The aim of this study—called the *Mainspring* study— was to test an intervention strategy in acute care hospital units to improve nurses' HHC compliance and to compare the short-term and sustained effects of this novel strategy. The objectives were: 1) to develop an original intervention that improves nurses' HHC compliance, 2) to analyse the effects of the intervention, and 3) to identify the determinants of success or failure of the strategy, which are further expanded upon in Sands and Aunger, 2019.[19]

Study Population

The setting for the *Mainspring* study involved two medical-surgical teaching hospitals located in the United States, named Hospital A and Hospital B to maintain anonymity. All participating hospital units provided acute care, with each having a different specialty of care. Unit characteristics can be seen in Table 6-1. All units had 12 hour shifts.

Study Design

The study adopted a multiple baseline design, which has been recognized as a useful experimental design for studying behaviour change.[20-22] Each hospital unit deliberately receives the intervention at a different point in time. With this form of time-series design, the same groups can be compared over time by repeatedly measuring and analysing data, with baseline measures acting as the control comparisons.

In the *Mainspring study*, the delivery of the intervention was staggered across time and unit for each hospital, with at least a month in between each implementation session. The hospital units were randomly assigned start dates. The study ran for nine months, with the first hospital unit receiving the intervention in August 2016 and the last hospital unit receiving the intervention in April 2017.

Ethical Considerations

The Ethics Committee of LSHTM granted permission for this research (reference number 14411) and the hospital review boards both exempted the study considering it a quality improvement project instead.

Data Collection

The two hospitals were purposively selected as they had the same electronic compliance monitoring (ECM) technology, were in the same geographic area of the United States, were comparable in size and type of care provided, and had initially reported not completing or participating in a formal HH intervention in the six months before January 2016, which was necessary to ensure true baseline rates. HHC was measured through soap and alcohol-based hand rub (ABHR) dispensers fitted with ECM technology. A module in the dispenser recognized, tracked, and transmitted near real-time HH activity data continuously throughout the day.

To control for the levels of reported influenza-like illness (ILI) during the study (which might influence HHC independently of the intervention), we obtained the weekly rates of ILI data from the CDC's virologic surveillance database, which combines information from the US and World Health Organization (WHO) Collaborating Laboratories System and the National Respiratory and Enteric Virus Surveillance System (NREVSS). WHO/NREVSS ILI data was available at the state level and for all dates included in the study.

Outcome Measure

The outcome measure was the proportion of opportunities in which HH was undertaken over the course of a week in each unit – that is, rates of HH were calculated by dividing the number of dispenses of soap or sanitizer by the entry of a patient room plus the exit counts on each day. An opportunity occurred whenever an individual entered or exited a patient room. As the sensors were not able to discriminate between the individuals, all entries and exits into a patient room were counted. However, nurses typically have the most interactions with patients and thus constitute the most entries and exits of a patient's room due to their role in the hospital and the nature of care provided. [23, 24] It was assumed that the proportions of non-nursing staff and visitors is not expected to change over time. Readings from sensors in patient room doorways and from dispensers in rooms and the hallway were compiled for six months before and after the intervention (where available). Proportion of opportunities was calculated as the number of dispenser pushes divided by the number of entries and exits during a 24-hour period on a unit.

Data Cleaning

Entries for the same sensor and the same timestamp, which recorded to the second, were considered duplicates and removed. Unfortunately, several date ranges demonstrated drastic, discontinuous jumps in calculated rates of HHC, including for all Hospital A units—A1, A2, A3, and A4—from March 1, 2016 to March 31, 2017 and for Hospital B's unit B2 from October 27 to November 15, 2016. The cause of these discrepancies could not be determined, so data outside of the above ranges was excluded from the analysis for Hospital A's units as the intervention took place during this timeframe, while data from Hospital B's Unit B2 was excluded from its relatively small (less than 3-week) discontinuity.

Statistical Analysis

To identify the effect of the intervention on HHC rates, interrupted time series (ITS) analysis using a quasi-Poisson regression model was performed. The model included dummies to control for levels of reported ILI, linear secular trends (separately for the Unit B1 and all the other non-MICU units), unit-level baseline rates, and the differences in absolute numbers of HHC events across units. The linear secular trends were controlled for using separate dummy variables for MICU and non-MICO units; seasonal variation due to influenza prevalence was controlled for using a dummy reflecting state-specific ILI data. We expected an immediate effect from the HH intervention on HHC that would then be modified over time, and so we included a measure of the treatment effect for the two months immediately following the intervention in addition to time beyond the two months. The quasi-Poisson regression models were constructed for ITS analysis as follows (Model 6-1):

Model 6- 1: Overall treatment effects model

$$\begin{aligned}\log(E(\text{HHC Rate} \mid x)) = {} & \beta_0 + \beta_1 * \text{treatmentImmediate}_x + \beta_2 * \\ & \text{treatmentSustained}_x + \\ & \beta_3 * \text{time}_x + \beta_4 * \text{MICU\_trend} + \\ & \beta_5 * \text{unit}_x + \\ & \beta_7 * \text{flu\_like\_illness}_x\end{aligned}$$

Where:

treatmentImmediate$_x$	dummy variable represents treatment status in the given unit on the measured day, such that β_1 represents the overall treatment effect of the intervention for the first two months post-intervention
treatmentSustained$_x$	dummy variable represents treatment status in the given unit on the measured day, such that β_2 represents the overall treatment effect of the intervention for the period more than two months post-intervention
time$_x$	dummy variable represents date of the intervention, such that β_3 represents the overall secular trend in rates of hand hygiene
MICU_trend	represents date of the intervention for the one MICU unit, such that β_4 represents the difference between the overall secular trend in rates of hand hygiene and the trend for the MICU
unit$_x$	dummy variable represents each of the units in the program, such that β_5 is a vector that represents the differing base rates of each unit
flu_like_illness$_x$	represents a continuous variable capturing the percentage of cases in the unit's state that were correlated with the number of flu-like illnesses in the

State by week, so that β_7 measures the additive change in hand hygiene rates that varies linearly with flu-like-illness rates

Unit-level immediate and sustained treatment effects were also calculated using a second model that was otherwise identical to the first.

Statistical Process Control (SPC) analysis was further conducted to determine whether the observed changes in HHC rates were a result of the intervention or were due in whole or part to naturally occurring variation. The basic tenet of SPC is that repeated measurements from a process will exhibit variation. Variation within a process occurs according to an underlying statistical distribution if the parameter remains constant over time; this variation is predictable within a range that can be described by one of the several statistical models of distribution.[25] Measured values that deviate from the random distribution are considered unnatural variation, and are most likely due to events, changes, or circumstances that are not inherent in the regular process.[26] SPC charts were created for each of the units to tease out the variability inherent within the process and to determine if the intervention had the desired impact and if it was sustained beyond the intervention time period. These were P charts using Laney's correction for large sample sizes with an assumed mixed distribution.

RESULTS

Descriptive Analysis

The basic descriptive statistics for the hospital units appear in Table 6-2. The intervention was delivered on different dates in each of the units, aside from Units A1 and A2, which received the intervention on the same date. Recorded sensor reading counts varied substantially between units. The temporal length of data available also varied by unit. Figure 6-1 presents a graphical representation of the HHC rates by unit, averaged by week, both before and after intervention dates (represented by vertical lines of the same colour as the unit rate-line). As can be seen from Figure 6-1, Unit A1 has the highest average rate, while Unit B1 is lowest.

ITS Analysis

The results in terms of basic compliance rates are summarized in Table 6-3. In the two months following the intervention, the aggregate effect was a general positive and statistically significant increase in HHC rates, with unit level effects varying from increases in Units A3, A4, B1, and B2 to decreases in Units A1 and A2. Beyond two months, there were increases in HHC rates in all units except for Units A4 and B2. Note that there was no data beyond 60 days post-intervention for Unit B2, and only one day of data beyond 60 days post-intervention for Unit A4; thus no statistical conclusions could be drawn.

It is evident that the overall result from the intervention was positive and that the effect was generally sustained for months post-intervention. Most of the average effect was driven by Unit B1 and B2, which observed large increases in the rates of initial and sustained compliance. Unit A1 and Unit A2 saw small initial decreases in HH but then small increases after two months, while Hospital A’s other units exhibited immediate and sustained increases in handwashing. It is worth remembering, however, that the Hospital A rate changes are not statistically significant after controlling for trends, and even the sustained change in Unit B2 was not significant, despite being quite large.

SPC Analysis

For each hospital unit, a SPC chart was created with the control limit (CL) set as the overall HHC rate for pre-intervention and post-intervention periods combined (Figure

6-2, a-f). The solid vertical lines on the charts indicate the point of intervention delivery. The upper and lower limits (UCL and LCL, respectively), were set at ±2SDs from the mean. Traditional statistical techniques used in the medical literature typically use 2SD as the statistical criteria for making decisions. While most SPC charts in industries outside medicine use 3SDs, we were aware that setting the limits too wide would lead to a high risk of type II error. These are bimodal models, adjusted for seasonal (e.g. flu) and linear (secular) trends.

The SPC charts indicate that Unit A1 had a small increase in its HHC rate immediately following intervention delivery with a cluster of data points outside the UCL. However, the data fell within UCL and LCL by early October, which was about a month after the intervention delivery. Units A2, A3, and A4 showed increases in HHC rates, but these rises were within the expected variance. The data points that did breach the UCLs were few and were not clustered together. There was a small increase in HHC rates in Unit A3 prior to the intervention. Unit B1 had a strong, increasing uptick in rates post-intervention with most of the data points above of the UCL. Finally, Unit B2 has an immediate drop off, with many of the data points falling outside the LCL.

DISCUSSION

From the ITS analysis, it is apparent that on the aggregate level there was a positive, statistically significant impact of the intervention on HHC rates. However, the patterns by unit were varied and in multiple cases, not statistically significant once temporal trends were considered.

The two units with statistically significant increases in HHC were Unit B1 (MICU) and Unit A3 (neuro-surgery ICU). The baseline HHC rates for these units were lower as compared to the other units, thus allowing for more substantial increases in HHC rates. From the literature, we know that the number of opportunities for HH is largely dependent on the process of care provided.[27] Researchers have found that the higher the demand for hygiene— the more opportunities to practice it— the lower the adherence.[27-34] The lowest adherence rates have been found in ICUs while some of the highest rates have been found in surgical and pediatric units.[27] The two units that were found to have statistically significant increases in HHC rates were both ICUs. Once again, these units' baseline rates were slightly lower than the other units and the nurses most likely had a larger number of opportunities for practicing HH. Units A1 (stem-cell transplant) and A2 (oncology) had the highest HHC rates for the baseline and post-intervention periods, which was most likely due to the nature of care; nurses were attending to patients with compromised immune systems.

Additionally, other factors apart from the intervention may have influenced the outcomes. For instance, in Unit B1, Nurse Mangers provided an incentive of catered lunch to the unit if enough nurses participated in the study. From non-participant observation—which is expanded upon in the process evaluation[19]—it was noted that the intervention was consistently mentioned on the unit floor and nurses were reminded of the intervention through automated emails. This could have impacted the nurses' level of engagement with the intervention. In Unit A3, HHC rates for the unit were on the computer monitors at the nurses' stations. From observations made, the unit also had a pledge that spanned the walls of the nurses' lounge that read: "I pledge to clean my hands with soap and water or Purell before and after I visit each patient's room. If I forget to do so, I want to be reminded, and I promise to respond positively and with respect." Once again, additional factors may have contributed to the positive effect.

Moreover, there were several unexpected findings. First, it was noted that in several units, compliance rates were higher more than two months after the intervention than in the months immediately following the intervention delivery. It is rare for the effects of an intervention to build over time without consistent additional inputs. This could be attributed the process evaluation survey. The process evaluation survey was conducted in each of the hospital units six weeks after the intervention delivery. The process evaluation asked about retention of the HH message as well as use of the cue-association activity. The survey—and the presence of the research group in the hospital unit— may have served unknowingly as a reminder of the intervention for the participants. In addition, this could have prompted the Nurse Managers of the respective units to further emphasize the importance of the intervention and HH.

Another finding was that the ILI effect was slightly negative. As the rate of ILI admissions increased, the HHC rates decreased. This runs counter to the conventional assumption that the HH rates of HCWs increases with the threat of disease. There are two possible explanations for this occurrence. The first is that the assessment of risk among HCWs can manifest in attitudes towards, and fear of, infectious disease.[35] When HCWs feel fear, they have a higher tendency to avoid patient contact.[36] In assessing risk, nurses could subconsciously view the flu as a non-serious threat hence the decrease in performing HH. Additionally, the threat of the flu season could have been somewhat normalized. For example, in both hospitals, there were informational posters about the flu as early as August and in Hospital A nurses had stickers on their ID badges that posed the question: *Have you gotten your flu shot yet?* This could have changed HCWs' perceptions of the flu away from that of fear. Second, increased admissions could mean increased patient loads and thus increased work stress. From the literature, it is evident that high degrees of occupational stress can lead to suboptimal patient care, safety breaches, and increased frequency in errors in everyday clinical practice.[37-39] While increased patient loads may be acting as a confounder, we are unable to assess whether this was occurring, given the available data.

Finally, there were significant differences in the responses between the units – with some showing strong positive overall effects such as Unit B1 (MICU) and Unit A3 (neuro-surgery ICU), others with little effect initially like Unit A4 (mother-baby), and some showing an initial negative effect such as Unit A1 (stem-cell) and Unit A2 (oncology). This could be due to issues with intervention implementation. In the process evaluation, Sands and Aunger (2019) identified that relatively few nurses were reached by the intervention (less than 50% on average) and even those who were reached did not actively engage with the cue-association exercise.[19] In addition, the context in which the intervention was delivered—from the varying settings of the hospital units themselves to dynamic nature of providing health care—could have directly influenced behaviour and thus impacted the nurses' responses to the intervention in these different units.

The SPC control charts showed that there was significant natural variation within the process, referred to as *common cause variation.*[25, 26] The increases in HHC rates seen in Units A1, A2, A3, and A4 fall within the natural variation expected. Thus, Unit A3's statistically significant increase in its HHC rate could be due to common cause variation rather than to the intervention itself. The increase in the HHC rate of Unit B1 was strong and fell outside of the upper limits indicating *special cause variation*. The measured values for Unit B1 deviated from the random distribution models, indicating that the increase in HHC rates could not be explained by naturally occurring variation within the system. Thus, it can be assumed that Unit B1’s statistical evidence of change can be due to outside factors—such as the intervention, the involvement of the unit’s Nurse Manager, the offering of incentives, or a combination of these.

Where the model and SPC may be limited in its ability to discriminate between variation owed to the intervention and variation arising from other causes outside of the naturally occurring variance, the process evaluation can help tease out whether there were factors associated with intervention implementation, specifically reach and engagement, or if there the substantial variation in the units themselves impacted the observed outcomes.

Limitations

Study Design

A potential limitation of the multiple baselined design is the inability to assess the impact of concurrent events on the outcomes of the intervention—such as staffing or policy changes. It was hypothesised that by using multiple time-series from different hospital units we could increase confidence that the intervention was responsible for the change in outcome as we could compare changes in HHC rates across units; the aggregate analysis does this. However, the unit-level analysis was more vulnerable to the unit-specific confounders. While we could control for trends, the dimensionality of the setting and situational factors that varied in each of the hospital units could not be controlled for in this quantitative analysis. For instance, the social culture of the hospitals and units, the level of accountability nurses were held to, and the safety culture promoted by Nurse Managers in their respective units varied extensively. Additional evaluation and analysis of the process behind intervention implementation and delivery is necessary to better understand the possible influencing factors. As a result, more credence should be given to aggregate effects than unit-level effects.

A limitation of the SPC application arises from the data used in the control charts. The oversampling of HHC rates for units whose values are out of control can pull the statistic in the direction of derangements.[40] This was apparent with Unit B2, whose CL, UCL, and LCL may have been affected by values that were consistently out of control months prior to the delivery of the intervention.

Data Collection

As we used an ECM system without personal badges, we were unable to discriminate between individuals such as nurses, physicians, environmental service technicians, or visiting family members. The basic assumption, however, was that nurses, having the most interaction with patients, constituted most of the entries and exits of patients' rooms and thus dispenser uses. We also assume that the behaviour of other people frequenting the units was not affected as they were not exposed to the intervention.

Additionally, while the intervention was aiming to increase compliance rates upon entering patient rooms, all dispenser pushes were included in the analysis as it was difficult to discern which dispensers were used specifically in that context – nurses could use ABHR from a dispenser in the hallway outside a patient's room prior to entering, could use a dispenser inside the door of the patient's room, or could use the soap dispenser at the sink not far from the door. Thus, various dispensers could be used to 'foam-in', hence the general inclusion of all dispensers in the analysis.

The existence of periods during which levels of recorded sensor triggering shifted considerably without an obvious explanation are also worrying; however, their exclusion should not significantly influence the analysis, as they did not occur during crucial periods with respect to the intervention.

CONCLUSION

HH is widely accepted as the most important measure for the prevention of HAIs, but HHC rates are typically low. Numerous efforts have been made to increase HH among HCWs, and yet these initiatives have been unable to bring about sustained changes in behaviour. We developed a 'wise' intervention— a simple intervention based on a specific psychological theory— that centred on an attempt to re-animate nurse's sense of professional identity and responsibility. This was implemented in six acute care units across two different hospitals in the United States during 2016-2017. The study adopted a multiple baseline design with the delivery of the intervention being staggered across time and units. An ITS analysis using a quasi-Poisson regression model was performed. Overall there was a positive, statistically significant impact of the intervention on HHC rates among those visiting patient rooms. Yet, at the unit-level, the impact of the intervention varied, in several cases was not statically significant, and showed unusual temporal patterns of change. SPC analysis indicated that most of the increases in HHC rates could be due to naturally occurring variance. However, one of the two units that was found to have a statistically significant increase in its HHC rate (Unit B1, the MICU), had changes that could not be accounted for by natural variance; this a statistical evidence of change occurred in that unit. In all, these aspects of the outcome evaluation suggest that the aggregate impact should not be taken as evidence of intervention effectiveness; the null effects in some units were simply due to unmeasured confounders. This study therefore cannot be considered to have provided a strong foundation for use of a 'wise' intervention targeting professional identity at scale, despite its relatively small financial, logistical and psychological cost. However, given these potential benefits, such interventions should be further studied and tested.

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FIGURES

Figure 6- 1: Calculated HHC rates by unit over time (weekly aggregates)

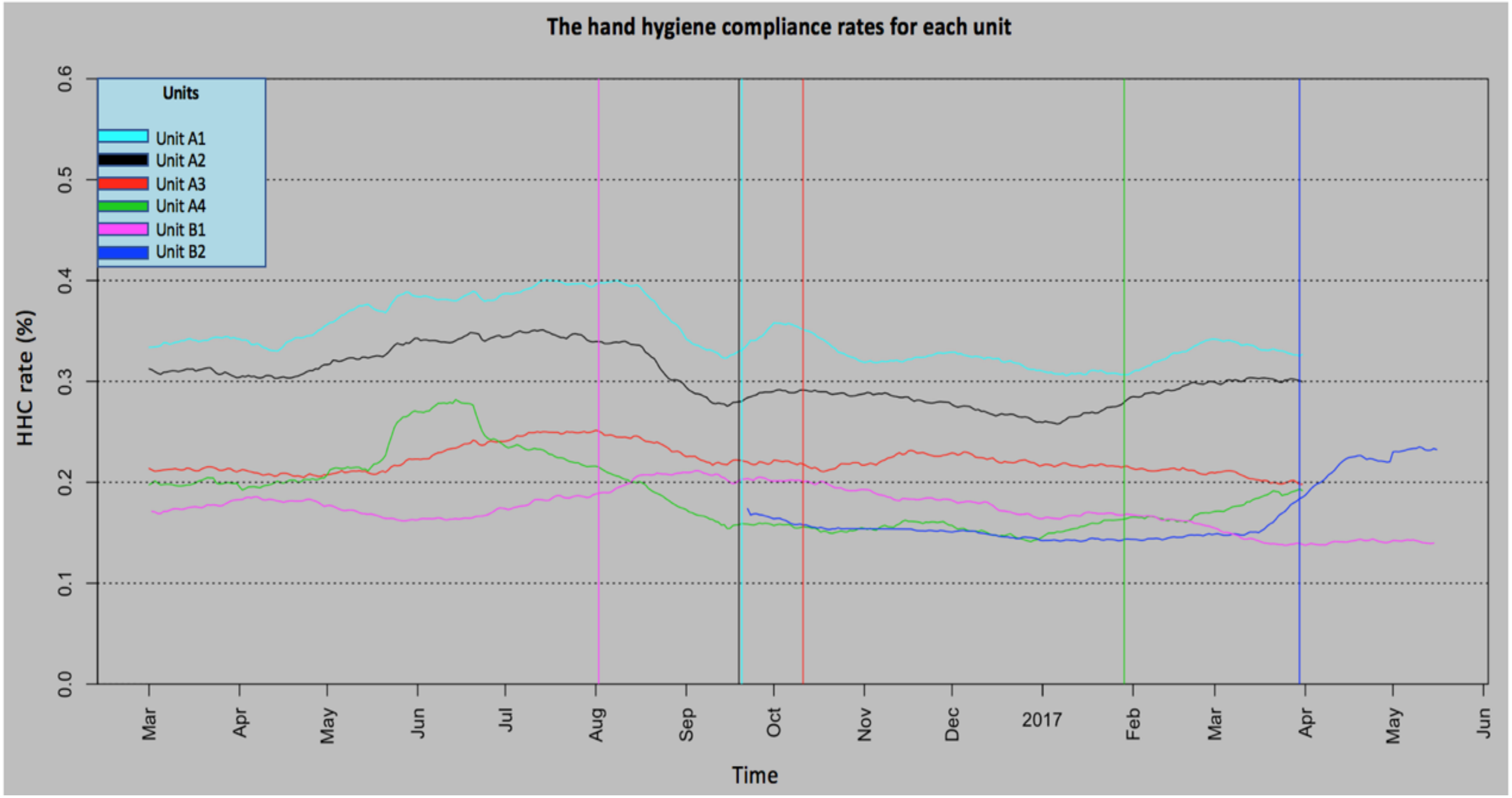
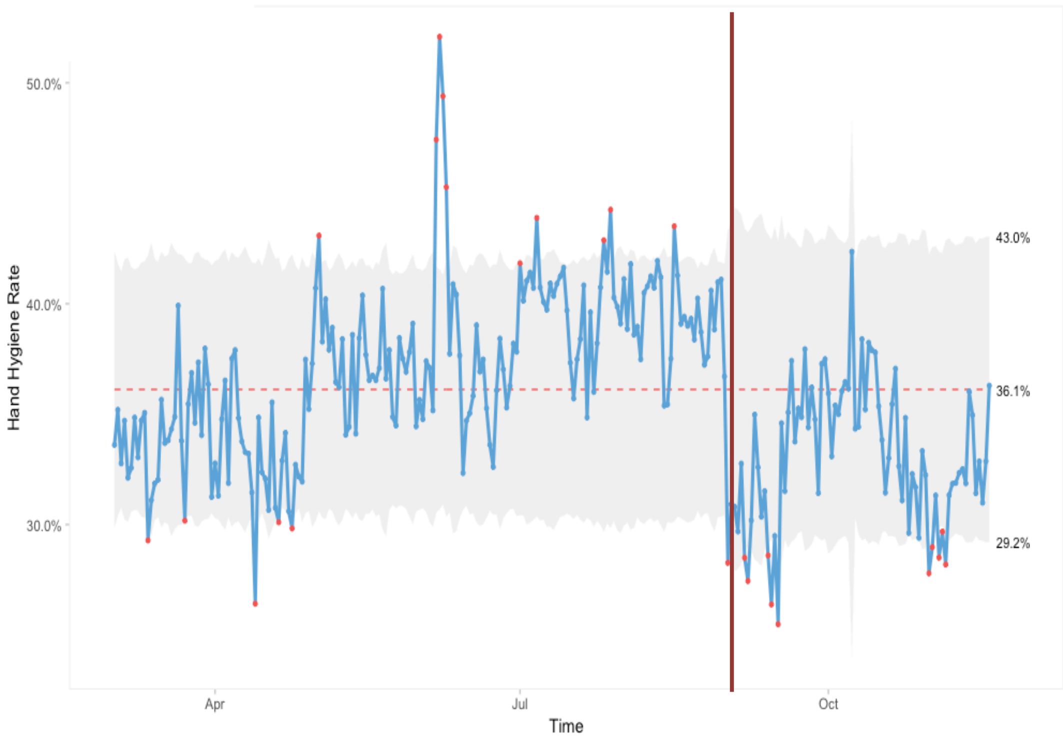
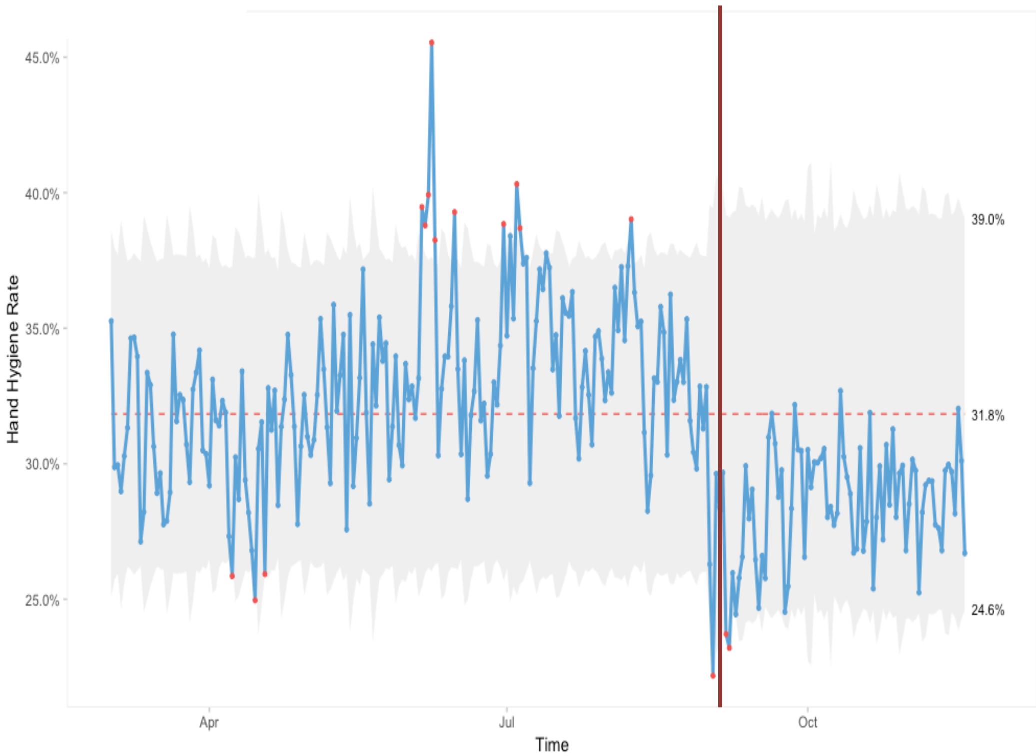


Figure 6- 2: SPC control charts for each of the units

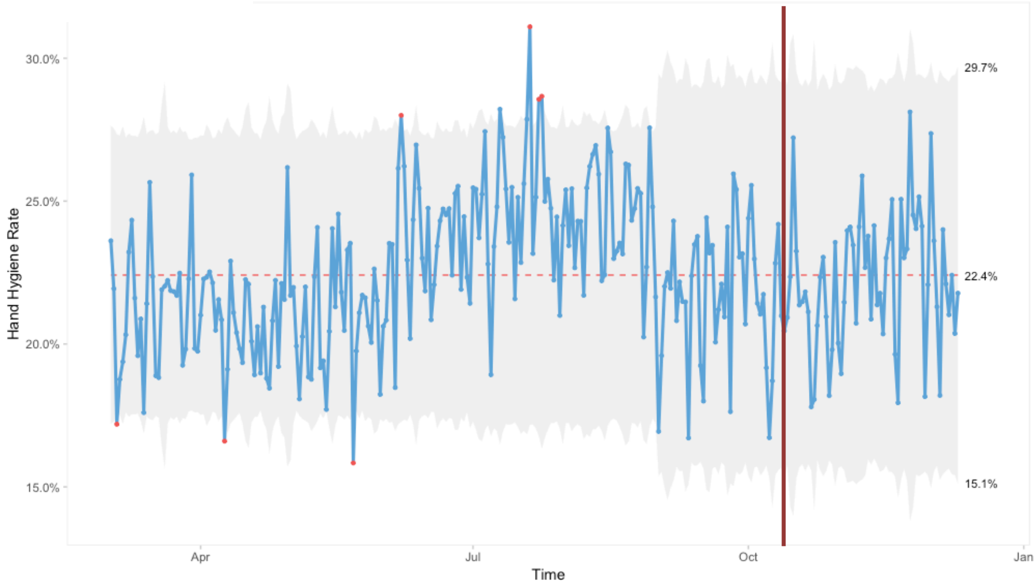
a. Unit A1



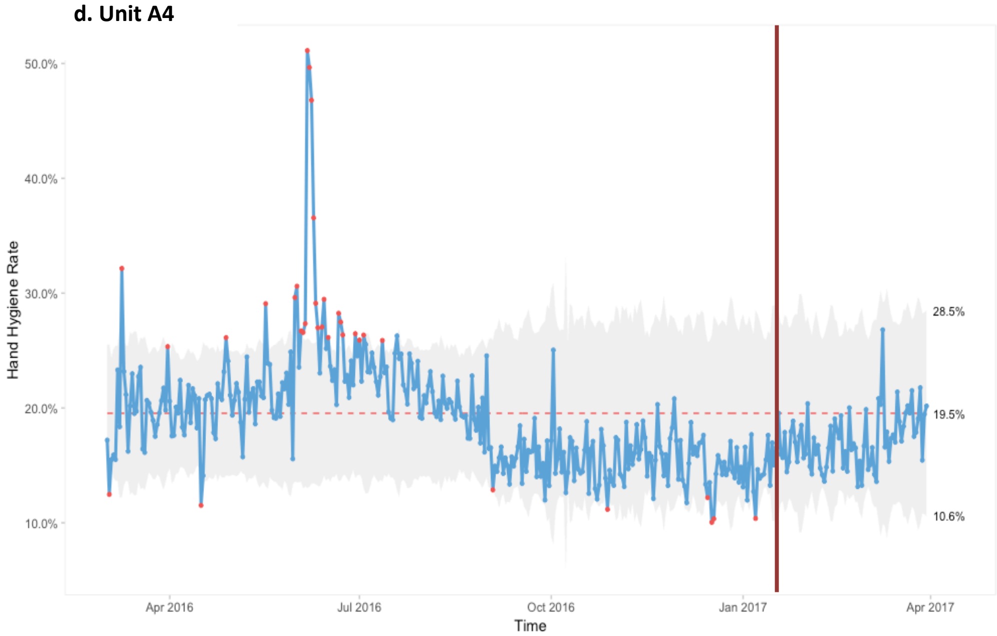
b. Unit A2



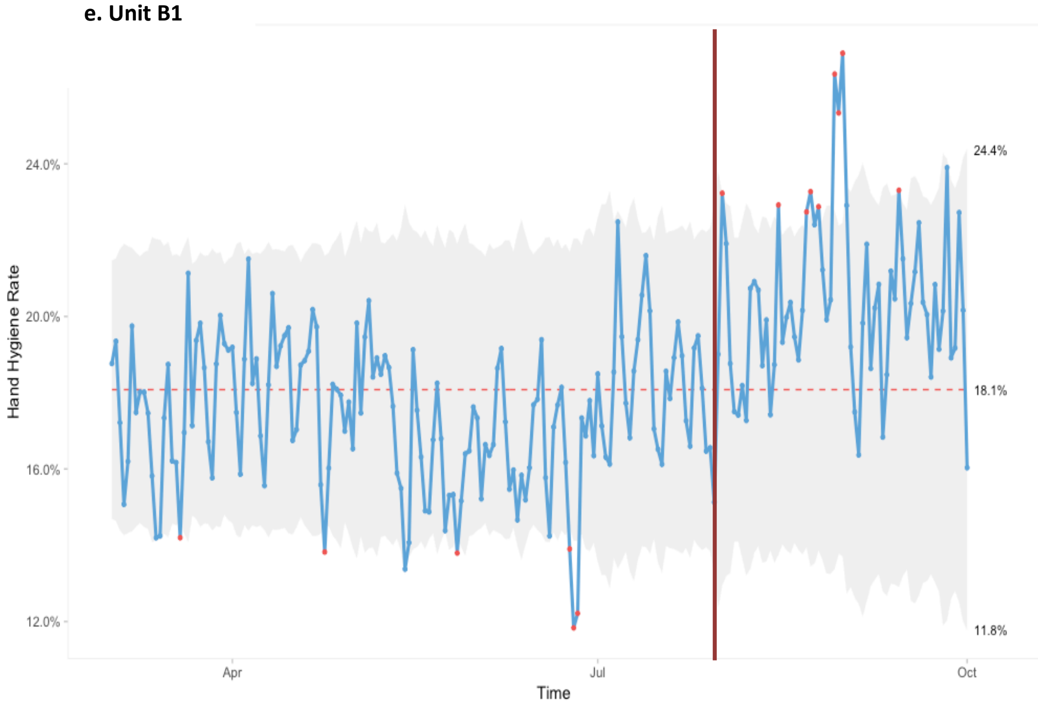
c. Unit A3



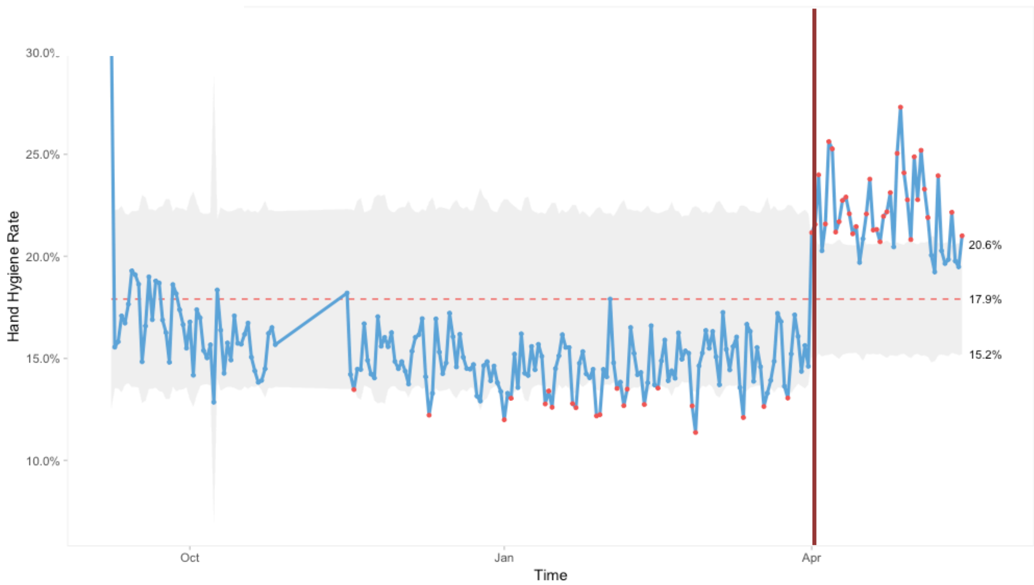
d. Unit A4



e. Unit B1



f. Unit B2



TABLES

Table 6- 1: Unit characteristics

	Hospital A				Hospital B	
	Unit A1	**Unit A2**	**Unit A3**	**Unit A4**	**Unit B1**	**Unit B2**
Type of unit	Stem cell transplant	Oncology	Neurology/ Neuro-surgery ICU	Mother-baby	MICU	Medical Surgical Cardiology
Number nurses	60	63	42	40	78	97
Number patient beds	40	40	28	32	26	47

Table 6- 2: Sample characteristics

	Hospital A				Hospital B	
	Unit A1	*Unit A2*	*Unit A3*	*Unit A4*	*Unit B1*	*Unit B2*
n= (number of days)	396	396	396	396	440	231
First measured date	1 Mar 2016	1 Mar 2016	1 Mar 2016	1 Mar 2016	2 Mar 2016	7 Sep 2016
Date of intervention	19 Sep 2016	19 Sep 2016	11 Oct 2016	29 Jan 2017	2 Aug 2016	30 Mar 2017
Last measured date	31 Mar 2017	31 Mar 2017	31 Mar 2017	31 Mar 2017	15 May 2017	16 May 2017
Pre/Post intervention days	203/193	203/193	225/171	335/61	154/286	185/47
Dispenses ***(daily mean (SD))***	2143 *(616)*	2428 *(862)*	1608 *(567)*	915 *(484)*	1954 *(722)*	2279 *(1692)*
In ***(daily mean (SD))***	2992 *(634)*	3828 (1078)	3623 *(1192)*	2300 *(886)*	5484 (1798)	6181 *(3165)*
Out ***(daily mean (SD))***	3126 *(680)*	4033 *(1127)*	3624 *(1170)*	2379 *(901)*	5703 *(1891)*	6540 *(3284)*
Flu-like illness ***(mean % of patients (SD))***	2.03 *(1.10)*	2.03 *(1.10)*	2.03 *(1.10)*	2.03 *(1.10)*	0.59 *(0.73)*	0.83 *(0.86)*

Table 6- 3: Intervention impact summary

Unit	Pre-intervention base HHC rate	Compliance rate <2 months after intervention	Relative change from base HHC rate <2 months after intervention	Compliance rate >2 months after intervention	Relative change from base HHC rate >2 months after intervention
Overall	20.6%	23.9%	+11.6% (11.4, 11.9)*	23.7%	+11.5% (11.2, 11.9)*
Unit A1	40.5%	38.9%	-3.9% (-7.4, -0.3)*	41.0%	+1.3% (-2.7, 5.3)
Unit A2	35.8%	33.4%	-6.5% (-9.9, -3.1)*	36.0%	0.7% (-3.2, 4.6)
Unit A3	24.9%	25.9%	+4.3% (-0.3, 9.0)	27.5%	+10.7% (5.6, 15.7)*
Unit A4	22.3%	22.7%	+1.8% (-5.1, 8.6)	27.5%	n.d.
Unit B1	19.5%	25.7%	+31.8% (26.4, 37.2)*	26.0%	+33.2% (+25.1, 41.3)*
Unit B2	17.6%	25.9%	+45.9% (41.4, 50.4)*	NA	NA

*Note: *: p < 0.05; n.d. = no data shown due to insufficient sample size; NA = no applicable data from period*

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SECTION A – Student Details

Student	Madeline Sands
Principal Supervisor	Dr. Robert Aunger
Thesis Title	Infection Control in Our Hands: Developing and Evaluating a Novel Intervention to Improve the Hand Hygiene Behaviour of Nurses in Acute Care Hospital Units in the US

If the Research Paper has previously been published please complete Section B, if not please move to Section C

SECTION B – Paper already published

Where was the work published?			
When was the work published?			
If the work was published prior to registration for your research degree, give a brief rationale for its inclusion			
Have you retained the copyright for the work?*	Choose an item.	Was the work subject to academic peer review?	Choose an item.

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SECTION C – Prepared for publication, but not yet published

Where is the work intended to be published?	Implementation Science
Please list the paper's authors in the intended authorship order:	Madeline Sands Robert Aunger
Stage of publication	**Not yet submitted**

SECTION D – Multi-authored work

For multi-authored work, give full details of your role in the research included in the paper and in the preparation of the paper. (Attach a further sheet if necessary)	Madeline Sands made substantial contributions to the conception and design of the study, contributed to the analysis and interpretation of results, and drafted the manuscript.

Student Signature: Madeline Sands **Date:** 5 October 2019

Supervisor Signature: [signature] **Date:** 15 October 2019

CHAPTER 7: PROCESS EVALUATION

Development of a behaviour change intervention using a theory-based approach, Behaviour Centred Design, to increase nurses' hand hygiene compliance in US hospitals

ABSTRACT

Background: This paper describes a process evaluation nested within a multiple baseline design—called the *Mainspring* study— that took place in six acute care units in two medical-surgical teaching hospitals in the United States during 2016-2017. The *Mainspring* study sought to increase the hand hygiene compliance (HHC) rates in each of the hospital units by 50% over the units' respective baseline HHC rate for a three month period. The specific target behaviour focused on nurses practicing hand hygiene (HH) before entering a patient's room. The intervention was developed using the Behaviour Centred Design (BCD) approach, and it centred on the use of the threat to professional identity to prompt change. The aim of this process evaluation was to enhance our understanding of outcome evaluation.

Methods: Through non-participant observation and questionnaires administered to intervention participants and the intervention's Facilitator, we examined how the intervention was implemented in practice, the extent to which the intervention reached the target population, and whether the steps in the theory of change occurred as expected.

Results: We found that aspects of the implementation—including the mode of delivery, the use of incentives, and how nurses were recruited and complied with the

intervention—affected its reach and likely effectiveness. While some of the mechanisms of impact of the intervention—such as the element of surprise—were successful, they ultimately did not translate into consistent use of a cue that prompts HH or performance of the target behaviour. Performance was also not affected by use of an implementation intention as repeated performance of HH over years of being a nurse have likely already established well-ingrained practices. Context did have an effect; the safety culture of the units, the involvement of the units' Nurse Managers, the level of accountability for HH in each unit, and the hospitals themselves all influenced levels of engagement.

Conclusion: In this evaluation, we highlighted the importance of examining the process behind the intervention implementation and delivery. Through observation and questionnaires, we gained a deeper understanding of how the implementation, select mechanisms of interest, and the context enhanced or detracted from the effectiveness of the *Mainspring* intervention. These conclusions should have implications for those designing hand hygiene improvement programs.

INTRODUCTION

Reporting and evaluating interventions in healthcare is a complex process.[1-3] Various components of an intervention may influence its effectiveness both independently and interdependently, which can make the evaluation of the strategy challenging.[4] Outcomes are mainly reported for intervention studies with focus being placed on whether it succeeded or failed.[4-6] A process evaluation documents the steps involved in implementing an intervention, helps to disentangle the factors that led to the outcome, and describes what may have gone wrong and why; this evaluation further seeks to identify which components of an intervention were key to the observed outcome and to identify the conditions in which the intervention is likely most effective. To advance the field of behaviour change and our understanding of applied interventions, it is necessary to document the ways in which interventions succeed or fail by evaluating the processes they initiate. This paper describes a process evaluation nested within a multiple baseline design—called the *Mainspring* study— that took place in six acute care units in two medical-surgical teaching hospitals in the United States during 2016-2017.

BACKGROUND

Healthcare Associated Infections and Hand Hygiene

Healthcare associated infections (HAIs) are the most common complication in hospital care and are associated with high morbidity, mortality, and healthcare costs.[4, 7-9] Hand hygiene (HH) is the most effective measure for reducing the incidence of HAIs.[8, 10] Unfortunately, healthcare workers (HCWs) compliance to HH recommendations are generally low. [8, 11-16] Strategies to improve compliance rates have been successful in producing immediate changes in compliance, but long-term behaviour changes are typically not maintained. [9, 13, 17-21] These interventions are multimodal and traditionally consist of multiple components such as education, feedback, reminders, access to alcohol-based hand rub (ABHR), and administrative support.[4, 22-24] More recent research shows that HH implementation strategies grounded in theories that also incorporate behaviour change approaches demonstrate modest but sustained improvements.[25,26]

The *Mainspring* Study

The *Mainspring* study sought to increase the HHC rates in each of the hospital units by 50% over the units' respective baseline HHC rate for a three month period. The specific target behaviour focused on nurses practicing HH before entering a patient's room. The intervention was developed using the Behaviour Centred Design (BCD) approach, and it centred on the use of the threat to professional identity to prompt change.[27] The health message— which explained that nurses were less likely to perform HH at room entry than at room exit— drew attention to the incongruity between the nurses' current HH practice and their required practice.[28] This message was intended to surprise the nurses. To decrease defensiveness and, in turn, increase openness to the message, a values affirmation exercise was included as the first part of the intervention.[29] This is an example of a 'wise' intervention, a brief intervention that seeks to disrupt a recursive process, and thus facilitate a positive experience that leads to later positive outcomes.[30] The intervention is described in Appendix 6-1 using the TIDieR checklist as a guide[31] and the Theory of Change is depicted in Figure 7-1.

Process Evaluation Framework

There are numerous process evaluation frameworks and guidelines in the literature. This evaluation drew from De Silva et al.'s (2014) Theory of Change approach[32] and was also guided by the framework of Linnan and Steckler (2002).[33] This process evaluation measured the following domains: intervention implementation, mechanisms of impact, and context. Terms are modified from Linnan and Steckler (2002)[33] and defined in Table 7-1.

The effectiveness of the intervention implementation was assessed through *recruitment*, *reach*, and *fidelity*. The mechanisms of impact— specifically, how the intervention activities and participants' interactions triggered change— was assessed through *participant engagement* and *mediators*. *Context* was assessed by evaluating the various aspects of the intervention setting, including the social and physical environment, which could have influenced intervention implementation or receipt.

METHODS

Aims and Objectives

The aim of this process evaluation was to enhance our understanding of the findings from Tidwell et al. (2019) which provided an evaluation of the trial's outcomes.[34] In this paper we examined how the intervention was implemented in practice, the extent to which the intervention reached the target population, and whether the steps in the theory of change occurred as expected. The objectives were: 1) to determine *what* was delivered and *how* it was delivered, 2) to test the causal assumptions that linked intervention activities to outcomes, called the *mechanisms of impact*, and 3) to understand how the context surrounding intervention delivery impacted its implementation and the reported outcomes.

Study Population

The *Mainspring* study was implemented in two medical-surgical teaching hospitals located in the Midwestern United States—and given the pseudonyms Hospital A and Hospital B. All participating hospital units in this study provided acute care with each unit having a different specialty of care; nurses in all units had a 12-hour shift. The characteristics of the units in the study are included in Table 7-2.

Process Evaluation Design and Overview

The process evaluation incorporated the use of questionnaires and non-participant observation. Questionnaires were administered to the nurses and the intervention Facilitator following the delivery of the intervention. The non-participant observation was conducted during the intervention delivery. The research questions, data collection methods used, and variables produced in the assessment are included in Table 7-3.

Nurse Questionnaire

The intent of this self-report questionnaire was to measure the level of exposure, to elicit nurses' reflections of the intervention, and to determine if the theoretical constructs of interest were effective in influencing behaviour change. All responses were anonymous. The questionnaire consisted of ten closed-ended questions [in Appendix 5-1] and was administered to nurses 4-6 weeks following the intervention implementation; the dates for delivery in each unit are provided in Table 7-4. Nurses were purposively sampled. Nurses at Hospital A received the questionnaire in-person during unit meetings or through the course of their shift. The Facilitator distributed the questionnaires. All nurses in Hospital B received the questionnaire online.

Facilitator Questionnaire

The questionnaire for the Facilitator centred on the recruitment, delivery, and consistency of these processes across the various hospital units. The questionnaire consisted of 14 open-ended questions [Appendix 5-2]. The Facilitator completed the questionnaire immediately after the delivery of the intervention in each of the units. The approach to qualitative data analysis involved the identification and coding by authors MHS and RA of themes that appeared in the text. The codes included *feasibility of delivery*, *recruitment*, *participant engagement*, *reach,* and *context* [which are expanded upon in Appendix 7-1]. Quotes were extracted and included in this evaluation.

Non-Participant Observation

Observations of the intervention implementation assessed fidelity, participant engagement, and the barriers, facilitators, and competing or intervening influences on participation and exposure. The observation aimed to provide a nuanced understanding of context. The observer (MHS) neither participated nor engaged in intervention delivery. In four of the hospital units, MHS witnessed the delivery of intervention and recorded whether the scheduled activities were implemented in a manner that aligned with the intended delivery. Fieldnotes were handwritten discreetly during the observation period. Immediately following the implementation, the notes were expanded upon and turned into a descriptive narrative. The fieldnotes were coded by MHS under the general themes of *feasibility of delivery*, *recruitment, participant engagement*, *reach*, and *context* (which were also used for the Facilitator questionnaire analysis).

Ethical Considerations

The Ethics Committee of LSHTM granted permission for this research. The Committees of each respective hospital also approved the research. Questionnaires for the nurses were anonymous. Nurses in both hospitals were verbally requested to participate in the study. Each participant was free to take part, refuse, or withdraw at any time during the intervention delivery, without any consequences.

RESULTS

Descriptive analysis was first conducted on the data from the nurse questionnaire. The delivery method and the reach of both the intervention and process evaluation across the units are presented in Table 7-5 and Table 7-6, respectively. The results are further described below under each of the three process evaluation domains. In addition, additional figures and graphical representations of the Results are provided in Appendix 7-2.

Intervention Implementation

Recruitment: Hospital and Unit

The intervention Facilitator served as the point-of-contact for recruitment efforts. Hospitals were recruited based on the initial specific inclusion criteria agreed upon in the study protocol (Chapter 5): hospitals must a) be located in the same geographical region of the United States, b) have the same electronic compliance monitoring (ECM) technology installed for at least six months prior to the intervention, c) have acute care units willing to participate, and d) have not participated in a HH intervention for at least six months prior to the start of the baseline data collection.[35] It was difficult to find hospitals, with multiple units available, which were willing to participate in the study. Both recruited hospitals had a longstanding research relationship with the Project Funder with research and ethics approval in place for concurrent projects, and so could rapidly participate in the study. At the time of recruitment (April 2016), Hospital A had organized an institution-wide HHC awareness day to take place in mid-June 2016. There was about a three-month gap between the HH awareness campaign and the first day of the Mainspring intervention delivery, which did not comply with the inclusion criteria of there could be no HH intervention for at least six months prior to start of baseline collection. Hospital A divulged this information after the study had already begun. In Hospital B, Unit B2 did not have the ECM system installed at the beginning of the study. It was installed less than six months before the intervention delivery; this resulted in Unit B2 having a later start date for the intervention meaning the research team was unable to collect data past two months post-intervention before the study's end date. The two hospitals were asked to identify units to be used in the study.

The actual recruitment process between the two hospitals differed slightly. When first reaching out to Hospital A, the hospital administration had to be convinced of the value of the intervention to obtain permission to conduct the study. The intervention was explained in detail, including the tasks nurses were asked to perform and reasons why the research team believed these tasks would lead to an increase in HH. Once the project was approved, the hospital identified units for participation. The Nurse Managers for each of these designated units were then approached by the Facilitator.

Hospital B assigned a Project Manager to work with the research team on the implementation. The Facilitator explained the various components of the intervention and how implementation would occur. The Project Manager, the Nurse Manager for Unit B1, and hospital administrators had a follow-up meeting in which the intervention was explained in detail and the plans for implementation were agreed upon. After receiving approval, the Facilitator coordinated dates for delivery with the Nurse Managers of Units B1 and B2. The Facilitator did not find the recruitment effort with Hospital B to be as difficult (Quote 7-1).

Quote 7-1: *"All of the people I spoke with at the hospital were favourable toward working with us. They wanted to know exactly what we planned to do in their unit. I was able to answer all of their questions."* –Facilitator, Hospital B

Recruitment: Nurses

Once units had been selected by the hospitals, the Facilitator discussed the intervention with unit Nurse Managers. The Nurse Managers were tasked with raising awareness and encouraging participation amongst the nurses in the unit. Nurse Managers sent e-mails to nursing staff detailing the upcoming intervention project and mentioned the intervention during staff meetings prior to the delivery. The Nurse Manager in Unit A2 told nurses the intervention was a mandatory in-service exercise. The other units in Hospital A presented the intervention as a hospital quality improvement project. In Hospital B, the Nurse Managers provided an incentive of a catered lunch if enough nurses participated in the study.

Fidelity: Mode of Delivery

The delivery of the intervention required flexibility across and within the hospitals (Table 7-5). Hospital A received the intervention materials in-person during shifts. Delivery methods included meeting with nurses in groups during shift changes, approaching nurses individually, attending staff meetings, and standing at a nurse station. In Hospital A, the Facilitator implemented the intervention in-person over the course of a week predominantly during team meetings or by approaching individual nurses during their shifts.

The intervention was delivered online for both Hospital B units. The survey was distributed to the nurses via e-mail and then was followed-up by three separate reminder e-mails sent at three days, one week, and two weeks after the initial e-mail. Reminder e-mails were sent only to those who had not yet completed the survey. The Facilitator visited Unit B1 over the course of three days to alert the nurses of the e-mail sent. Nurses were told that if 80% of the nurses on their unit completed the survey, the staff would receive a catered lunch from a popular local restaurant. The Facilitator did not visit Unit B2. Instead, Hospital B’s Project Manager took on the responsibility of raising awareness.

Reach

Reach was reported for both the intervention as well as the process evaluation. It was calculated as the number of completed questionnaires divided by the population of the respective hospital unit. Reach encompassed the response rate and the completion rate for each unit (see Table 7-6). The response rate was calculated as the number of nurses who completed the intervention divided by the number of nurses in the unit. The completion rate was calculated as the number of nurses who completed the intervention divided by the number of nurses who engaged in the intervention. The research team aimed to reach 80% of nurses in each unit. However, the percentages of nurses that participated were fewer than the intended goal. Overall, 63% of nurses participated in the intervention in Hospital A as compared to 41% for Hospital B. Differences in the completion rates were also striking: the percentage of participants who started and completed the questionnaire was 64% in Hospital B as compared to 98% for Hospital A.

Mechanisms of Impact

Participant Engagement

Participants' retention of key messages and recognition of the intervention components are presented in Table 6. Of all the participants who were surveyed, less than three quarters recalled the main HH message. Unit B1 had the lowest recall rate with only 51% of participants remembering the message as compared to the highest rate of 69% of participants from Unit A2. Regarding the cue-behaviour link, 50% or more of surveyed individuals from all units in Hospital A remembered their object as compared to 20% of participants from Units B1 and B2.

Participation was measured by evaluating how many of the respondents attempted to use the object to remind themselves to practice HH and how many still use it (Table 7-7). Remembering the object did not always signify use, and initial use did not always translate into continued use for all the respondents.

Acceptability was evaluated through Likert questions that centred on emotional responses and reflections to the key message as presented in Table 7-8. Over fifty percent (50%) of the surveyed participants in all units who remembered the key message believed the information to be true, except for Unit A4.

Participants from each of the units responded differently to the receipt of the message. When asked if they felt irritated when reading the information, Unit A2 had the most participants of all the units (56%) agree whereas in Unit A3 more participants indicated not feeling irritated (40%) as compared to feeling neutral or irritated. The other units had less than 44% or less of respondents reporting feeling irritated. Regardless, most participants (75% or more) in each unit agreed that it was useful to know this information.

When asked if the participants were glad they learned about the key message, many respondents from each unit agreed. Units A2 and A3 had at least 90% of participants in agreement while B2 had 89% in agreement as compared to units A1, A4, and B1 with percentages that ranged from 62-66%.

Mediators

A cornerstone of the intervention was the use of surprise, which depended on nurses being unfamiliar with the HH message. An overwhelming majority of surveyed participants who had recalled the HH message in Units A1, A2, A4, and B2 had indicated not seeing the message before (88%, 62%, 75%, and 89% respectively)

(Table 7-9). However, in Units A3 and B1, more respondents had been aware of the information prior to participating in the intervention.

Context

Through context, we sought to understand the dimensionality of the situational factors that affect human behaviour. Context was conceptualized based on Johns' (2006) classification: *omnibus context* and *discrete context*.[36] Omnibus context is the general description of the implementation setting. Discrete context includes the specific situational variables that directly influence behaviour or mediate relationships between variables.

Omnibus context

Hospitals. The two teaching hospitals in this study are both part of the CDC's Prevention Epicentre Program which establishes a collaboration between the CDC and academic investigators at these institutions to conduct infection control and prevention research. In addition, the Project Funder has conducted HH research with both hospitals in the past and had concurrent projects in other units of these hospitals. Moreover, the hospitals were engaged in their own quality improvement projects and campaigns, with Hospital A having its own handwashing recognition day during the summer of 2016.

Units. All units included in the study provided acute care. Literature has shown that the number of opportunities for HH is largely dependent on the process of care provided, and that there higher the demand for HH—meaning the more opportunities to perform it—the lower the adherence tends to be.[8, 9, 14, 37-41] The lowest adherence rates have been found in ICUs.[8]

Flu season. The United States experiences epidemics of seasonal flu each year. The influenza virus is most common during the fall and winter months in the Northern Hemisphere with activity peaking between December and March.[42] The flu activity during the 2016-2017 season reflected this trend.[43] Although considered a moderate season, Hospitals A and B were in states that had reported widespread flu. It was noted that by mid-September 2016, nurses in Hospital A (primarily in Units A1 and A2) were wearing bright orange stickers on their ID badge that read "Have you received your flu shot?"

Discrete context

Discrete context includes pertinent information about tasks in the hospital unit that assist in nurses' HHC such as accountability, autonomy, and resources available.

Accountability. All units emphasized the importance of practicing HH. In both hospitals— and in all units— there were physical HH signs. These had been in place for some time and were not part of the intervention. While the signs hung as reminders for nurses and patients alike to practice HH, they also served to legitimize and stress the importance of the behaviour; HH was expected to be practiced. In addition, multiple units had the HHC rates for the month on bulletin boards in the nurses' lounge further adding to the legitimization. Unit A3 had the HHC rates on the computer monitors at the nurses' stations and pods. This unit also had a pledge that spanned the walls of the lounge. The pledge read: "I pledge to clean my hands with soap and water or Purell before and after I visit each patient's room. If I forget to do so, I want to be reminded, and I promise to respond positively and with respect."

Autonomy. In nursing, autonomy translates into feeling as if nurses have the authority of total patient care, the power to make decisions in a relationship with the patient and next of kin, and the freedom to make clinical judgments, choices, and actions.[44] Throughout the observations, it was noted that there was a struggle between nurses feeling in control and feeling as if they were reacting to matters outside of their control. This was particularly evident in the relationship between nurses and physicians. A common view shared amongst the observed units was that physicians regarded themselves as being entirely in charge of patient care. Nurses remained reluctant to challenge the physicians or assert themselves. The Nurse Managers in all the units in Hospital A unanimously stressed that it was imperative for nurses to act in the best interest of the patient, even if that meant asking for further assistance or another medical opinion regarding care. Each made a point during staff meetings or shift report to remind the nurses that they had a right to act immediately, without first reaching out to the physician, if the patient was in need. These opinions were not observed—or as evident— in Hospital B. However, there was a clear division between physicians and nurses, as physicians had their own station that was separate from the nurses' stations. (In Hospital A, nurses and physicians often shared work space.)

Resources. Each unit in the study had ABHR easily accessible. There were dispensers outside most patient rooms as well as immediately inside. There were also liquid soap dispensers next to all sinks throughout the unit (including in patient rooms). In addition, there were pump bottles of ABHR at the nurses' stations and pods. Having ABHR easily accessible has been shown to increase HHC rates.[8, 41] As the ECM system was installed in each of the hospitals, dispensers were required to be situated outside the entrance to a patient's room and then, in some cases depending on the layout, immediately inside the patient's room.

DISCUSSION

The *Mainspring* study sought to sustainably increase HHC rates by 50% over the units' respective baseline rates using a 'wise' intervention. The intervention, designed for nurses in acute care, sought to reanimate a nurse's sense of professional identity and responsibility, thus influencing the likelihood they would practice HH at expected moments. Our discussion of the Results will be partitioned into three domains—*intervention implementation*, *mechanisms of impact*, and *context*—and also seek to elucidate the outcome results.

In the outcome evaluation, Tidwell et al. (2019) showed that there was an overall positive, statistically significant impact on HHC rates that was generally sustained for months post-intervention (see Table 7-10).[34] However, this average effect was driven by Unit B1 and B2, which observed relatively large initial increases in the rates of compliance. Unit A1 and Unit A2 saw slight initial *decreases* in HHC rates but then small increases after two months, while the other Hospital A units (A3 and A4) exhibited immediate and sustained increases in handwashing. The two units with notably statistically significant increases in HHC were Unit B1 (MICU) and Unit A3 (neurology/neuro-surgery ICU). However, none of the units had increases in rates that were close to the goal of a 50% increase in the overall HHC rate. The average increase across units was in fact only 3%.

Given the poor reach and subpar level of participant engagement, it is difficult to infer that the intervention was solely responsible for the pattern of change in HHC rates. While the element of surprise did occur temporarily, actual re-evaluation of the target behaviour did not take place. Moreover, the intervention set out to modify already strongly formed HH habits, which is difficult to do without a more extreme disruption. Even though there was a small immediate overall increase in HHC rates, this could be due to several factors apart from the intervention such as: a) the types of units and their starting baseline compliance rates, b) the safety culture of the hospitals and units, c) the respective Nurse Manager involvement in the delivery of the intervention, and d) the inherent variability due to imperfections in the ECM data collection process. These confounders are presented in Table 7-11.

Intervention Implementation

Reach

The reach of the *Mainspring* intervention was suboptimal. The intention was to reach 80% of nurses in each unit, but exposure fell considerably short of this mark, ranging from 47% (Unit A1) to 78% (Unit A4). For Hospital A, the difficulty was recruiting nurses. As the delivery was limited to a single week, only the nurses that were working during that time were reached. Nurses who had time off, who worked on days where delivery did not occur, or who had weekend shifts were not included. Moreover, the intervention was delivered at morning shift and evening shift changes to ensure access to nurses on both shifts. However, some nurses were unable to participate due to pressing patient needs. One nurse was direct with the Facilitator as to why he could not participate. With the nurses coming off shifts, it was difficult to convince them to stay to participate in the intervention as many were exhausted and ready to leave the hospital.

In Hospital B, the difficulty was getting nurses to complete the intervention. Unit B1 had a completion rate of 71% while Unit B2's rate was 57%. The Facilitator visited Unit

B1 to talk with nurses, raise awareness, and encourage participation, but did not visit Unit B2 as the hospital's Project Manager led outreach efforts in this unit. This could explain Unit B2's lower completion rate. As compared to Hospital A, Hospital B had overall lower completion rates most likely due to the lack of the Facilitator presiding over the actual delivery. Having a Facilitator to lead intervention delivery during a set time in an agreed-upon place resulted in higher compliance rates.

Incentives

Another major difference in implementation was the use of incentives. Incentives, or the lack thereof, shaped how Nurse Managers presented the intervention to staff, which in turn could have affected nurses' general impression of the importance and pertinence of the intervention. Both units in Hospital B were presented with the incentive of a catered meal if 80% of nurses in the respective unit completed the intervention. It was observed that the Nurse Manager in Unit B1 mainly emphasized the incentive when encouraging nurses to participate. It had been decided by the Project Funder that regardless of the actual number of participants, a catered meal would be provided; thus, the nurses in the units received the meal prior to the delivery of the process evaluation questionnaires. This may have led to the initial rise in HHC rates noted in both of Hospital B's units.

The same type of incentive was not offered to units in Hospital A at the request of the hospital.[§§] While all the Nurse Managers in Hospital A presented the intervention as a hospital quality improvement project, participation was framed in different ways. The Nurse Managers of Units A2 and A4 made the intervention part of a mandatory in-service, which led to these units having the largest completion rates. The other Nurse

[§§] Hospital A could neither administer the intervention or process evaluation questionnaires online nor could it offer an incentive due to agreements in place with the union of registered nurses.

Managers included the intervention at the end of their monthly staff meetings; however, many of the nurses were unable to stay to participate in the intervention as they had to attend to patients. It is difficult to produce a large change in HHC rates when only half (or less) of nurses on the unit have been exposed to the intervention.

In addition, inconsistency in delivery— including mode, use of incentives, and recruitment of nurses— diminished our ability to 1) accurately make comparisons between the units and 2) confidently evaluate the implementation process and its possible impact on the results. Not having uniformity in delivery introduced even more variability that was difficult to completely account for.

Mechanisms of Impact

Participant Engagement

Retention of the HH message was lower than expected for each unit. In Hospital A, the nurses were facing competing distractions while completing the intervention activities. Phones rang, beepers buzzed, and computer screens in the workroom were constantly being updated with patient information. Many nurses saw the intervention as an impediment and therefore completed the intervention activities as quickly as possible so that they could return to their nursing duties and responsibilities. The nurses that were coming off the shifts were exhausted and found it difficult to concentrate, as one nurse candidly shared with the Facilitator her difficulty to process the information presented in the intervention. Thus, the nurses were unable to fully concentrate on the questionnaire, which made information retention difficult.

Nurses in Hospital B completed the intervention online outside of work. As they were in a different setting (at home rather than in the hospital) and were potentially in the middle of performing a different role (such as parent rather than nurse), they could have been in a different mind-set. Reflection or immediate practice of using the object as a reminder most likely did not occur, which could explain their low retention rates, especially regarding the object.

The values affirmation exercise appeared to have worked in creating openness to the message. While the exercise did not reduce irritability in all participants, at least half of the participants in each unit found the statement to be true, to be useful to know, and were glad that they learned about the HH message. Regardless of how acceptable the HH message was found to, the overall level of engagement was low. Again, this could be due to poor reach of the intervention in addition to the inconsistency of delivery across hospital units.

Mediators

In three units, more than half of the participants had not heard the message about general patterns of HHC before (Units A1, A2, and A4). These units also had the highest retention rates for both the HH message and object, indicating that the *element of surprise* could have positively impacted retention. While message retention often corresponded to participants remembering their chosen object for the cue-association activity, this recall did not translate into continued use of the object. As most participants did not actually use the object to remind themselves to perform HH, the intention-implementation exercise was therefore not fully realized.

Worth noting was the absence of manipulation checks for several variables such as implementation intentions and motives (nurture and disgust). Thus, we were unable to fully explore participants' perceptions of how the implementation intention exercise might have impacted HH behaviour. In regard to motives, we were unable to definitively say whether the re-evaluation had occurred in the first place, and if so, whether it was meaningful enough re-evaluation to result in conscious behaviour change.

Nevertheless, what is of most significance is that this intervention sought to create a habit for a behaviour that was already practiced intensively, and for which strong cue-associations have already been formed. Even though behaviours are initially the products of rational decision processes and can therefore be amenable to information interventions, as a behaviour is constantly practiced in a stable context over time, it becomes automatic. Once the behaviour becomes automatic it is initiated almost reflexively by environmental cues. The intervention sought to surprise nurses with the "shocking" HH message, which would cause re-evaluation. At which time, the cue-association activity would help nurses be more effective at practicing HH upon entering a patient's room. To influence a behaviour that is already habit, there must be a disruption in behavioural context that requires people to revert to deliberate decision making.[45] The break in context means that the doer of the action cannot continue their habitual behaviour and must instead consciously reconsider and reengage in deliberate decision making, allowing their attitudes to influence behaviour again.[45] However, the intervention itself did not cause a large enough discontinuity in context.

Context

Omnibus context

Hospitals. Both hospitals were on the forefront of healthcare research and innovation, especially in regards to HH. Thus, it was difficult to produce a significant increase in HHC rates in hospitals with already high baselines, who had ABHR dispensers conveniently located and easily accessible, and who constantly promoted and emphasized HH. These hospitals had their own research studies dedicated to improving compliance rates, their own past campaigns and HH initiatives, and continued partnerships with the CDC and consumer healthcare companies. In addition, both hospitals were preparing for several upcoming hospital assessments while also actively pursuing awards for excellence in patient care and nursing; these assessments would evaluate the hospitals on their HH programs and HHC rates. The hospitals were constantly launching hospital-wide quality improvement projects, which the research team later discovered often had components of HHC improvement. This may have unintentionally resulted in a negative impact on the nurses due to burn out from the repetitive HH interventions.

Hospital A is telling example. Three months before Units A1 and A2 received the *Mainspring* intervention, Hospital A had introduced their own HH campaign. The hospital administrator behind Hospital A’s HH awareness day had told the research team that HHC rates typically increased because of the campaign but would then fall below the baseline rates before stabilizing once again. This could have impacted the HHC rates for Unit A1 and A2, which had the highest HHC rates of any of the units in Hospital A, but also experienced a slight decrease in rates immediately after the intervention.

Units. The number of opportunities for HH is largely dependent on the process of care provided.[8] Researchers have found that the higher the demand for hygiene, the lower the adherence.[8, 9, 14, 37-41] In addition, the lowest adherence rates have been found in ICUs while some of the highest rates have been found in surgical and pediatric units.[8] Both units that were found to have statistically significant increases in HHC rates were ICUs. This was most likely because their baseline rates were slightly lower than the other units and that nurses most likely had greater number of opportunities for HH. Units A1 (stem-cell transplant) and A2 (oncology) had the highest HHC rates for both the baseline and the two months post-intervention, which is most likely due to the nature of care as nurses were attending to patients with compromised immune systems. Due to insufficient data size or lack of data from the analysed time-period, it is difficult to draw conclusions for Unit A4 and Unit B2.

Discrete context

Accountability and *autonomy* were the two factors that we considered to impact the flow of implementation and the change process.

Accountability. While each unit stressed the importance of practicing HH and made clear the expectation that all were to wash hands, Unit A3 had the most apparent culture of accountability. This factor could have made the nurses of Unit A3 more receptive to the intervention, especially as this unit also had the lowest reported rates of irritability regarding intervention participation.

Autonomy. In Hospital A, frustrations with the ability to provide care in conjunction with physicians was often voiced. The Nurse Managers in all units stressed the importance for nurses to act in the best interest of the patient. In addition, HH was talked about in terms of protecting patients. Therefore, we hypothesize that nurses could have seen HH as one of the ways to directly care for patients that did not require engagement with physicians first. The *Mainspring* intervention sought to encourage this empowering view of HH, but through the means of reactivating nurses' commitment to their professional roles as caregivers.[46] However, this revaluation may not have been sufficiently strong to impact behaviour.

Limitations

In this paper, we have addressed the delivery, feasibility, and acceptability of the *Mainspring* intervention. In doing so, we considered recruitment and reach and we analysed the quality and fidelity of the intervention delivered. We also measured various mechanisms of interest as well as the internal validity (by measuring differences between the study populations included) and the external validity and transferability. In judging the level of the study's evidence with respect to effectiveness, there were mediators and theoretical constructs that were neither fully evaluated (through manipulation checks) nor analysed using mediation techniques (such as structured equation modelling). In all, isolating these problems with the Theory of Change, and identifying other influences provide a deeper understanding of how the implementation, mechanisms of interests, and the context enhanced or detracted from the effectiveness of the *Mainspring* intervention.

CONCLUSION

To sustainably increase the HHC rates of nurses, we developed a 'wise' intervention that sought to reanimate nurse's sense of professional identity and responsibility, thus influencing the likelihood they would practice hand hygiene at expected moments. This paper describes a process evaluation of the resulting *Mainspring* intervention, which was implemented in six acute care units in two medical-surgical teaching hospitals in the United States. Evidence was collected through questionnaires distributed to nurses and the intervention facilitator, together with non-participant observation.

We examined the intervention's implementation, mechanisms of impact, and context against its Theory of Change. We found that aspects of the implementation—including the mode of delivery, the use of incentives, and the means by which nurses were recruited and complied with the intervention — affected its reach and likely effectiveness. In particular, for the intervention to create the desired impact, it had to establish a cause-effect cascade. We found that the values affirmation exercise worked in creating openness to the HH message, resulting in participants feeling less defensive. Next, surprise had to be created, leading to a re-evaluation of target behaviour and a disruption of its performance in the appropriate setting. Although surprise did lead to retention of the intervention message and cue, it did not translate into consistent use of the cue or performance of the target behaviour. Performance also did not seem to be affected by use of an implementation intention, because repeated performance of HH over years of being a nurse have likely already established well-ingrained practices. Context did have an effect; the safety culture of the units, the involvement of the Nurse Managers, the level of accountability for HH in each unit, and the hospitals themselves all influenced levels of engagement. These conclusions should have implications for those interested in the applicability of 'wise' interventions and those seeking to improve HHC in hospitals.

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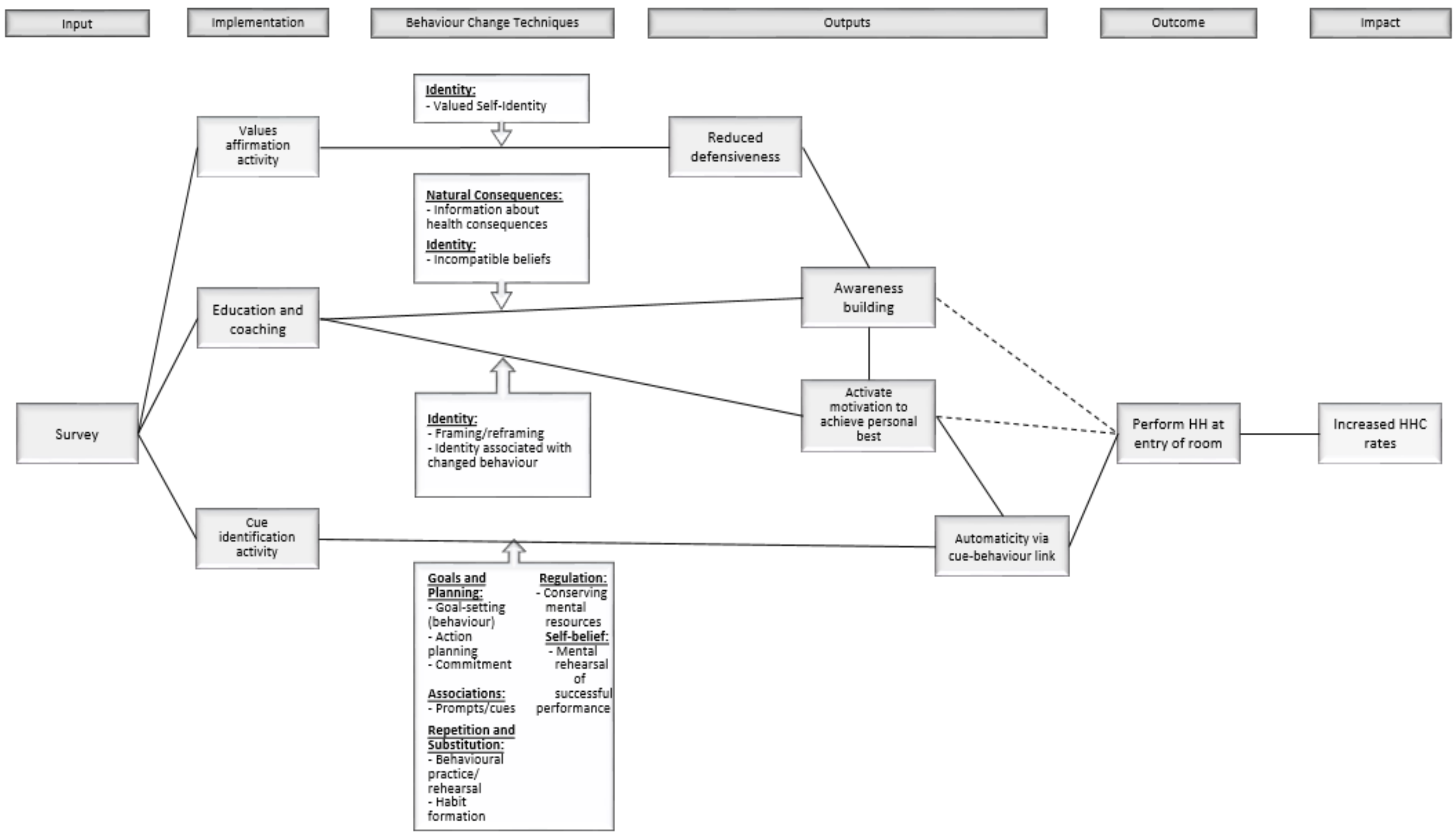
FIGURES

Figure 7- 1: Mechanisms of change and the BCTs



TABLES

Table 7- 1: Definitions of terms used in the process evaluation

TERMS	DEFINITIONS	TOOLS/ PROCEDURES
DELIVERY		
recruitment	the procedures used to approach and attract prospective program participants	• non-participant observation documenting all recruiting activities • facilitator’s questionnaire
reach	the degree to which the intended audience participated in the intervention	• hospitals' staffing numbers • number of completed intervention surveys
fidelity	the quality of the implementation of the intervention	• non-participant observation documenting intervention delivery • facilitator’s questionnaire
IMPACT		
participant engagement	the receipt, understanding, and use of the intervention’s main message	• non-participant observation documenting participation • nurses’ questionnaire • facilitator’s questionnaire
mediators	the behaviour determinants behind the proposed mechanism(s) of change)	• non-participant observation • nurses’ questionnaire
CONTEXT		
context	various aspects of the intervention setting, including the social and physical environment, which could have influenced intervention implementation or receipt	• non-participant observation • facilitator's questionnaire

Table 7- 2: Unit Characteristics

	Hospital A				**Hospital B**	
	Unit A1	**Unit A2**	**Unit A3**	**Unit A4**	**Unit B1**	**Unit B2**
Type of unit	Stem cell transplant	Oncology	Neurology/ Neuro-surgery ICU	Mother-baby	MICU	Medical Surgical Cardiology
Number of nurses	60	63	42	40	78	97
Number of patient beds	40	40	28	32	26	47

Table 7- 3: Research questions and methods

Evaluation Domains	Research Question	Method	Data Captured
Intervention Implementation			
Reach	To what extent did the nurses in each acute care unit participate in the intervention?	Facilitator questionnaire	Percentage (or proportion) of nurses reached for each unit
Fidelity	Was the intervention carried out in the way it was intended?	Facilitator questionnaire	Content and quality of delivery Successes and challenges of intervention implementation
Recruitment	*Hospitals and Units*		
	Which subgroups of hospitals were more (or less) likely to be successfully recruited? Why were certain hospitals more (or less) likely to be recruited? Was the recruitment process consistently applied across all hospitals?	Facilitator questionnaire	Recruitment strategies To determine if there was a biased sample to make sure we avoid overgeneralizing findings to all subgroups are attributing widespread success to a project that was not truly tests in all populations
	Nurses		
	How were nurses within the units recruited? Which nurses were most likely to participate? Was this recruitment process applied across all units?	Facilitator questionnaire Field observation	Recruitment strategies and any challenges
Mechanisms of Impact			
Participants engagement	To what extent did the nurses actively engage with the intervention? To what extent did the nurses understand, accept, and retain key messages?	Facilitator questionnaire Nurse questionnaire	Retention of key messages and reflections Recall and recognition of intervention Comprehension of messages and emotional responses
Mediators	How did behavioural determinants change due to exposure to the intervention?	Facilitator questionnaire	Quantitative capture of indicators relating to hypothesized behaviour determinants
Context			
Context factors	How did contextual factors act as facilitators or barriers to implementation and uptake?	Facilitator questionnaire Nurse questionnaire Field observation	Other recent HH interventions; Joint Commission visits; products being used; information of the unit;

Table 7- 4: Intervention and process evaluation delivery dates

	Hospital A				Hospital B	
	Unit A1	*Unit A2*	*Unit A3*	*Unit A4*	*Unit B1*	*Unit B2*
First day of intervention delivery	19 Sep 2016	19 Sep 2016	11 Oct 2016	29 Jan 2017	2 Aug 2016	30 Mar 2017
First day of process evaluation delivery	10 Oct 2016	10 Oct 2016	8 Nov 2016	5 Mar 2017	11 Oct 2016	8 May 2017

Table 7- 5: Various delivery approach in each hospital unit

Delivery in Hospital A	*Unit A1*	Facilitator approached individual nurses during their shifts
	Unit A2	Attended change-of-shift reports in the morning
	Unit A3	Attended mandatory staff meetings and approached individual nurses during their shifts
	Unit A4	Administered to nurses organized by Nurse Managers and approached individual nurses during their shifts
Delivery in Hospital B	*Unit B1*	Administered online with reminder e-mails; Facilitator present to remind staff
	Unit B2	Administered online with reminder e-mails; Facilitator not present

Table 7- 6: Reach of intervention and process evaluation

Setting	Delivery			Reach of Intervention and Process Evaluation									Timespan
Hospital Unit	Method	Facilitator present on site*		Nursing staff level (no. of nurses)	Intervention (no. of nurses)				Process Evaluation (no. of nurses)			% Target population that completed both the intervention and process evaluation	Total number of intervention days
		Intervention	Process Evaluation		All intervention participants	Participants who completed the intervention	Completion rate (%)	Response rate (%)	Completed questionnaires	Completed questionnaires by intervention participants†	Percentage of questionnaires that were completed by intervention participants (%)		
A1	In-person	Yes	Yes	60	28	28	100%	46.7%	20	14	70.0%	23.3%	3
A2	In-person	Yes	Yes	63	44	43	97.7%	68.3%	31	23	74.2%	36.5%	3
A3	In-person	Yes	Yes	42	26	25	96.2%	59.5%	20	17	85.0%	40.5%	3
A4	In-person	Yes	Yes	40	31	31	100%	77.5%	12	12	100.0%	30.0%	3
B1	Online	Yes	No	78	57	41	71.9%	52.6%	49	43	87.8%	55.1%	30
B2	Online	No	No	97	52	30	57.7%	30.9%	32	26	81.3%	26.7%	30

* The facilitator led the in-person sessions. For the online sessions, in the case of Units B1 and B2, the facilitator was present to alert nurses to the intervention, explain what was required of the nurses, and to remind the nurses to fill it out online. The facilitator was only present in Unit B1 and Unit B2 a total of three days each.

† Nurses in Hospital A and Hospital B were prompted to fill out the process evaluation forms. Some of the nurses who were given the process evaluation had not been a part of the intervention.

Table 7- 7: Participants recall of message and object, and use of object as a cue

Hospital Units	Completed process evaluation questionnaires	Recall of HH message		Recall of object		Initial use of object		Continual use of object	
	N nurses	N nurses	%	N nurses	%	N nurses	%	N nurses	% still use
A1	14	9	64.29	8	88.89	8	88.89	8	100
A2	23	16	69.57	12	80.00	12	80.00	11	91.67
A3	17	10	58.82	9	90.00	9	90.00	8	88.89
A4	12	8	66.67	6	100	6	100	6	100
B1	43	22	51.16	6	66.67	6	66.67	4	66.67
B2	26	9	34.62	5	100	5	100	4	80.00

Table 7- 8: Acceptability of HH message

Hospital units	Completed process evaluation questionnaires	Participants who remembered the HH message	Believe the message to be true					Felt irritated					Found the message useful to know					Glad to learn the message				
			Disagree		Neutral	Agree		Disagree		Neutral	Agree		Disagree		Neutral	Agree		Disagree		Neutral	Agree	
			Strongly	Somewhat		Strongly	Somewhat	Strongly	Somewhat		Strongly	Somewhat	Strongly	Somewhat		Strongly	Somewhat	Strongly	Somewhat		Strongly	Somewhat
A1	14	9	0	4	0	0	5	2	1	3	2	1	0	0	1	5	3	1	1	1	4	2
A2	23	16	3	2	3	3	5	1	3	3	5	4	0	1	1	13	1	0	1	0	12	3
A3	17	10	0	1	2	0	7	3	1	3	0	3	0	0	0	6	4	0	0	1	4	5
A4	12	8	2	1	5	0	0	0	1	4	1	2	0	0	2	4	2	0	0	3	3	2
B1	43	22	0	3	4	5	10	1	5	9	0	7	1	1	1	7	12	0	1	7	5	9
B2	26	9	0	2	1	1	5	0	0	5	1	3	1	0	0	2	6	0	0	1	2	6

Table 7- 9: Mechanism of surprise

Hospital Units	Recall of message	Previous exposure to message			
		Have seen message before		Have not seen message before	
	Number of nurses	Number of nurses	% nurses who recalled the message	Number of nurses	% nurses who recalled the message
A1	9	1	11.11	8	88.89
A2	16	6	37.50	10	62.5
A3	10	6	60.00	4	40.00
A4	8	2	25.00	6	75.00
B1	22	12	54.55	10	45.45
B2	9	2	22.22	8	88.89

Table 7- 10: Intervention impact summary

Unit	Baseline HHC rate	Compliance rate	Relative change from baseline HHC	Compliance rate	Relative change from baseline HHC
	Pre-intervention	*<2 months post-intervention*	*<2 months post-intervention*	*>2 months post-intervention*	*>2 months post-intervention*
Overall	20.6%	23.9%	+11.6% (11.4, 11.9)*	23.7%	+11.5% (11.2, 11.9)*
Unit A1	40.5%	38.9%	-3.9% (-7.4, -0.3)*	41.0%	+1.3% (-2.7, 5.3)
Unit A2	35.8%	33.4%	-6.5% (-9.9, -3.1)*	36.0%	0.7% (-3.2, 4.6)
Unit A3	24.9%	25.9%	+4.3% (-0.3, 9.0)	27.5%	+10.7% (5.6, 15.7)*
Unit A4	22.3%	22.7%	+1.8% (-5.1, 8.6)	27.5%	n.d.
Unit B1	19.5%	25.7%	+31.8% (26.4, 37.2)*	26.0%	+33.2% (+25.1, 41.3)*
Unit B2	17.6%	25.9%	+45.9% (41.4, 50.4)*	NA	NA

*Note: *: p < 0.05; n.d. = no data shown due to insufficient sample size; NA = no applicable data from period*

Reprinted from Tidwell et al. (2019)[34]

Table 7- 11: Possible confounders and likely effects

PROCESS VARIABLE	HOSPITAL	POSSIBLE CONFOUNDER	LIKELY EFFECT (+) positive (-) negative
Intervention Implementation			
Delivery of Intervention	Hospital A	In-person delivery	(+) Reach—led to more nurses participating (-) Participant Engagement—led to decreased engagement due to competing distractions (ringing phones, buzzing beepers, patients' call buttons)
		Delivered during a single week at shift changes	(-) Reach— nurses who did not work during days of delivery were not included
		Facilitator present for delivery	(+) Reach— led to higher participation rates as compared to online
	Hospital B	Online delivery over course of a month	(-) Reach—resulted in lower participation rates as prompting participation was difficult (-) Participant Engagement—led to lower engagement as nurses were in a different setting and in different roles
		Facilitator present for delivery in Unit B1	(+) Reach— may have resulted in higher participation rates as compared to Unit B2
		Facilitator absent for delivery in Unit B2	(-) Reach— may have resulted in lower participation rates as facilitator was not present to encourage participation
Presentation of intervention	Hospital A	Presented as the hospital's quality improvement project	(+) Participant Engagement—could have impacted the nurses' general impression of intervention's importance
		Part of mandatory in-service in Unit A3	(+)
	Hospital B	Incentive of catered meal if target participation goal was met	(+) Reach— may have encouraged participation (-) Participant engagement—may have impacted the nurses' general impression of importance and pertinence of intervention
Context			
Teaching and research hospitals with special interest in HH	Hospital A	Part of the CDC's Prevention Epicentre Program; numerous quality improvement projects centred on HH	(+) Outcome/ Effectiveness—the safety culture is evident and nurses understand the importance of HH (-) Outcome/ Effectiveness—having higher than average HH rates makes it difficult to significantly raise rates (-) Participant Engagement—there may be burn out from repetitive HH interventions
		HH awareness day	(-) Outcome/ Effectiveness—may have impacted HHC rates

			of Unit A1 and A2 as HHC rates increased significantly and then fell below baseline rates before stabilising
	Hospital B	Part of the CDC's Prevention Epicentre Program; numerous quality improvement projects centred on HH	(+) Outcome/ Effectiveness—the safety culture is evident and nurses understand the importance of HH (-) Outcome/ Effectiveness—having higher than average HH rates makes it difficult to significantly raise rates (-) Participant Engagement—there may be burn out from repetitive HH interventions
Types of hospital units and care provided	Hospital A	Types of units - A1: Stem cell transplant - A2: Oncology - A3: Neurology/ Neuro-surgery ICU - A4: Mother-baby	(+/-) Outcome/ Effectiveness—number of HH opportunities largely dependent on process of care provided ○ Units A1 and A2: high baseline HHC rates likely due to nature of care (patients with extremely compromised immune systems) ○ Unit A3: lower baseline rate and greater number of opportunities for HH ○ Unit A4: insufficient data size
	Hospital B	Types of units - B1: MICU - B2: Medical Surgical Cardiology	(+/-) Outcome/ Effectiveness—number of HH opportunities largely dependent on process of care provided; ICUs have lowest HHC rates ○ Unit B1: lower baseline rate and greater number of opportunities for HH ○ Unit B2: insufficient data size to draw conclusion
Accountability	Hospital A	Unit A3 has most apparent culture of accountability (HHC rates on computer monitors and on bulletin boards around the unit)	(+) Outcome/ Effectiveness—nurses may have been more receptive to participating in the intervention (+) Participant Engagement—nurses may have been more receptive to participating in the intervention
Autonomy	Hospital A	Frustrations involving the ability to provide care in conjunction with physicians; Nurse Managers stressed importance of nurses acting in best interest	(+) Participant Engagement—nurses may have been more receptive to participating in the intervention

		of patient; HH discussed as a way to protect patients	
ECM Data Collection			
Staggered data collection	Hospital A Hospital B	Insufficient data size or lack of data from analysed time-period	(-) Outcome/ Effectiveness—unable to draw conclusions for Units A4 and B2
Indiscriminate data collection	Hospital A Hospital B	Unable to identify who used (or did not use) ABHR in the dispenser	(+/-) Outcome/ Effectiveness—not able to discriminate between nurses and other healthcare professionals and visitors

CHAPTER 8: DISCUSSION

The overall aim of this project was to develop and evaluate an original hand hygiene (HH) intervention for nurses in acute care hospital units. The intervention sought to sustainably improve hand hygiene compliance (HHC) rates. This was achieved by assessing the current state of HH interventions through a systematic literature review, by conducting formative research to explore underutilized factors that influence HH behaviour, by creating an intervention and designing a study to test the intervention, and by conducting an outcome and process evaluation to determine and understand the effects. This chapter summarises (a) the main findings of the work conducted for the thesis, (b) its main contributions to HHC and behaviour change, (c) its strengths and limitations beyond those discussed in previous chapters, and (d) areas of future work.

SUMMARY OF KEY FINDINGS

The purpose of the systematic review in Chapter 2 was to identify the mechanisms by which current HH interventions sought to improve HH behaviour amongst nursing personnel. Prior reviews have indicated that successful HH interventions are multifaceted approaches that bundle education, reminders, feedback, and, in some cases, access to ABHR and the inclusion of administrative support. We identified a shift in the types of behaviour change techniques (BCTs) used in recent studies on HH interventions, as compared with prior studies from before the review period. These newer interventions did not focus on providing access to alcohol-based hand rub (ABHR) or trying to encourage administrative support. Instead, they worked more on individual-level psychological factors. For example, they had nurses create goals and plan how to best facilitate HH, compared both individuals' and the group's behaviour towards others, and focused on the consequences arising from not practicing HH. In addition, several interventions incorporated techniques expected to work at the team-level, rather than the individual or institution. While the reviewed intervention studies incorporated numerous BCTs[1] from many different categories of psychological mechanisms, we found that only a few techniques within each group had been used. Moreover, most of the BCTs used were cognitive in nature. This meant that there were diverse groups of techniques yet to be explored in HH promotion. We hypothesised that paying greater attention to the habitual, contextual nature of HH would likely lead programmers to choose somewhat different BCTs than the cognitive, planning-orientated techniques that have proven popular in past interventions. Modifications of the healthcare environment are also likely to be helpful in such cases, nudging nurses into higher compliance over the long term.

Our formative research (Chapter 3) sought to assess the potential impact of the kinds of previously unexamined factors on the HHC of nurses: professional role and status, social affiliation, social norms, and physical modifications to the work environment, as well as institutional factors like safety climate. A survey questionnaire was developed and administered online to a panel of US nurses. Our multivariate regression modelling suggested that HHC was most likely to be influenced by the hospital management's openness in communication, being watched by peers, increased interactions with patients and other staff members, and the reduction in stress, busyness, and cognitive load associated with role performance. Thus, we concluded that a powerfully effective HH intervention for nurses should: 1) incorporate aspects of improving communication openness, 2) consider the impact of perceived performance by peers, 3) increase interactions with patients and staff, and 4) determine how to reduce the stress and cognitive load associated with role performance. As work-related and psychological factors have an impact on HH behaviour and ultimately on the spread of HAIs, our finding suggest that innovative approaches which focus on these behavioural levers and barriers might have an ability to sustainably increase HHC rates among nurses. Our intervention design paper (Chapter 4) detailed the creation of an original HH intervention that used the Behaviour Centred Design (BCD) approach.[2] What emerged from the development process was a 'wise' intervention, which is a psychologically precise, often brief intervention that aims to alter self-reinforcing process that unfold over time.[3] The mechanisms, and the corresponding BCTs, behind the hypothesised Theory of Change were identified and explained, demonstrating how the constructs of the behavioural framework were operationalised. The intervention was relatively simple compared to most HH initiatives in the literature, both in terms of having relatively few components and relatively easy field implementation.

The thesis then moved to an analysis of the outcomes from a trial implementation of this intervention among nurses in two hospitals in the Midwestern US (Chapter 6). Interrupted time series analysis, based on a quasi-Poisson regression model, was used for this purpose. It showed there was an overall positive, statistically significant impact of the intervention on HHC rates. However, looking at the units individually showed that the impact of the intervention varied; in several cases, the impact was not statically significant and in other instances there was unusual temporal patterns of change. Further, a statistical process control analysis suggested that most of the observed variation was due to naturally-occurring (but unmeasured) causes rather than the intervention. While the aggregate result demonstrated a positive increase in HHC rates, the stark differences in the individual units' responses indicate that this trial cannot be considered to have provided a strong foundation for use of a ‘wise’ intervention that targets professional identity at scale.

The process evaluation then sought to further investigate the sources of variability in HHC rates in an effort to explain the outcome (Chapter 7). This evaluation—through questionnaires and non-participant observation— examined the intervention’s implementation, mechanisms of impact, and context. We found that aspects of the implementation—including the mode of delivery, the use of incentives, and how nurses were recruited and complied with the intervention— affected its reach and likely effectiveness. For the intervention to create the desired impact, it had to establish a cause-effect cascade. We found that the values affirmation exercise worked in creating openness to the HH message, resulting in participants feeling less defensive. Next, surprise had to be created, leading to a re-evaluation of target behaviour and a disruption of its performance in the appropriate setting. Although surprise did lead to retention of the intervention message and cue, it did not translate into consistent use of the cue or performance of the target behaviour. Performance also did not seem to be affected by use of an implementation intention. This was because repeated performance of HH over years of being a nurse have likely led to established and well-ingrained HH practices. Context did have an effect; the safety culture of the units, the involvement of the Nurse Managers, the level of accountability for HH in each unit, and the hospitals themselves all influenced levels of engagement. It was these extraneous factors not associated directly with the intervention, that likely accounted for significant parts of the variation in HHC rates among units around the time of the intervention.

MAIN CONTRIBUTIONS OF THE THESIS

As explained in Chapter 2, objectively evaluating complex interventions is challenging.[4] Various approaches, such as Qualitative Comparative Analysis (QCA) and Intervention Component Analysis (ICA), have been recently employed in systematic reviews to understand the mechanisms through which different interventions attempt to change behaviour.[5-7] In our systematic review, we used logic models and the identification of BCTs and corresponding determinants to categorise and analyse HH interventions, based on an ICA process, while following standard quantitative systematic review practices for filtering studies based on the quality of their research design. By creating logic models— which are normally not developed by reviewers or considered in HH intervention analyses— and combing those with components of ICA, we adopted a comprehensive approach that articulated the theoretical basis and identified the critical BCTs and components of each HH intervention. In this way, our systematic review created an innovative approach to analysing interventions that combined quantitative and qualitative methods.

The methods of our formative research paper (Chapter 3) included an inventive questionnaire that incorporated concepts and measurement tools from fields such as sociology and psychology (such as vignettes and the self-reported habit index). These types of questions are neither commonly used in web-based questionnaires nor in surveys about HH practices. In addition, this paper highlighted the importance of using formative research to provide the theoretical basis for the *Mainspring* intervention; it showed a crucial part of the intervention development process that is not often detailed in the literature.

In designing the intervention (Chapter 4), we used the Behaviour Centred Design (BCD) approach. What emerged from the development process was a 'wise' intervention, which has not to our knowledge been used in HH interventions before. Our intervention was relatively simple compared to most HH initiatives in the literature, both in terms of having relatively few components and relatively easy field implementation. In addition, unlike most intervention development papers, our paper clearly linked behaviour analysis to the intervention design.

The study protocol (Chapter 5) discussed how to test the intervention in a healthcare setting that requires the attention of HCWs that cannot be easily "pulled from the floor." In addition, given that we were using two different hospitals and different units, the multiple baseline design allowed us to control for threats to validity.

The outcome evaluation (Chapter 6) showed that there was an overall positive increase in HHC rates. However, as there was little consistency in how the units responded and given the intervention's suboptimal reach, we cannot confidently attribute the increase in HHC rates to the intervention. The contribution of this paper to the literature is the testing of a 'wise' intervention targeted at nurses' HH behaviour using a multiple baseline design. Our negative results also highlighted that while the 'wise' intervention focused on reactivating professional identity, it is difficult to change a behaviour that is already practiced intensively and for which strong cue-associations have already been formed. Moreover, application of statistical process techniques alongside interrupted time-series analysis is not commonly conducted in public health evaluations.

Process analyses are themselves unusual, but ones which can be so precise about the mechanisms by which interventions work are even more so. Our process evaluation analysed the intervention's implementation, mechanisms of impact, and the context surrounding the delivery. With the *Mainspring* intervention being so simple, it was possible to carefully track exactly what worked and what did not work with respect to the mechanisms of action. This paper allows healthcare workers and researchers alike to see how to evaluate the process by which effects are achieved for intervention studies how the role of theory is relevant to implementation research.

STRENGTHS AND LIMITATIONS

While the strengths and limitations of specific methods and analytical approaches have been discussed in each chapter, this sections focuses on the overarching strengths and limitations of the intervention.

Strengths

Behaviour Centred Design

One of the key strengths of this thesis was the use of the innovative BCD approach. Founded in both behavioural science and design thinking practice, BCD is based on several key theories: a) reinforcement learning, which explains how through a reward behaviour-environment interactions can change future behaviour, b) behaviour settings theory, which shows how context can be altered to cause change, c) evolutionary psychology, which demonstrates how three levels of behaviour control have evolved, and d) a five-step design thinking process that constructs and evaluates an intervention.[2] The BCD framework offered both a theory of change for behaviour and a practical process for designing and evaluating interventions. Having the singled-minded focus on behaviour as the key outcome and approaching the study of behaviour in terms of its physical, social, biological, and temporal context ensures that every aspect of the behaviour is examined and that the result of efforts is the change in behaviour itself. In addition, by using a structured approach, there was cohesive direction throughout the research process. Each of the steps— Assess, Build, Create, Deliver, and Evaluate— had a defined purpose, a set goal, and was built upon the step before. BCD provided a flexible framework that allowed for the adoption of new methods and tactics based on previous findings and situational constraints.

Methodological Approaches

Another strength is the use of both qualitative and quantitative research methods. Some of the methods involved library work, some involved fieldwork, and some involved running a trial. The combination of both quantitative and qualitative methods was used at times to either sequentially or simultaneously answer the same research questions—as with the systematic literature review and the formative research. Other times, the mixed methods design exhibited the function of expansion in which the qualitative data was used to explain findings from the analyses of quantitative data—as with the outcome evaluation and the process evaluation. By using an array of methods, we were best able to advance our understanding of the current state of HH and to explain underlying mechanisms and context.

Limitations

Intervention Design

The research team faced numerous constraints when designing the intervention. First, we were given a three-year period by the Project Funder to design, implement, and evaluate the intervention. Second, we were instructed to create an intervention that had a small financial cost and minimal logistical complexities. Third, the intervention could not rely on creating any changes—be it minor or drastic in nature—to the environment as per the requirements of the hospitals. Fourth, the intervention had to be relatively quick as nurses could not be taken off the floor for long periods of time. Thus, the research team had to creatively design an intervention that caused behaviour change while taking all the above factors into consideration. This impeded our ability to adequately explore the entire range of behaviour change mechanisms and techniques.

Electronic Compliance Monitoring (ECM) System

The ECM system provided real-time data collection. While this enabled the team to collect large volume of data on HH rates without the resulting Hawthorne effect, there were severe limitations to this type of data collection. First, as we did not use a badge-based system, we were unable to accurately isolate and measure nurses' HHC rates. While the majority of data points were from nurses providing care, it is difficult for us to fully see how the intervention may have affected HHC rates, as other groups—such as visitors, environmental services, and HCWs like doctors— were also included in the data. Second, the ECM does not provide information about the HH event in the context of care delivery; thus, there is a limited evaluation of the context surrounding the moment for HH.[8] And third, the sensors in the dispensers may break down or HCWs may 'game' the automated counters, resulting in under- or overestimation of HHC.[9]

Implementation and Evaluation

We were restricted to two hospitals and to whatever acute care units the hospitals made available to participate. This affected our ability to make the results generalizable. In addition, as we did not have control over the recruitment of units, we were unable to choose units that were completely comparable. As a result, uncontrolled variance was introduced into the data collection.

In addition, neither the delivery of the intervention nor the process evaluation survey were consistent between the hospitals or within the units themselves. Inconsistencies in implementing the intervention and process evaluation affected nurse recruitment and ultimately had a negative impact on the reach and the level of participant engagement. Furthermore, it made it difficult to compare the outcomes.

INTERPRETATIONS AND CONSIDERATIONS

In the end, we were unable to draw robust conclusions about whether the *Mainspring* intervention was effective in promoting HHC. This was largely due to key methodological limitations of the study design. For instance, the implementation of the intervention was inconsistent across units and hospitals; this negatively impacted reach and engagement, and made it extremely difficult to compare the HH rates across each unit. In addition, the ECM system was unable to discern between nurses and others who used the dispensers; this could have been a problem if there were changes in the proportion of people entering and exiting a patient's room who were not nurses during the time of the study. Moreover, each of the hospital units included in this study provided a different type of care; as such, this did not allow for a true comparison of HHC rates across the units. Finally, not being able to have a dedicated time during the shift for the nurses to engage meaningfully with the intervention was a major limitation; it is near impossible to change behaviour if the participants are not engaged or focused on the intervention at hand. Thus, we believe that this study was not a valid test of the *Mainspring* intervention, and as such drawing a clear conclusion is difficult to do.

AREAS OF FURTHER RESEARCH

The systematic review made it clear that the BCTs used by current and past HH intervention fell into a relatively narrow range, and suggested that new campaigns should look to other, unused forms of promotion to achieve sustained improvements in HHC. Paying greater attention to the habitual, contextual nature of HH would likely lead programmers to choose somewhat different BCTs than the cognitive, planning-orientated techniques have proven popular to study in the past. Modifications of the healthcare environment are also likely to be helpful in such cases, nudging nurses into higher compliance over the long term.

The formative research identified levers and facilitators to HH behaviour and thus emphasized the need to develop an innovative approach that seeks to incorporate the following factors: a) improvement in communication openness, b) consideration of the impact of perceived performance by peers, c) increases in the interactions with patients and staff, and d) reduction in the stress and cognitive load associated with role performance.

The outcome and process evaluations further highlighted the importance of further studying and testing interventions that depend on a precise understanding of people's psychological reality (what it is like to be them and how they see themselves and their social worlds), that are brief, simple, and have relatively small financial and logistical cost. In regard to the *Mainspring* intervention, I strongly encourage a smaller pilot study to be conducted which addresses the limitations discussed in detail above. Psychological frameworks of behaviour change demonstrate significant potential for improving HHC; it is imperative that we continue to develop theory-based interventions to improve HHC so that we can ultimately increase the quality of care received patients and limits the spread of infections in healthcare settings.

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APPENDICES

APPENDIX 2-1: SEARCH STRINGS

Search strings for the systematic literature review.

SEARCH STRINGS

1. handwashing
2. hand washing
3. hand wash
4. handwash
5. hand hygiene
6. 1 OR 2 OR 3 OR 4 OR 5
7. intervention*
8. program*
9. activit*
10. technique*
11. technolog*
12. protocol*
13. initiative*
14. campaign*
15. 7 OR 8 OR 9 OR 10 OR 11 OR 12 OR 13 OR 14
16. 6 AND 15
17. compliance*
18. observance
19. 17 OR 18
20. 16 AND 19
21. hospital*
22. healthcare
23. health care
24. healthcare environment*
25. health care environment*
26. healthcare setting*
27. health care setting*
28. 21 Or 22 OR 23 OR 24 OR 25 OR 26 OR 27
29. 19 AND 28
30. nurse*
31. nursing
32. 30 OR 31
33. 28 AND 32
34. Limit 33 to English and publications between 2002-2016

APPENDIX 2-2: COMMON AND RELEVANT BCTs

Table A2- 1: Explanation of most common and relevant BCTs

Grouping	BCTs	Definition
Goals and planning	Problem-solving	Analyse, or prompt the person to analyse, factors influencing the behaviour and generate or select strategies that include overcoming barriers and/or increasing facilitators (includes 'relapse prevention' and 'coping planning')
	Goal-setting (outcome)	Set or agree on a goal defined in terms of a positive outcome of wanted behaviour
	Action planning	Prompt detailed planning of performance of the behaviour (must include at least one of context, frequency, duration and intensity). Context may be environmental (physical or social) or internal (physical, emotional or cognitive includes 'implementation intentions')
	Discrepancy between current behaviour and goal	Draw attention to discrepancies between a person's current behaviour (in terms of the form, frequency, duration or intensity of that behaviour) and the person's previously set outcome goals, behavioural goals or action plans (goes beyond self-monitoring of behaviour)
	Commitment	Ask the person to affirm or reaffirm statements indicating commitment to change the behaviour
Feedback and monitoring	Feedback on behaviour	Monitor and provide informative or evaluative feedback on performance of the behaviour (e.g. form, frequency, duration, intensity)
	Self-monitoring of behaviour	Establish a method for the person to monitor and record their behaviour(s) as part of a behaviour change strategy
	Feedback on outcome(s) of behaviour	The infection and HHC rates were shared during the monthly quality meetings. This provided feedback on how the unit was performing.
Social support	Social support (practical)	Advise on, arrange or provide practical help (e.g. from friends, relatives, colleagues, 'buddies' or staff) for performance of the behaviour

Shaping knowledge	Instruction on how to perform the behaviour	Advise or agree on how to perform the behaviour (includes 'skills training')
Natural consequences	Information about health consequences	Provide information (e.g. written, verbal, visual) about health consequences of performing the behaviour
	Salience of consequences	Use methods specifically designed to emphasise the consequences of performing the behaviour with the aim of making them more memorable (goes beyond informing about consequences)
	Demonstration of the behaviour	Monitor and provide informative or evaluative feedback on performance of the behaviour (e.g. form, frequency, duration, intensity)
Comparison of behaviour	Social comparison	Draw attention to others' performance to allow comparison with the person's own performance
	Information about others' approval	Provide information about what other people think about the behaviour. The information clarifies whether others will like, approve or disapprove of what the person is doing or will do
Associations	Prompts/cues	Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour. The prompt or cue would normally occur at the time or place of performance
Repetition and substitution	Behavioural practice/rehearsal	Prompt practice or rehearsal of the performance of the behaviour one or more times in a context or at a time when the performance may not be necessary, in order to increase habit and skill
	Habit formation	Prompt rehearsal and repetition of the behaviour in the same context repeatedly so that the context elicits the behaviour
	Generalisation of target behaviour	Advise to perform the wanted behaviour, which is already performed in a particular situation, in another situation
Comparison of outcomes	Credible source	Present verbal or visual communication from a credible source in favour of or against the behaviour

Reward and threat	Social reward	Arrange verbal or non-verbal reward if and only if there has been effort and/or progress in performing the behaviour (includes 'positive reinforcement')
	Social incentive	Inform that a verbal or non-verbal reward will be delivered if and only if there has been effort and/or progress in performing the behaviour (includes 'positive reinforcement')
	Non-specific incentive	Inform that a reward will be delivered if and only if there has been effort and/or progress in performing the behaviour (includes 'positive reinforcement')
	Incentive (outcome)	Inform that a reward will be delivered if and only if there has been effort and/or progress in achieving the behavioural outcome (includes 'positive reinforcement')
	Reward (outcome)	Arrange for the delivery of a reward if and only if there has been effort and/or progress in achieving the behavioural outcome (includes 'positive reinforcement')
Antecedents	Restructuring the physical environment	Change, or advise to change the physical environment in order to facilitate performance of the wanted behaviour or create barriers to the unwanted behaviour (other than prompts/cues, rewards and punishments)
	Adding objects to the environment	Add objects to the environment in order to facilitate performance of the behaviour
Identity	Framing/reframing	Suggest the deliberate adoption of a perspective or new perspective on behaviour (e.g. its purpose) in order to change cognitions or emotions about performing the behaviour (includes 'cognitive structuring')
	Identity associated with changed behaviour	Advise the person to construct a new self-identity as someone who 'used to engage with the unwanted behaviour'
Scheduled consequences	Situation-specific reward	Arrange for reward following the behaviour in one situation but not in another (includes 'discrimination training')

Self-belief	Mental rehearsal of successful performance	Advise to practise imagining performing the behaviour successfully in relevant contexts
	Focus on past success	Advise to think about or list previous successes in performing the behaviour (or parts of it)

APPENDIX 2-3: EXPLANATION OF BCTs IDENTIFIED IN STUDIES

Table A2- 2: Explanations of BCTS codes for *Fox et al.*

Fox et al. 2015			
Inputs and Implementation			**Code and Reasoning**
Element	**Activity**	**Components**	
Training	Meeting	Members of nursing staff received verbal instructions from a study team member	**4.1 Instruction on how to perform a behaviour** The intent of verbal instructions was to ensure that the nursing staff understood the correct hand hygiene technique.
		Monitored for proper return demonstration of the patient hand hygiene protocol (PHHP)	**2.2 Feedback on behaviour** Nurses demonstrated the PHHP and were monitored for proper return. ‘Monitor’ was interpreted as meaning that the nurses were watched closely for the purposes of ensuring performance aligned with the PHHP. It is assumed that feedback was provided. **6.1 Demonstration of behaviour** The team provided feedback to ensure performance aligned with the PHHP. **8.1 Behavioural practice/rehearsal** Nurses were prompted to practice the PHHP multiple times even though the actual intervention had yet to be implemented. The intention was to establish correct delivery of the PHHP.
	EMR	Electronic medical record (EMR) triggers a timely reminder to perform the PHHP three times a day	**7.1 Prompts/cues** As nurses are focused on other duties (such as charting), they are reminded to perform the PHHP through prompts on the EMR. **8.3 Habit formation** The repeated prompting to perform the PHHP leads to the continuous repetition of performing the PHHP.
		Prompt in the EMR also requires nurses to document HH protocol adherence	**2.3 Self-monitoring of behaviour** Nurses are required to report whether or not they performed the PHHP. **15.3 Focus on past success** By reporting one’s compliance with the PHHP, nurses are required to reflect and focus on the action—the performance of the PHHP—that has just been completed.
	Room visits	PHHP cleaning patients hands	**8.6 Generalization of target behaviour** In healthcare settings, attention regarding the promotion of HH is focused mainly on HCWs. In this intervention, the promotion of HH is focused on the patients. **13.2 Framing/reframing** The act of performing the PHHP is framed in terms of patient care. The patient is at the centre of this intervention—nurses’ own HH behaviour is not emphasized, only adherence to the PHHP. **13.5 Identity associated w/changed behaviour** **Reasoning:** By performing the PHHP, nurses create bonds with their patients. The nurses adopt the identity of nurturer. Therefore, the role of the nurse is expanded, and as such identity is impacted.

Table A2- 3: Explanations of BCTS codes for *Erasmus et al.*

Erasmus et al. 2010			
Inputs and Implementation			**Code and Reasoning**
Element	**Activity**	**Components**	
Structured Interview	Education and reflection	Importance of hand hygiene	**5.1 Information about health consequences** It is assumed that in discussing the importance of HH, the consequences of not performing HH would also be included.
		Rated self-compliance	**1.6 Discrepancy between current behaviour and goal** By asking the participants to reflect on their own HH behaviour through rated self-compliance, participants must consider their own behaviour and compare it to the desired behaviour learned about in the previous component.
		Preferred methods of hand hygiene	**Unable to code** **Reasoning:** The description of this component is vague and unable to be coded.
		Possible barriers encountered	**1.2 Problem solving** An analysis of barriers to performing HH were identified.
	Implementation intention	Action plans	**1.4 Action planning** plans for performing HH in specific contexts were created by the participants.
	Coping Plan	Coping planning	**1.2 Problem solving** Participants anticipated and planted alternatives for moments when they were unable to execute their own action plan. This is coping planning.

Table A2- 4: Explanations of BCTS codes for *Stock et al.*

Stock et al. 2015			
Inputs and Implementation			**Code and Reasoning**
Element	**Activity**	**Components**	
12- 45 minute sessions of ' training' over 1.5 days	First part: Initial objective structured clinical examination (OSCE) via stations	Evaluate one of the key hygiene skills defined previously	**Unable to code** The description of this component is vague and unable to be coded.
		Give participants the chance to reflect on their hygiene and communication skills***	**1.6 Discrepancy between current behaviour and goal** By asking the participants to reflect on their own HH behaviour and communication skills, participants must consider their own behaviour and compare it to the desired behaviour. **15.2 Mental rehearsal of successful performance** Participants were presented new information and asked to reflect on their own behaviour as well as on the new material presented. It is assumed that in doing so, the participants imagined performing the behaviour successfully.
	Second part: a combined theoretical and practical learning session	Lectures and role-play to train communication and feedback methods	**8.1 Behavioural practice/rehearsal** The lectures and role-play allow for participants to repeatedly practice the behaviour in a simulated context.
		Reflection and evaluation of communication abilities	**2.3 Self-monitoring of behaviour** The participants monitor their behaviour through constant reflection and evaluation. What sets this component apart from the reflection component in the initial OSCE phase is the word 'evaluate'. Participants evaluate their own abilities.
		Quality management in hospital hygiene	**Unable to code** **Reasoning:** The description of this component is vague and unable to be coded.
		Methods to address barriers to hygiene when	**1.2 Problem solving** Identifying and then creating strategies to address barriers is problem-solving.

*** It is difficult to code 'reflection.'

		communicating with peers and superiors	
	Third part: a combined theoretical and practical simulation training	Theoretical information	**Unable to code** The description of this component is vague and unable to be coded.
		Simulation training in hygiene skills in different situations. Participants were encouraged to ask questions and practiced hygiene skills under the supervision of the infection control nurse	**2.2 Feedback on behaviour** Participants demonstrated HH skills under the supervision of the infection control nurse. Participants were encouraged to ask questions. As such, it is assumed that the nurse provided feedback. **4.1 Instruction on how to perform the behaviour** The simulation training is a form of skills training. **6.1 Demonstration of the behaviour** The simulation requires participants to learn how to act in certain situations. It is assumed that such behaviour has been demonstrated by others, such as the infection control nurse. Also, participants could regard the infection control nurse as a role model, and as such, model their own behaviour accordingly. **8.1 Behavioural practice/rehearsal** Participants demonstrated HH skills in different situations under the supervision of the infection control nurse through the simulation training. It is assumed that the simulations were repeatedly run with participants practicing multiple times. **8.3 Habit formation** Participants demonstrated HH skills in different situations under the supervision of the infection control nurse through the simulation training. It is assumed that the simulations were repeatedly run with participants practicing multiple times.
	Fourth part: final OSCE evaluation	OSCE assessment was repeated to evaluate improvements in hygiene skills	**2.7 Feedback on outcome(s) of behaviour** The feedback provided is not specifically about performing the act of HH, but rather on the outcome of increased HH practice.

Table A2- 5: Explanations of BCTS codes for *Harne-Britner et al.*

Harne-Britner et al. 2011			
Inputs and Implementation			**Code and Reasoning**
Element	**Activity**	**Components**	
Control	Self-study module	Hand washing educational self-module with additional education about microorganisms	**4.1 Instruction on how to perform the behaviour** The educational module covers various aspects of handwashing. It is assumed that the module covers how to perform HH behaviour. **5.1 Information about health consequences** The educational module covers various aspects of handwashing. It is assumed that the module covers information about health consequences. **6.1 Demonstration of the behaviour** The educational module covers various aspects of handwashing. It is assumed that the module demonstrates how to perform HH behaviour.
Positive reinforcement[†††]	Individual sticker chart	Staff members placed a sticker beside peer's name as they witnessed HH being performed	**6.2 Social comparison** Stickers are awarded by peers. As a result, the staff members pays more attention to others' HH performance. This in turn allows for individuals to compare their own HH performance to that of the larger group. **6.3 Information about others' approval** Stickers are awarded by peers. As a result, the staff members pays more attention to others' HH performance.

[†††] The self-study module is also included in the positive reinforcement intervention.

		Staff member with most stickers received a reward	**10.8 Incentive (outcome)** Staff members were informed that the nurse with the most stickers would receive a reward. **10.10 Reward (outcome)** The staff member with the most stickers received a reward such as movie tickets and gift cards from local grocery stores, gas stations, and restaurants.
		Staff member with most stickers also received public recognition	**10.4 Social reward** The staff member with the most stickers received public recognition, which is a social reward. **10.5 Social incentive** Staff members were informed that the nurse with the most stickers would be publicly recognized.
	Unit reward	Unit rewarded a pizza party if HHC goal reached	**1.3 Goal setting (outcome)** The unit set a HHC goal to which it strived to work towards accomplishing. **10.8 Incentive (outcome)** The unit was informed that there would be a reward if the goal had been reached. **10.10 Reward (outcome)** If the unit reached its goal, it would receive a pizza party.
	Monthly quality meetings	Feedback on infection and HHC rates	**2.7 Feedback on outcome(s) of behaviour** The infection and HHC rates were shared during the monthly quality meetings. This provided feedback on how the unit was performing.
		Adherence goal-setting	**1.3 Goal setting (outcome)** A HHC goal was set and agreed upon.
Risk of Nonadherence[‡‡‡]	Posters	Cartoon bug posters stating "I am on your hands heading to your patients!" were placed around the unit	**5.1 Information about health consequences** This poster provided information visually about the consequences of not performing HH. **7.1 Prompts/cues** This poster was placed around the unit in order to prompt the staff members to practice HH.
		An additional poster of the agar plates about organisms found on the hands was also placed on walls.	**5.1 Information about health consequences** This poster provided information visually about the consequences of not performing HH. **7.1 Prompts/cues** This poster was placed around the unit in order to prompt the staff members to practice HH.
	Agar plate culture of hands	The results of hand cultures done on the unit were shared with the unit	**5.2 Salience of consequences** The agar plate culture component was specifically designed to emphasize the consequences of not practicing HH. This component of the intervention is memorable because it is different from the rest (posters, self-study module, etc.).

Table A2- 6: Explanations of BCTS codes for *Huis et al.*

***Huis* et al. 2012**			
Inputs and Implementation			**Code and Reasoning**
Element	**Activity**	**Components**	
State-of-the-art strategy	Meetings	Distribution of educational material/written information (leaflet) about HH that contained: the importance of HH; misconceptions about ABHR;	**4.1 Instruction on how to perform the behaviour** The material included the indications for the use of HH in addition to general information about HH. It is assumed that the material advised nurses on how to perform the behaviour. **5.1 Information about health consequences** It is assumed that in discussing the importance of HH, the consequences of not performing HH would also be included

‡‡‡ The self-study module is also included in the risk of nonadherence intervention.

		theory and practical indications for the use of HH	
		Notification of website: Educational material/written information about HH; knowledge quiz with feedback; nursing ward with highest number of visitors to the website was rewarded	**4.1 Instruction on how to perform the behaviour** The website contained educational material on HH. It is assumed that this advises nurses on how to perform the behaviour. **5.1 Information about health consequences** It is assumed that in discussing the importance of HH, the consequences of not performing HH would also be included. **10.6 Non-specific incentive** Nurses were informed that a reward would be given to the unit with the highest number of visits to the website. It is assumed from the study that the nurses did not know what the award was. **14.6 Situation-specific reward** The reward was specifically given to the unit with the highest number of visits to the website. This was a single event as compared to the continuous monitoring of HHC which is comprised of many smaller HH events.
		Bar charts of HH rates of every nursing ward were sent to the ward manager twice. It also included a comparison of ward performance to hospital performance	**2.7 Feedback on outcome(s) of behaviour** The bar charts provide feedback on the HHC rates of the unit. **6.2 Social comparison** The bar charts also drew attention to other units' performances which allowed for each unit to compare its own performance to other units in the hospital.
	Hospital-wide campaign launch	Practical demonstrations	**4.1 Instruction on how to perform the behaviour** It is assumed that the practical demonstrations provided instruction on HH performance. **6.1 Demonstration of the behaviour** The practical demonstrations provided an observable sample of HH performance.
	Newsletter	Interviews and messages	**Unable to code** **Reasoning:** The description of this component is vague and unable to be coded.
	Ad hoc	General reminders by opinion leaders/ ward management	**9.1 Credible source** Opinion leaders and ward management are considered to be credible sources as "they pull weight" and are influential.
	Environment modification	Screening and if necessary adapting products and appropriate facilities	**12.1 Restructuring the physical environment** Although vague, it is assumed from the description that when necessary there was a change to the physical environment in order to facilitate performance of HH. **12.5 Adding objects to the environment** Although vague, it is assumed from the description that when necessary there was a change to the physical environment in order to facilitate performance of HH.
		Posters that emphasized the importance of HH, particularly ABHR	**7.1 Prompts/cues** These posters were places around the unit in order to prompt the staff members to practice HH.
Team and leaders-directed strategy[§§§]	Meetings with ward management	Ward managers share experiences and discuss difficulties with one another	**1.2 Problem solving** Ward managers discussed difficulties with one another. It is assumed that the ward managers helped one another develop strategies to address the difficulties. **3.2 Social support (practical)** Ward managers discussed experiences and difficulties with one another. It is assumed that the ward managers helped one another develop strategies to address the difficulties.

[§§§] The team and leaders-directed strategy includes all the activities and components of the state-of-the-art strategy.

	Three interactive team sessions (1-1.5 hour)	Team members explore their own HH behaviour	**1.6 Discrepancy between current behaviour and goal** By asking the participants to reflect on their own HH behaviour, participants must consider their own behaviour and compare it to the desired behaviour.
		Team members analyse barriers and facilitators	**1.2 Problem solving** Team members identified barriers and facilitators to the performance of HH.
		Team members formulate improvement activities	**1.4 Action planning** Team members create improvement activities to aid in the performance of HH.
		Team members make commitment to achieve a substantial increase in HHC	**1.9 Commitment** Team members indicated a commitment to increasing HHC rates.
		Ward manager presents the HHC rates of the previous period	**2.7 Feedback on outcome(s) of behaviour** The ward manager provided feedback on the previous period's HHC performance.
		Team members discuss the rates by asking a series of questions reflecting on their behaviour (and how it could have affected the outcome).	**1.2 Problem solving** Team members identified barriers and facilitators to the performance of HH. **1.6 Discrepancy between current behaviour and goal** The attention of the team members was drawn to the discrepancies between their current HH behaviour and the set outcome goal (HHC rate). **15.3 Focus on past success** Team members had to think about their own past performance, which did include past successes.
	Ad hoc	Nurses address each other in case of undesirable HH behaviour	**3.2 Social support (practical)** Nurses advise one another on their HH performance. **6.3 Information about others' approval** The act of addressing another in terms of undesirable HH behaviour showcases what other people think.
		Modelling by informal leaders at the ward: informal leaders demonstrated good HH behaviour; informal leaders modelled social skills of team members in addressing HH behaviour of colleagues; informal leaders instructed and stimulated their colleagues in providing good HH behaviour	**3.2 Social support (practical)** Informal leaders advised and provided help in regard to the performance of HH. **4.1 Instruction on how to perform the behaviour** Informal leaders advised on how to perform good HH. **6.1 Demonstration of the behaviour** Informal leaders provided an observable sample of performing HH behaviour in addition to how to address HH behaviour of colleagues.

Table A2-7: Explanations of BCTS codes for *Boyce et al.*

Boyce et al. 2019			
Inputs and Implementation			**Code and Reasoning**
Element	**Activity**	**Components**	
Automated HH Monitoring System	The AHHM system was installed in the hospital	Sensors were placed in dispensers and in the entry ways of the patient rooms	**2.7 Feedback on outcome(s) of behaviour** The monitoring system provided HH rates. **12.5 Adding objects to the environment** The AAHHM system was added to the environment in order to help facilitate practicing HH.
Goal Setting	Nursing units team members set goals	Goals were set for improved HH performance rates. As goals were met, units celebrated their achievements and set new goals	**1.3 Goal setting and outcome** The team members agreed on a goal. **1.7 Review outcome goals** The team members reviewed outcome goals and modified goals in light of achievement. **2.7 Feedback on outcome(s) of behaviour** The team members monitored and provided informative feedback on outcome. **10.4 Social reward** When goals were met, there was a verbal reward in the form of positive reinforcement.
Frontline Ownership Initiative (Intervention 1)	An expert visited the hospital three times to assist in implementing FLO	FLO is aimed at owning the problem and to deepen awareness thereby prompting a solution	**1.2 Problem solving** By turning to an expert and trying to implement FLO, the hospital is trying to address the low HHC rates by owning the HH problem and analysing ways to move forward. **1.4 Action Planning** There is detailed planning of performance of the behaviour.
Support by Hospital Leadership (Intervention 2)	Hospital leadership sent a delegate to another hospital who had success in sustaining increased HHC.	Nurses, infection preventionist, and the vice president of medical affairs travelled to another hospital to learn about their successful multimodal HH campaign; discussed methods for analysing AHHMS data and additional promotional activities	**6.2 Social comparison** By drawing comparison to the other hospital's performance, the study hospital is able to compare their own performance. **9.3 Comparative imagining of future outcomes** Prompt or advise the imagining and comparing of future outcomes of changed versus unchanged
DO NO HARM team HH audit	Covert direct observations of HHC.	Members of the HH audit team covertly conducted direct observations of HHC upon entry and exit of patient rooms on all nursing units	**2.5 Monitoring of behaviour by others without feedback** The Do No Harm team conducted covert HH audits.
Toyota Kata (intervention 3)	Trainings for hospital leadership.	Mandatory training for management and leadership staff	**Unable to code** **Reasoning: T**he description of the training is vague and is unable to be coded.
	Develop institutional commitment	Through meetings and trainings, the hospital was able to create awareness, which allowed for ownership of the HH problem and further	**1.9 Commitment** The hospital is indicating a commitment to changing HH behaviour.

		displayed the hospital's commitment to tackling this problem	
	HH sheriff	On each unit, one person every day was assigned to wear a "HH Sheriff" badge and reminded personnel to perform HH	**2.2 Feedback on behaviour** The sheriff provides real-time feedback when encouraging personnel to practice HH. **7.1 Prompts/cues** Introduce or define environmental or social stimulus with the purpose of prompting or cueing the behaviour **13.1 Identification of self as role model** HH sheriff comments on others' behaviours; their behaviour is an example to others.
	Sharing HH rates	HH rates were reported at shift huddles and safety huddles; the rates were posted in the staff lounges and shared with hospital leadership	**1.6 Discrepancy between current behaviour and goal** By sharing HHC rates, the current HH behaviour can be compared the hospitals' set outcome goals. **2.7 Feedback on outcome(s) of behaviour** Sharing the HHC rates allows nurses to see where the unit's rates are that day/week.
	Coaching nurses	Healthcare personnel were coached when HHC decreased	**Unable to code** **Reasoning:** The description of how or what personnel were coached on is vague and is unable to be coded.

Table A2- 8: Explanations of BCTS codes for *Stella et al.*

Stella et al. 2019			
Inputs and Implementation			**Code and Reasoning**
Element	**Activity**	**Components**	
Eye image intervention	Posters	Placards depicting the human eyes with reminder to “clean hands on entry and exit” were displayed above soap and ABHR dispensers on exterior of patient rooms; they were rotated with the control image of mountains	**4.1 Instruction on how to perform behaviour** The posters specifically mention performing HH upon entry and exit. **7.1 Prompts/ cues** The posters were placed around the unit in order to prompt the staff members to practice HH. **16.1 Imaginary punishment** Advise to imagine performing the **unwanted** behaviour in a real-life situation followed by imagining an unpleasant consequence
Social norm message intervention	Posters	Placards depicting images of several healthcare professionals with a message encouraging compliance with social norms. A slogan included reference to being the ‘dirty one’. An authoritative agent was also referenced as sponsoring the poster	**6.2 Social comparison** On the poster are other HCWs. This will draw the attention of the staff members to others’ HH performance and allow comparison with the person’s own performance. **7.1 Prompts/ cues** The posters were placed around the unit in order to prompt the staff members to practice HH. **9.1 Credible source** Having the hospital as the sponsor and including HCWs who appear knowledgeable and assured lead to the message seeming like it comes from a credible source. **11.2 Reduce negative emotions** Advise on ways of reducing negative emotions to facilitate performance of the behavior [don’t be dirty one].

APPENDIX 2-4: LOGIC MODELS DEVELOPED FOR STUDIES

Logic models inferred for each study with the nominated BCTS and the theory of change behind each intervention.

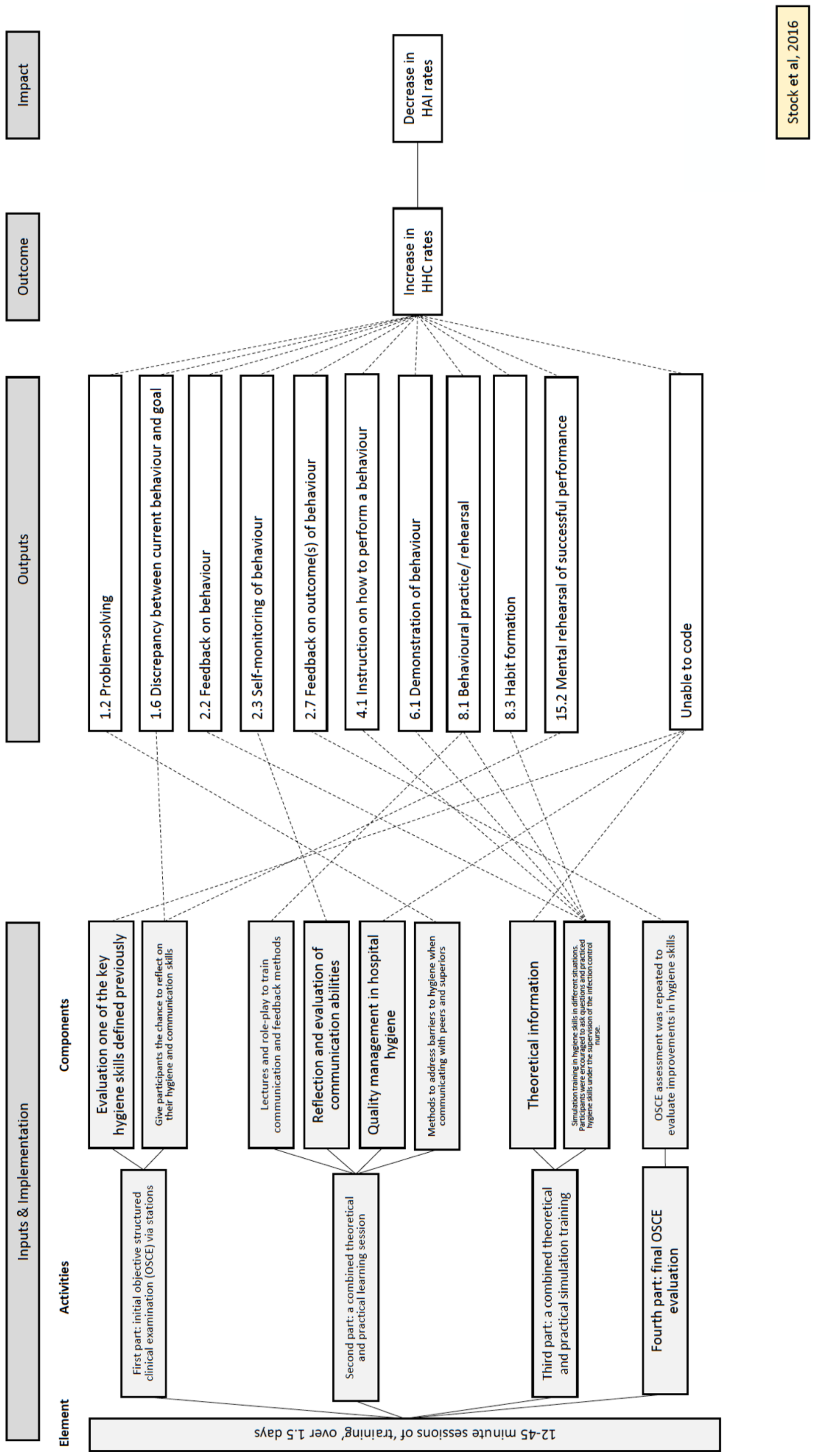


Figure A2- 1: Logic model for *Stock et al.*

Figure A2- 2: Logic model for *Erasmus et al.*

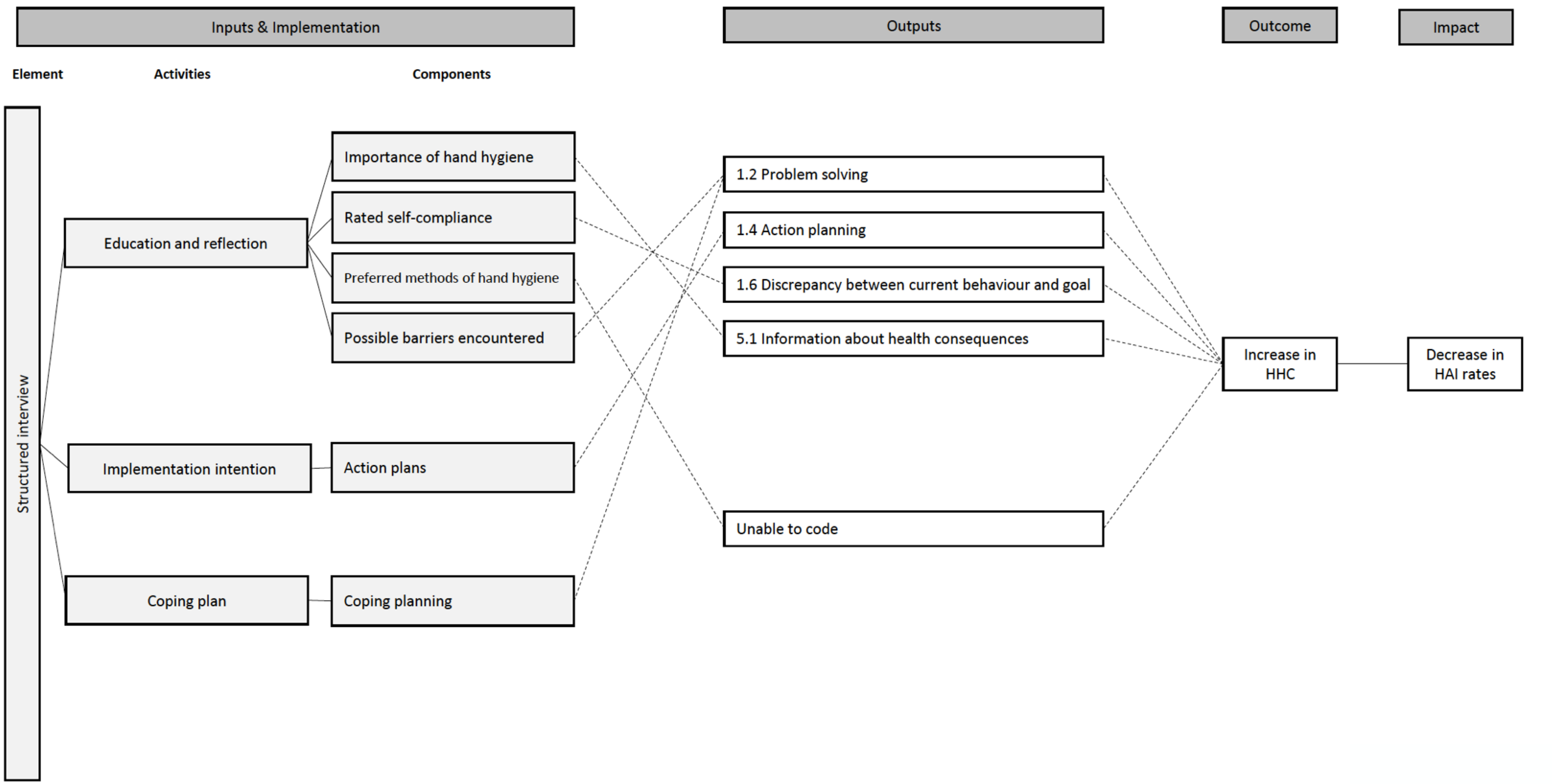


Figure A2- 3: Logic model for *Fox et al.*

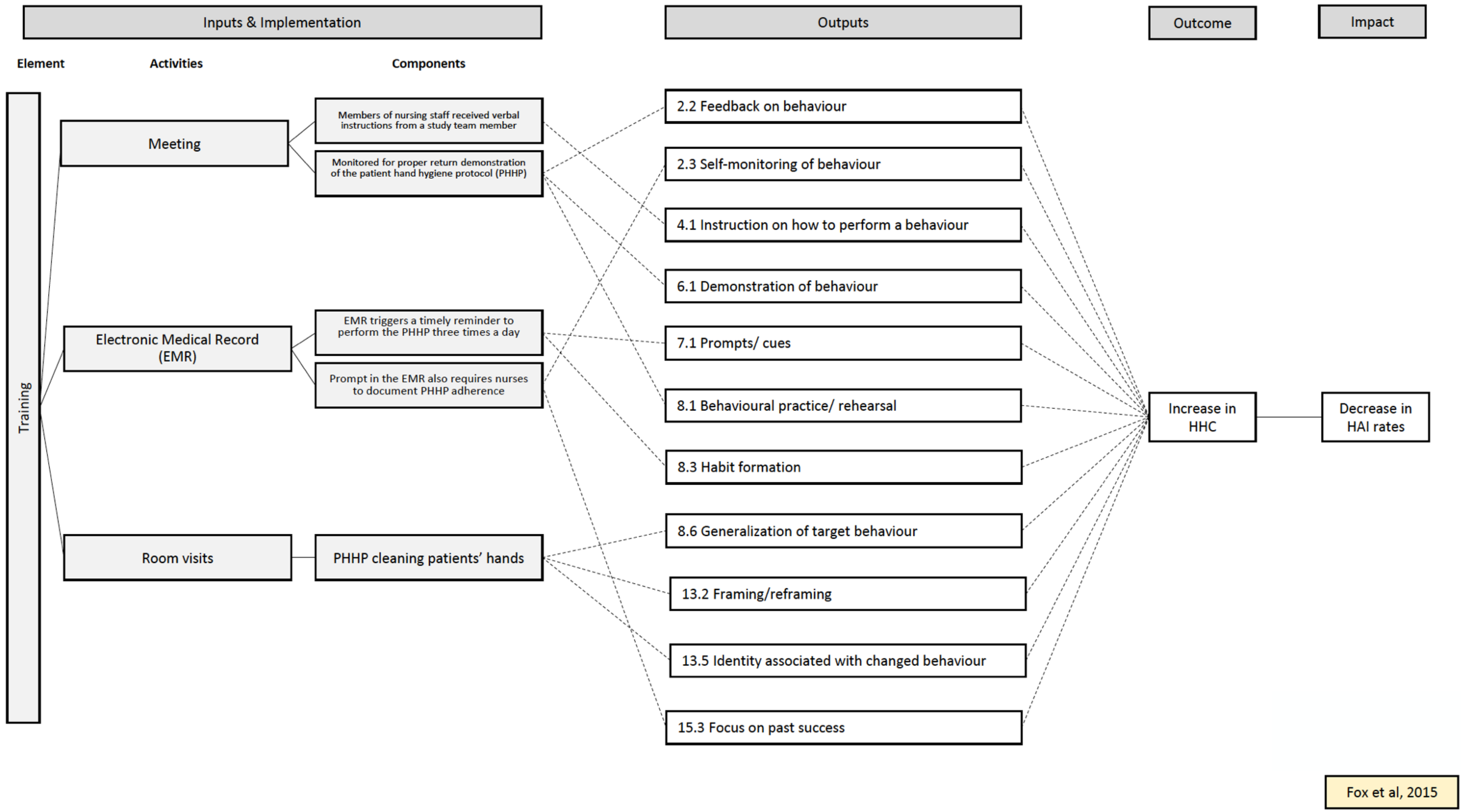


Figure A2- 4: Logic model for *Harne-Britner et al* control.

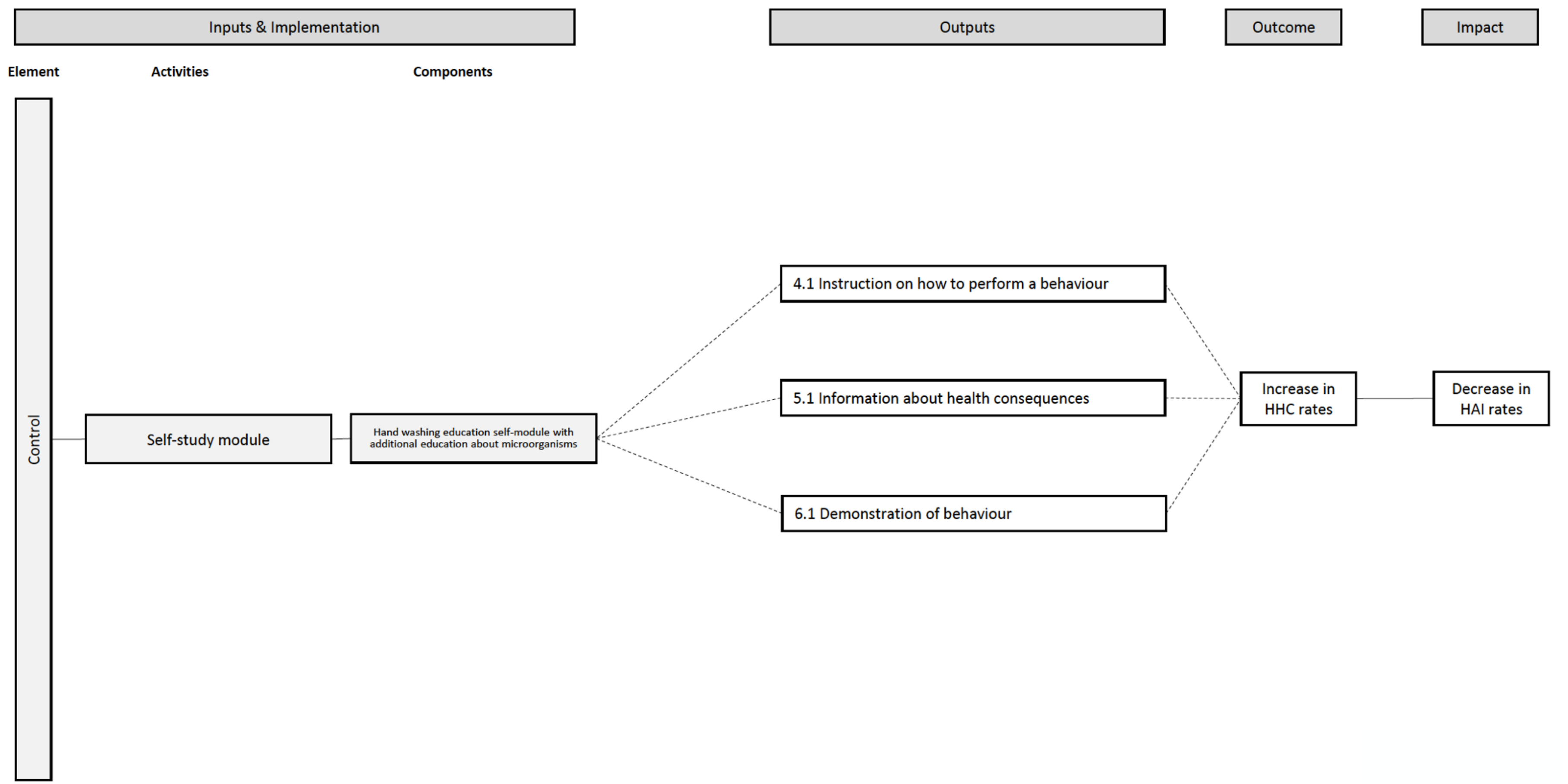


Figure A2- 5: Logic model for *Harne-Britner et al.* risk of nonadherence

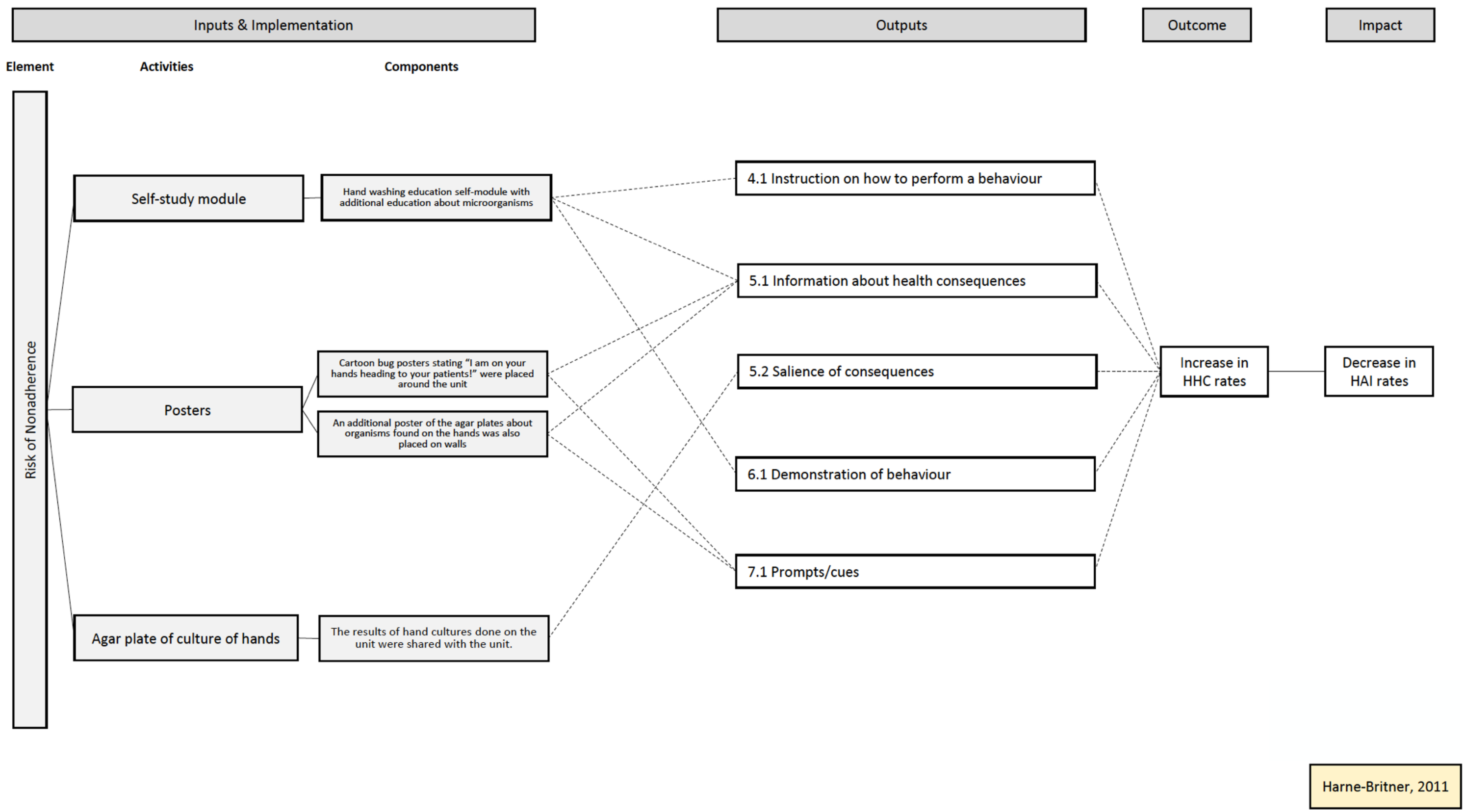


Figure A2- 6: Logic model for *Harne-Britner et al.* positive reinforcement

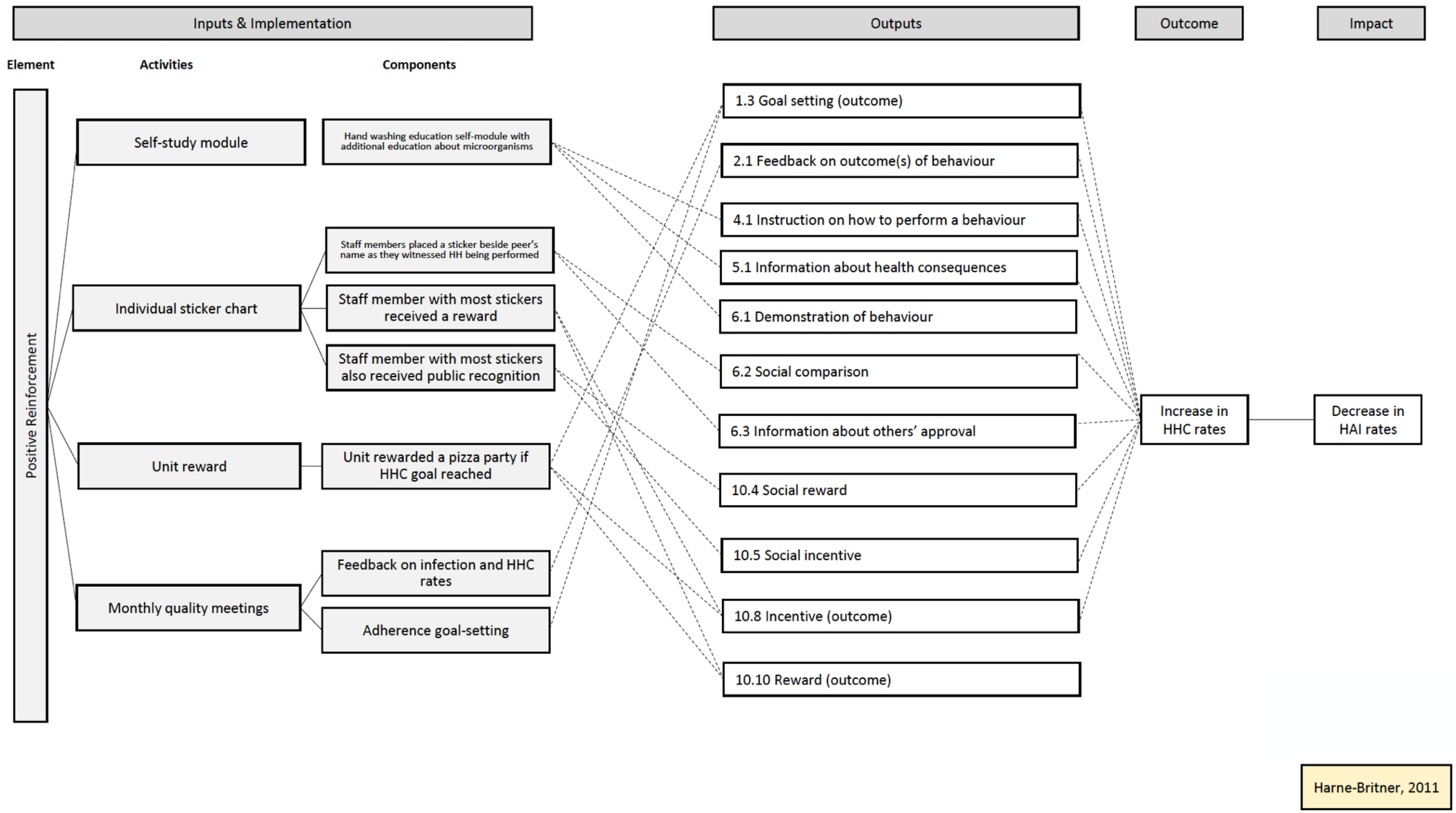


Figure A2- 7: Logic model for *Huis et al.* state-of-art-strategy

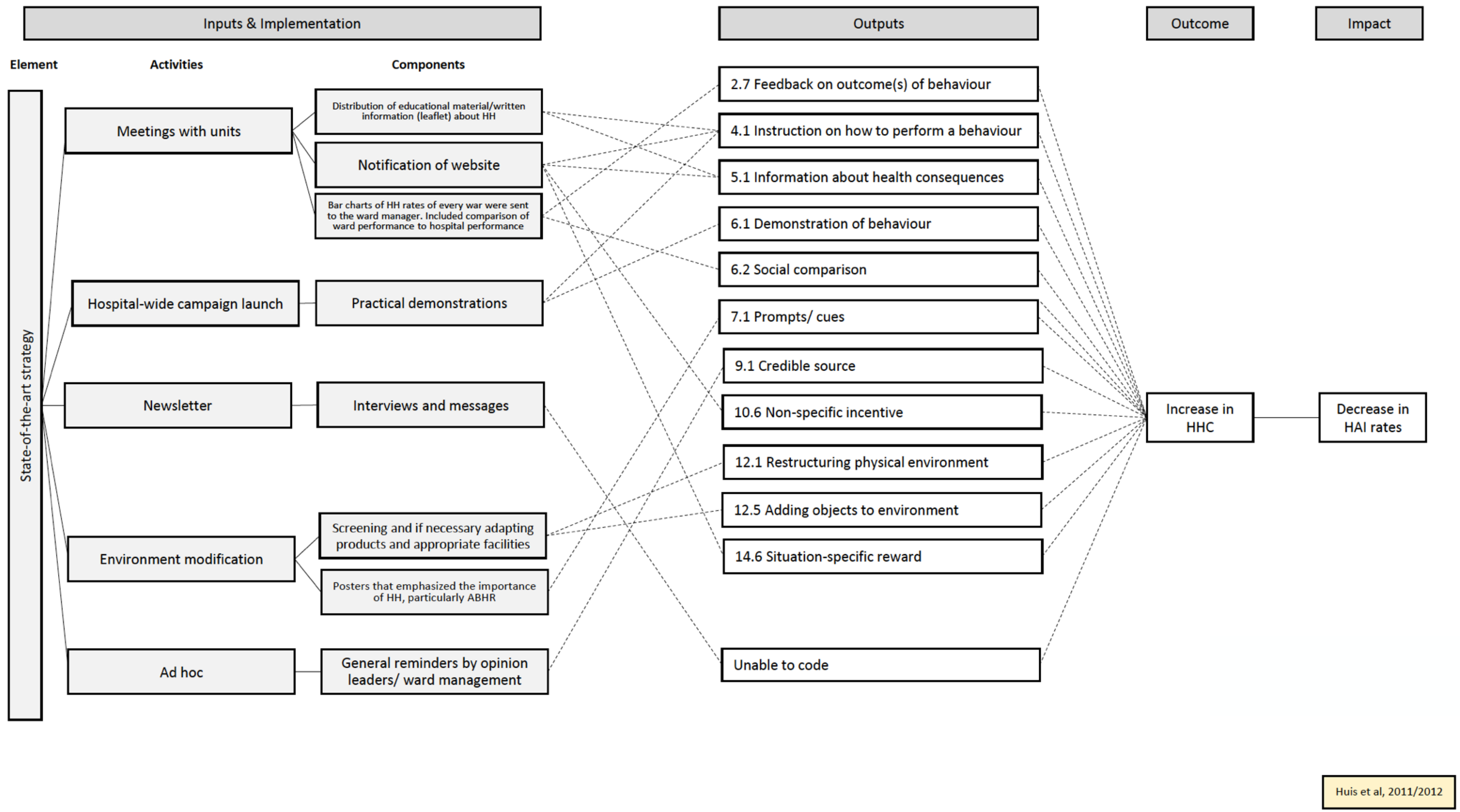


Figure A2- 8: Logic model for *Huis et al.* team strategy

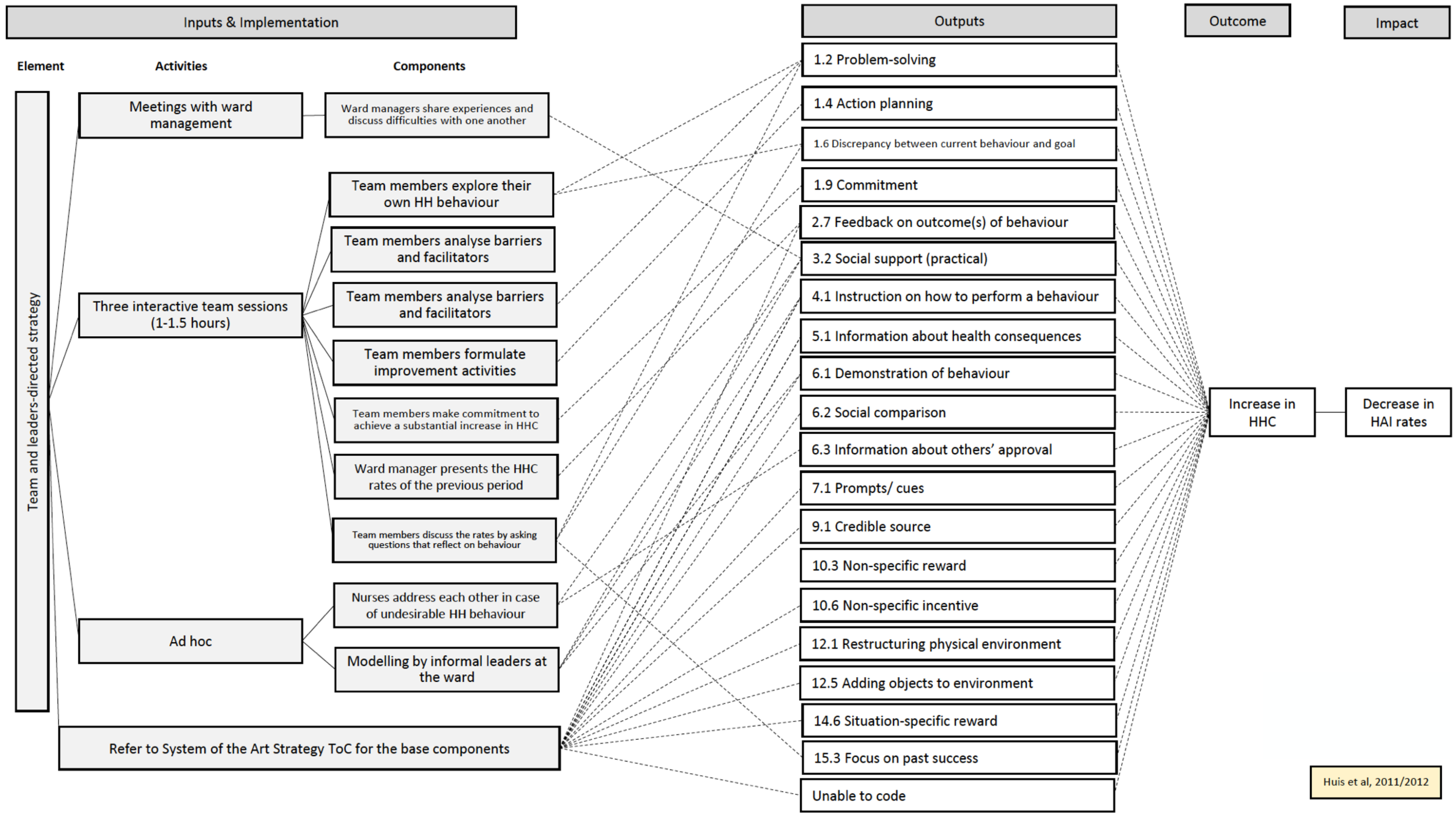


Figure A2- 9: Logic model for *Stella et al.* intervention

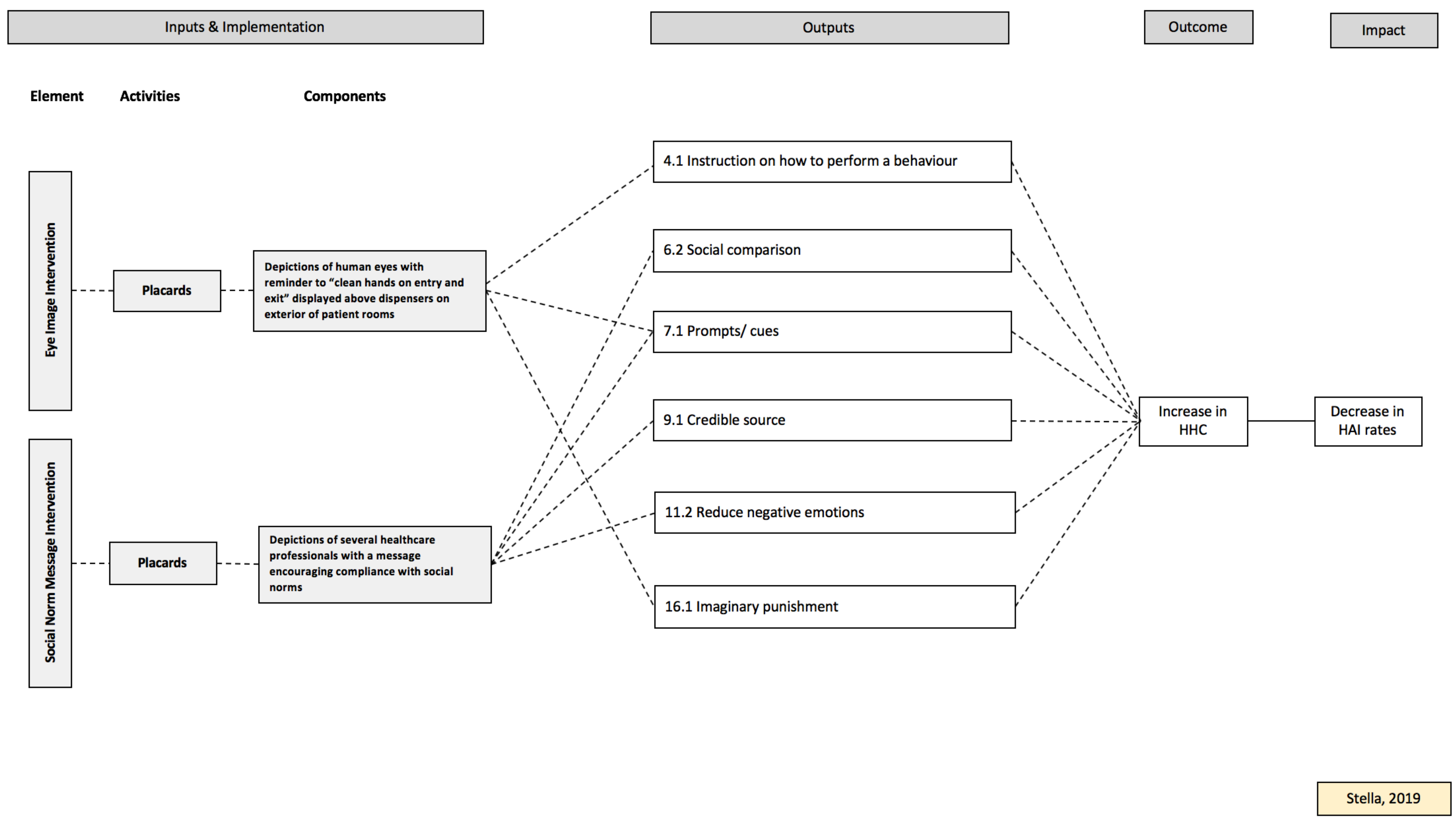


Figure A2- 10: Logic model for *Boyce et al.* interventions 1 and 2

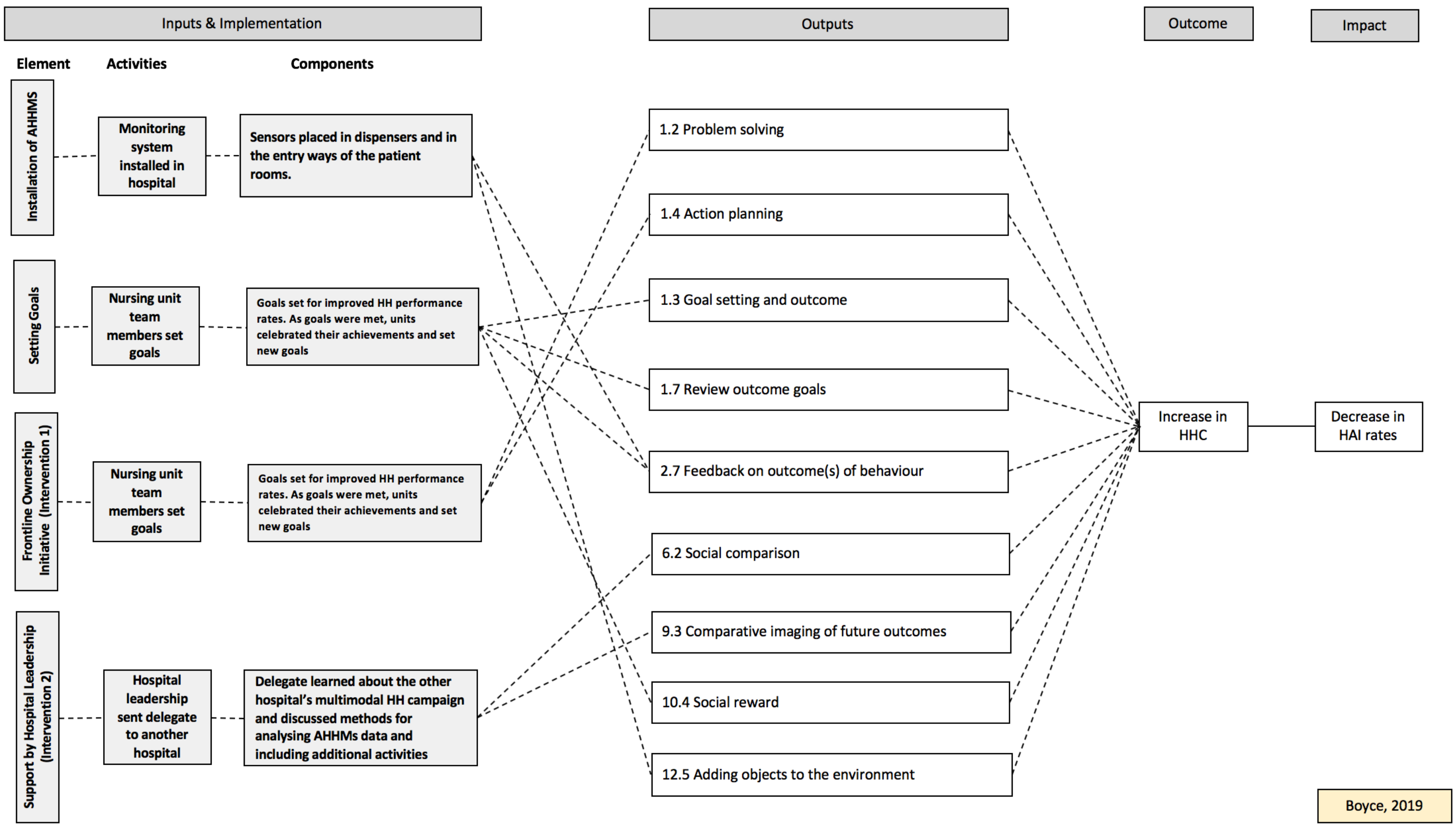
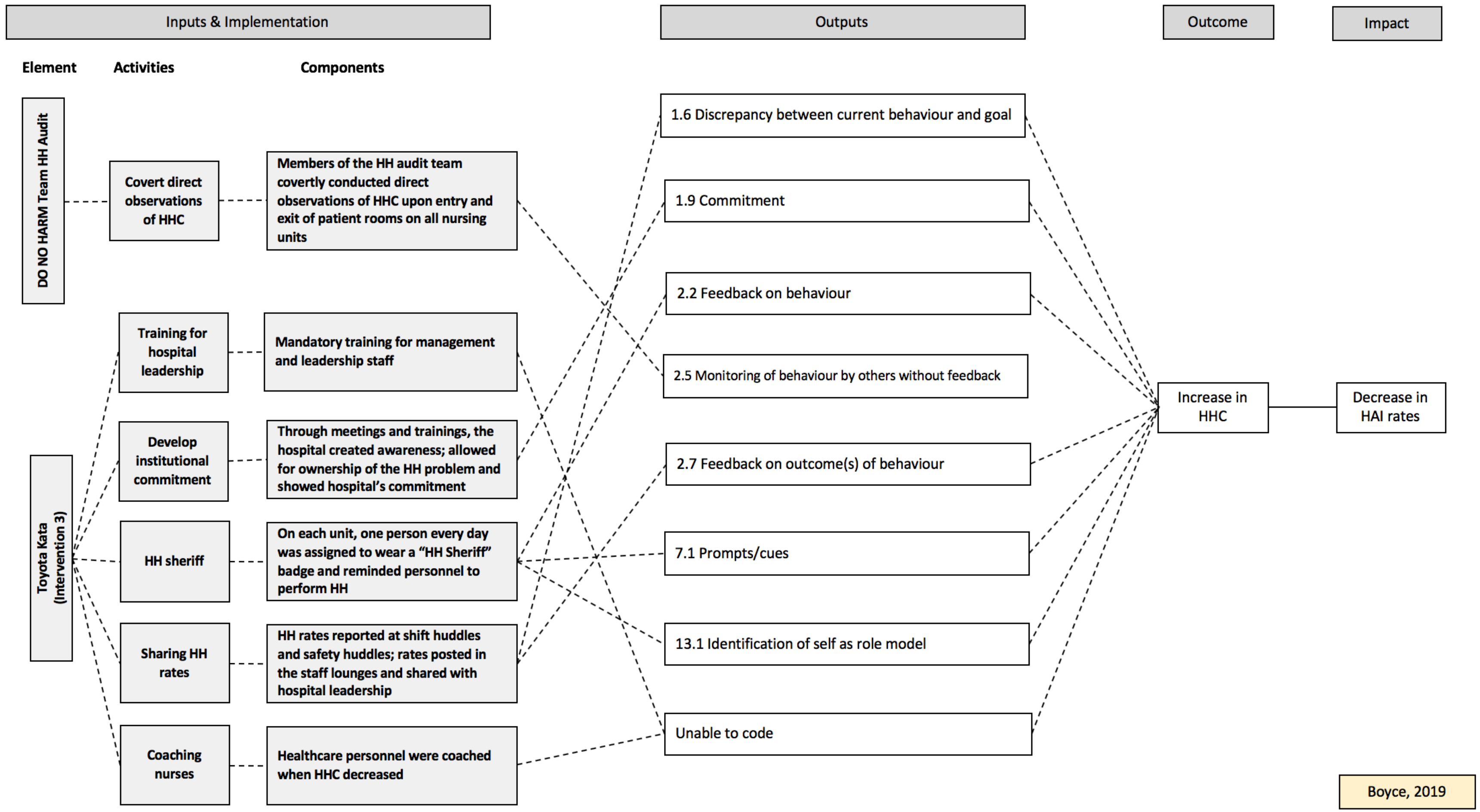


Figure A2- 11: Logic model *Boyce et al.* intervention 3



APPENDIX 3-1: SEARCH STRINGS FOR FORMATIVE RESEARCH

Table A3- 1: Search strings for the formative research literature review

Concept	Search Strings
Behaviour Change	**1.** behavio#r change OR behavio#r change ADJ3 theor* OR behavio#r change ADJ3 principle* OR behavio#r change ADJ3 model* OR behavio#r change ADJ3 strateg* OR behavio#r change ADJ3 attitude* OR behavio#r change ADJ3 value* OR behavio#r change ADJ3 health* OR behavio#r change ADJ3 promotion* OR behavio#r change ADJ3 maint* OR behavio#r change ADJ3 understand* OR social marketing OR health promotion **2.** Subject Headings/ Index for 'behavior change' (Medline: health promotion/ OR health behaviour/ OR health education/ OR health knowledge, attitudes, practice/ OR marketing of health services/ OR social marketing/) **3.** Search 1 OR Search 2
Hand Hygiene Compliance (HHC)	**1.** hand hygiene compl* OR hand hygiene adhere* OR hand hygiene ADJ3 compl* OR hand hygiene ADJ3 adhere* **2.** Subject Headings/Index for 'hand hygiene compliance' (Medline: hand hygiene/ OR hand disinfection/) **3.** Search 2 OR Search 2
Healthcare Workers (HCWs)	**1.** nurse* or nursing or physician* or doctor* **2.** Subject Headings/Index for 'health care personnel' (Medline: health personnel/ OR faculty, medical/ OR faculty, nursing/ OR infection control practioners/ OR medical staff/ OR nurses/ OR nursing staff/ OR physicians/) **3.** Search 1 OR Search 2
Initiatives	**1.** intervention* OR program* OR activit* OR technique* OR technolog* OR protocol* OR initiative* OR campaign*
Hand Hygiene	**1.** handwashing OR hand wash OR handwash OR hand hygiene **2.** Subject Headings/Index for 'hand hygiene' (Medline: hand hygiene/ OR hand disinfection/)
Healthcare-Associated Infection	**1.** Healthcare associated infection* OR health care associated infection* OR healthcare-associated infection* OR health care-associated infection* OR healthcare acquired infection* OR health care acquired infection* OR healthcare-acquired infection* OR health care-acquired infection* **2.** central line-associated bloodstream infections* OR CLABSI* OR catheter- associated urinary tract infection* OR CAUTI* OR surgical site infection* OR SSI*OR methicillin- resistant Staphylococcus aureus OR MRSA OR Clostridium difficile infection* OR C. difficile infection* **3.** Nosocomial pathogen* **4.** Search 1 OR Search 2 OR 3

APPENDIX 3-2: FORMATIVE RESEARCH QUESTIONNAIRE

The questionnaire administered to nurses during formative research.

CONFIDENTIAL

GOJO ACUTE CARE NURSE HH SURVEY (002-237), 11/2015

SECTION A

Imagine you are a nurse in Community General Hospital. You enter the patient room to draw the patient's blood for morning labs. Please look at the photo of the hallway/entrance to the patient room and the photo of the patient room and answer the following questions.

1a. How could the room be altered to better help you practice hand hygiene? [open-ended response]

1b. Are there any objects that could be added, removed, or modified to help facilitate hand hygiene? [open-ended response]

SECTION B

Now you will be asked to imagine yourself in a particular situation during a regular day at work. Read the scenario and answer the following questions.

2a. You are a nurse in Normal Hospital. You need to take the vitals for Mrs. Jones in room 2. You enter the room, say hello, explain the procedure, take Mrs. Jones' vitals, ask if she needs anything else, and then you head towards the door to leave.

How likely are you to practice hand hygiene upon exiting the room?

Not At All Likely	Slightly Likely	Moderately Likely	Very Likely	Extremely Likely
▼	▼	▼	▼	▼

2b. The unit is short-staffed today and you are busier than normal. You have to attend to two other patients, you need to debrief the attending physician, and fill out your shift report all before your shift ends in the next hour. This is on your mind as you are taking Mrs. Jones' vitals.

Upon finishing taking her vitals, how much more/less likely are you to do hand hygiene upon exiting the room than in the scenario above (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2c. As you are leaving Mrs. Jones' room, you take off the gloves you've been wearing.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2d. As you are leaving Mrs. Jones' room you notice that a fellow nurse is standing outside the doorway. You both make eye contact.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2e. As you are leaving Mrs. Jones' room you notice that the Infection Prevention director is standing outside the doorway.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2f. As you enter Mrs. Jones' room, you see your nurse manager. The manager is talking with you and Mrs. Jones as you take Mrs. Jones' vitals. Upon finishing, you and your nurse manager leave. The nurse manager does not practice hand hygiene.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2g. After taking Mrs. Jones' vitals you say goodbye and turn to leave the room. You go to use the hand sanitizer dispenser in the room, but the dispenser is empty. The closest dispenser is down the hallway.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2h. You have just finished taking Mrs. Jones' vitals when another nurse urgently comes into the room and asks for your immediate assistance with a procedure in another room.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2i. You are finishing taking Mrs. Jones' vitals when there is a code. One of the patients on the floor is going in to cardiac arrest. You immediately respond to the code.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (2a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

Now instead of exiting Mrs. Jones's room, you are ENTERING her room to take her vitals. Please answer the following questions.

2j. You need to take Mrs. Jones' vitals. You have just been charting and responding to physician orders. You are in the hallway, about to go into Mrs. Jones' room.

How likely are you to practice hand hygiene upon entering the room?

Not At All Likely	Slightly Likely	Moderately Likely	Very Likely	Extremely Likely
▼	▼	▼	▼	▼

2k. Upon entering Mrs. Jones' room to take her vitals, she politely asks you to practice hand hygiene.

How much more/less likely are you to do hand hygiene upon entering the room than in the scenario above (2j)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2l. You enter Mrs. Jones' room and try to use the hand sanitizer, but the dispenser is empty. The closest dispenser is down the hallway.

How much more/less likely are you to do hand hygiene upon entering the room than in the scenario 2j?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

2m. Before entering Mrs. Jones' room to take her vitals, you put on gloves.

How much more/less likely are you to do hand hygiene upon entering the room before putting your gloves on than in the scenario 2j?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

SECTION C

Now we would like you to respond to a different situation. Read the scenario and answer the following questions.

3a. You are a nurse at Normal Hospital. You are cleaning and bandaging Mr. Robinson's diabetic foot. After finishing the procedure, you take off your gloves, and then say goodbye to Mr. Robinson.

How likely are you to practice hand hygiene upon exiting the room?

Not At All Likely	Slightly Likely	Moderately Likely	Very Likely	Extremely Likely
▼	▼	▼	▼	▼

3b. The unit is short-staffed today and you are busier than normal. You have to attend to two other patients, you need to debrief the attending physician, and fill out your shift report all before your shift ends in the next hour. This is on your mind as you finish cleaning and reapplying bandages to Mr. Robinson's diabetic foot. Once again, you are wearing gloves.

This time, how much more/less likely are you to do hand hygiene upon taking the gloves off and leaving the room than in the scenario above (3a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

3c. You are leaving Mr. Robinson's room you notice that a fellow nurse is standing outside the doorway. You both make eye contact.

How much more/less likely are you to do hand hygiene upon taking the gloves off and exiting than in the scenario 3a?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

3d. As you are leaving Mr. Robinson's room you notice that the infection prevention director is standing outside the doorway.

How much more/less likely are you to do hand hygiene upon taking the gloves off and exiting than in the first scenario (3a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

3e. You enter Mr. Robinson's room to clean and bandage his wound post-surgery and you see your nurse manager. The nurse manager talks with you and Mr. Robinson as you clean and apply bandages. Upon finishing, you and the nurse manager leave. The nurse manager does not practice hand hygiene.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (3a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

3f. After cleaning and bandaging Mr. Robinson's wound, you turn to leave the room. As you go to use the hand sanitizer dispenser in the room, you notice that it is empty. The closest dispenser is down the hallway.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (3a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

3g. You have cleaned and bandaged Mr. Robinson's wound when another nurse urgently comes into the room and asks for your immediate assistance. Once again, you are wearing gloves.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (3a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

3h. You have cleaned and bandaged Mr. Robinson's wound and as you are about to leave his room there is a code. One of the patients on the floor is going in to cardiac arrest. You respond to the code. Once again, you are wearing gloves.

How much more/less likely are you to do hand hygiene upon exiting the room than in the first scenario (3a)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

CONFIDENTIAL

Now instead of exiting Mr. Robinson's room, you are ENTERING his room to clean and reapply his bandages. After reading each scenario, please answer the following questions.

3i. You need to clean and reapply bandages to Mr. Robinson's wound. You have just been charting and responding to physician orders. You are in the hallways, about to go into Mr. Robinson's room.

How likely are you to practice hand hygiene upon entering the room and putting on gloves?

Not At All Likely	Slightly Likely	Moderately Likely	Very Likely	Extremely Likely
▾	▾	▾	▾	▾

3j. Upon entering the room, Mr. Robinson asks you politely to practice hand hygiene before putting on gloves.

How much more/less likely are you to do hand hygiene upon entering the room and before putting on gloves than in the scenario above (3i)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▾	▾	▾	▾	▾

3k. You enter Mr. Robinson's room and try to use the hand sanitizer before putting gloves on, but the dispenser is empty. The closest dispenser is down the hallway.

How much more/less likely are you to do hand hygiene upon entering the room and before putting on gloves than in the scenario above (3i)?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▾	▾	▾	▾	▾

SECTION D
Please answer the following questions.

5a. Which of these qualities or traits did you wish you had exhibited more of during your last shift? Choose FIVE from the following list.

Empathy
Respect
Confidence
Technical Competence
Leadership
Good Communication 0 Skills
Reliability
Awareness
Critical Thinking

Stress Management
Flexibility
Physical Endurance
Mental Endurance
Friendliness
Patience
Good Judgement
Patient Advocate
Resourcefulness
Responsiveness
Cooperativeness

5b. Which of the following statements would you LEAST like to hear said about you as a nurse? Choose FIVE from the following list.

"You do not provide emotional support to your patients."
"You are unsure of yourself as a nurse."
"You do not handle stress well."
"You are not as technically skilled as you should be."
"You are curt and short with the patients."
"You do not show leadership qualities."
"You do not communicate well with others."
"You neglected a patient."
"You are not dependable."
"You are not always aware of what is going on around you."
"You hurt a patient."
"You neglected a patient."
"You do not know your patient's wants or needs."
"You are not flexible and able to adapt."
"You are not a team player."

SECTION E

Please answer the following questions.

6. Out of 10 nurses working in your unit, how many do you think ALWAYS use hand sanitizer/soap:
   - 6a. before entering a patient's room?
   - 6b. when exiting a patient's room?
   - 6c. after taking a patient's vitals?
   - 6d. after cleaning a patient's wound?
   - 6e. before charting in the nurse station?
   - 6f. after talking to a colleague in the hallway?

7. Do YOU think you SHOULD use hand sanitizer/soap:

Never	Seldom	About Half the Time	Usually	Always
▾	▾	▾	▾	▾

   - 7a. before entering a patient's room?

7b. when exiting a patient's room?
7c. after taking a patient's vitals?

7d. after cleaning a patient's wound?
7e. before charting in the nurse station?

8. Do you believe most OTHER NURSES you work with THINK THAT YOU SHOULD use hand sanitizer/soap:

Never	Seldom	About Half the Time	Usually	Always
▼	▼	▼	▼	▼

7a. before entering a patient's room?
7b. when exiting a patient's room?
7c. after taking a patient's vitals?
7d. after cleaning a patient's wound?
7e. before charting in the nurse station?
7f. after talking with fellow nurses in the break room?

9. What would happen to a nurse in your unit if he/she did not practice appropriate hand hygiene? [open-ended]

10. If you saw a fellow nurse not use hand sanitizer/ soap after performing a procedure with a patient, what would you do? [open-ended]

SECTION F

Please indicate your agreement or disagreement with the following statements about hand hygiene.

11. Practicing hand hygiene before ENTERING a patient's room is something:

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
▼	▼	▼	▼	▼

11a. I do frequently.
11b. I do automatically.
11c. I do without having to consciously remember.
11d. that makes me feel weird if I do not do it.
11e. I do without thinking.
11f. that would require effort not to do it.
11g. that belongs to my patient care routine.
11h. I start doing before I realize I'm doing it.
11i. I would find hard not to do.
11j. I have no need to think about doing.
11k. that's typically "me."
11l. I have been doing for a long time.

12. Practicing hand hygiene when EXITING a patient's room is something:

    12a. I do frequently.
    12b. I do automatically.
    12c. I do without having to consciously remember.
    12d. that makes me feel weird if I do not do it.
    12e. I do without thinking.
    12f. that would require effort not to do it.
    12g. that belongs to my patient care routine.
    12h. I start doing before I realize I'm doing it.
    12i. I would find hard not to do.
    12j. I have no need to think about doing.
    12k. that's typically "me."
    12l. I have been doing for a long time.

Please rate your agreement with the following statements using the scale below.

Strongly Disagree	Disagree	Neither	Agree	Strongly Agree
▼	▼	▼	▼	▼

13. A nurse's practice of hand hygiene is influenced by their belief that fellow nurses think someone who doesn't practice hand hygiene is a bad nurse.
14. Nurses should continue to practice hand hygiene consistently even if the administration and staff in their hospitals do not view it as a priority.
15. It is simply wrong NOT to practice appropriate hand hygiene.
16. Even if no one ever knew I was practicing hand hygiene, I would continue to do it every time.
17. I would rather be forced to wear flip-flops than not be allowed to do hand hygiene.
18. I would rather be forced to work 5 more hours a week at the same pay than not be allowed to do hand hygiene.
19. I would rather lose my lunch break than not be allowed to do hand hygiene.

SECTION G
Please read the stories below and respond to the following questions.

A nurse uses hand sanitizer before entering a patient's room. The nurse talks with the patient and asks about the patient's pain levels and general mood. The nurse then takes the patient's vitals and leaves the patient room. Upon exiting, the nurse uses hand sanitizer. The nurse manager has been watching this interaction and tells the nurse, "great job using the hand sanitizer! You are really on top of your game. Thanks for being responsible!"

20. If you were to receive this feedback, how much more likely are you to use hand sanitizer than you normally would do?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

A nurse uses hand sanitizer before entering a patient's room. The nurse talks with the patient and asks about the patient's pain levels and general mood. The nurse then takes the patient's vitals and leaves the patient room. Upon exiting, the nurse uses hand sanitizer. The patient calls out to the nurse, "Thank you for using hand sanitizer. I feel safer and more confident in my care. I appreciate you doing that."

21. If you were to receive this feedback, how much more likely are you to use hand sanitizer than you normally would do?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

A nurse uses hand sanitizer before entering a patient's room. The nurse talks with the patient and asks about the patient's pain levels and general mood. The nurse then takes the patient's vitals and leaves the patient room. Upon exiting, the nurse uses hand sanitizer. A fellow nurse has been watching this interaction and tells her colleague, "Thank you for using hand sanitizer. I feel safer and more confident in my care. I appreciate you doing that."

22. If you were to receive this feedback, how much more likely are you to use hand sanitizer than you normally would do?

Much Less Likely	Somewhat Less Likely	No Difference	Somewhat More Likely	Much More Likely
▼	▼	▼	▼	▼

23. Was hand hygiene emphasized during your training as a nurse?
    YES
    NO

24. Have you taken a continuing education course on hand hygiene?
    YES
    NO

25. Have there been any hand hygiene initiatives or programs at the facility where you work?
    YES
    NO

26. Is hand hygiene regarded as a priority at the facility where you work?
    YES
    NO

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27. Are nursing staff in your unit ever punished (even if only verbally) for not practicing hand hygiene?
    YES
    NO

28. Are nursing staff in your unit ever rewarded (even if only verbally) for properly practicing hand hygiene?
    YES
    NO

Please indicate your agreement or disagreement with the following statements about your "unit."

NOTE: "Patient safety" is defined as the avoidance and prevention of patient injuries or adverse events resulting from the processes of health care delivery.

Strongly Disagree ▼	Disagree ▼	Neither ▼	Agree ▼	Strongly Agree ▼

29. Hospital management provides a work climate that promotes patient safety.

30. Patient safety is never sacrificed to get more work done.

31. Our procedures and systems are good at preventing errors from happening.

32. Staff feel like their mistakes are held against them.

33. Nurses in our unit help each other out regularly.

34. I can depend on getting help from other nurses.

35. In this unit, people treat each other with respect.

36. Some of my closest friends are my work colleagues.

37. We sometimes work in "crisis mode" trying to do too much, too quickly.

38. Hand hygiene is considered to be a part of patient safety where I work.

39. My supervisor/manager overlooks patient safety problems that repeatedly happen.

40. My supervisor/manager seriously considers staff suggestions for improving patient safety.

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41. My supervisor/manager says a good word when he/she sees a job done according to established patient safety procedures.

42. Hospital management seems interested in patient safety only after an adverse event happens.

How often do the following things happen in your work area/unit?

Never	Seldom	About Half the Time	Usually	Always
▼	▼	▼	▼	▼

43. Staff will freely speak up if they see something that may negatively affect patient care.

44. In this unit, we discuss ways to prevent errors from happening again.

45. Staff feel free to question the decisions or actions of those with more authority.

46. Staff are afraid to ask questions when something does not seem right.

47. When a mistake is made that could harm the patient, but does not, how often is this reported?

SECTION H

48. What is your job title?
Staff Nurse
Nurse Manager
Assistant Nurse Manager
Nursing Director
Clinical Educator
Advanced Practice Nurse
Other:

49. Most of my patients in my current job are:
Adults
Paediatric
Neonatal
Multiple Age Groups
I do not provide direct patient care

50. In a typical work week, about what percent of your work time is spent performing the following kinds of tasks? Note: Your responses should add up to 100%.

_____% Interacting with patients (All nurse/patient time, either in the patient's room or in the hallways, e.g., transporting, ambulating)

_____% Preparing therapies (Preparing intravenous therapies, medications, treatments, etc.)

_____% Shift change activities (Reporting, counting narcotics, getting assignments, and making patient rounds, either during or after report)

_____% Professional interaction (All face-to-face communications except communications with patients. For example, communications with visitors, doctors, social workers, other nurses, hospital staff.)

_____% Paperwork (Charting, checking physician orders, filling out forms, incident reports, requisitions, or any other paperwork)

_____% Phone/E-mail communications

_____% Obtaining supplies (time spent outside of the patient's room looking for or obtaining supplies, but not requisitioning)

_____% Other (Any activity not listed above, including meals and break time)

APPENDIX 3-3: ADDITIONAL FIGURES FOR FORMATIVE RESEARCH RESULTS

Additional figures for the Results sections of the formative research paper (Chapter 3).

Figure A3- 1: Comparison of base vignettes

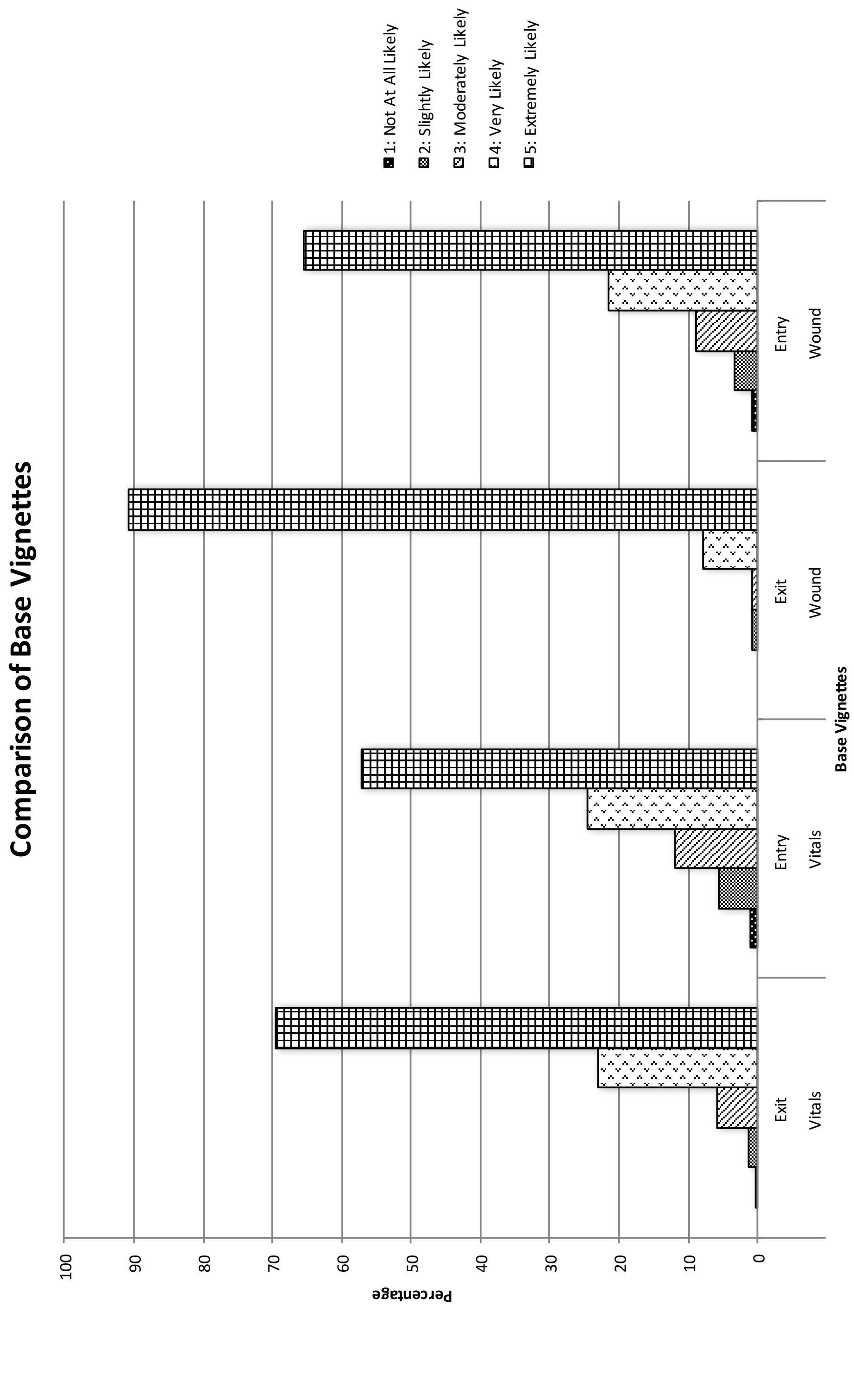


Figure A3- 2: Vitals vignette— Exit

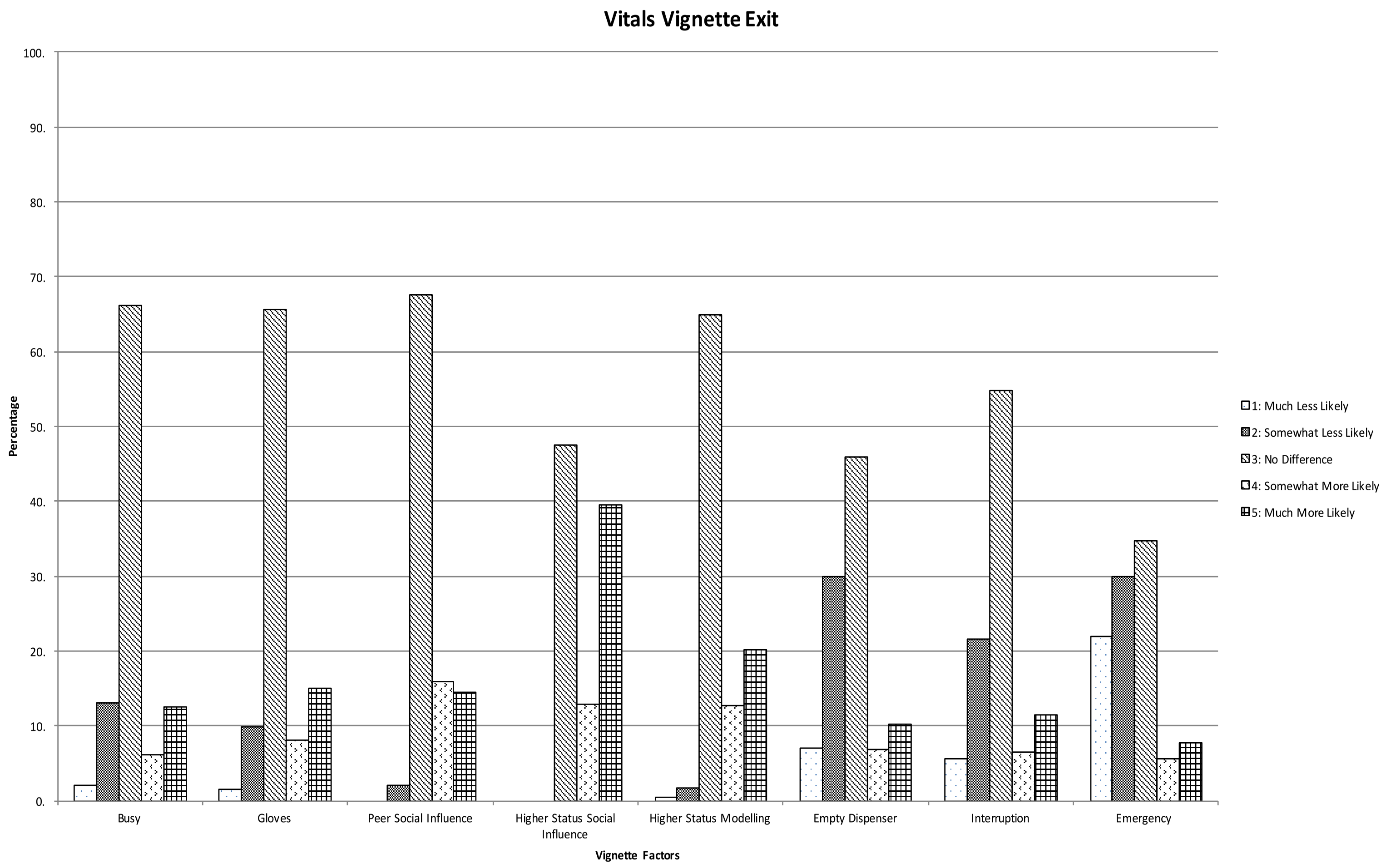


Figure A3- 3: Vitals vignette— Entry

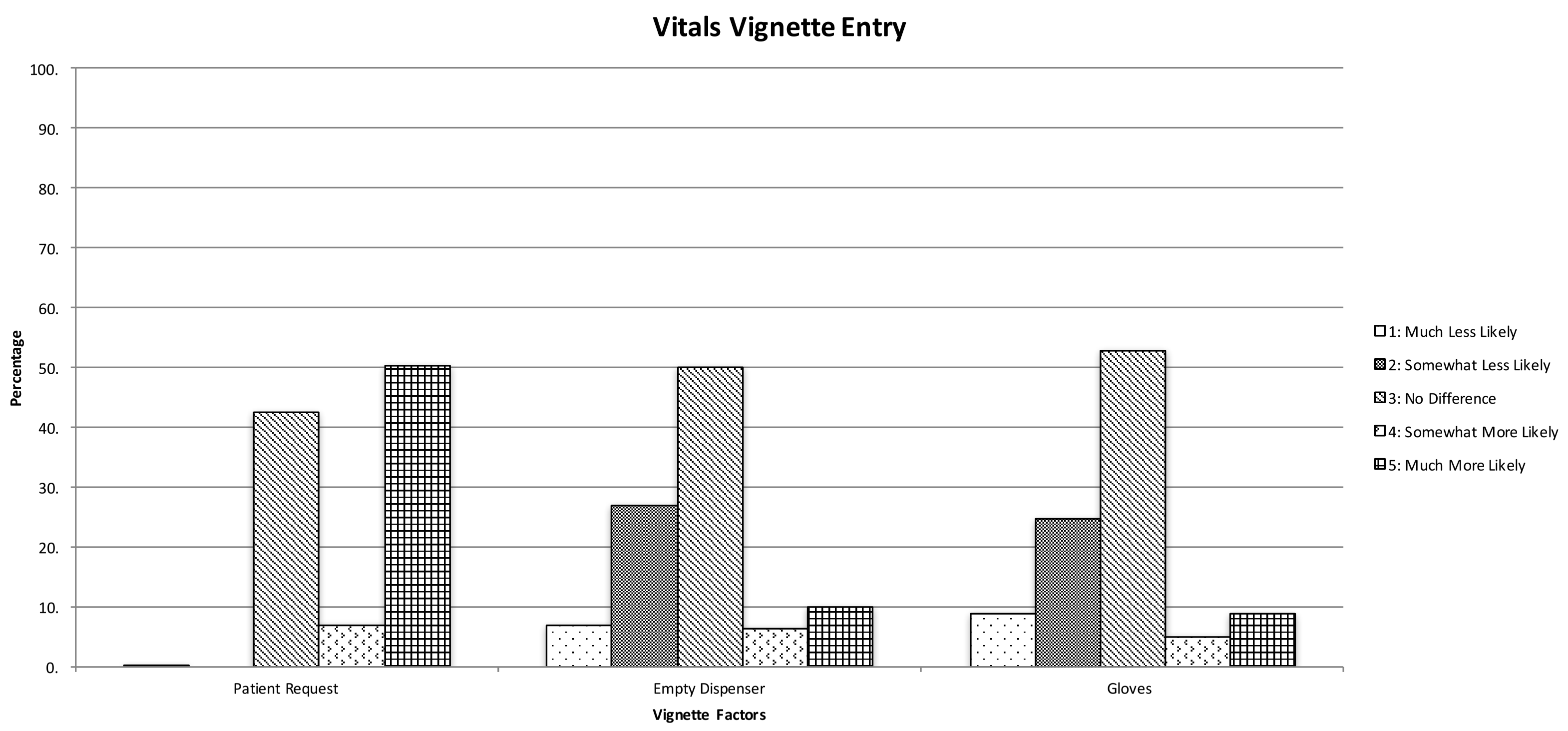


Figure A3- 4: Cleaning wound vignette— Exit

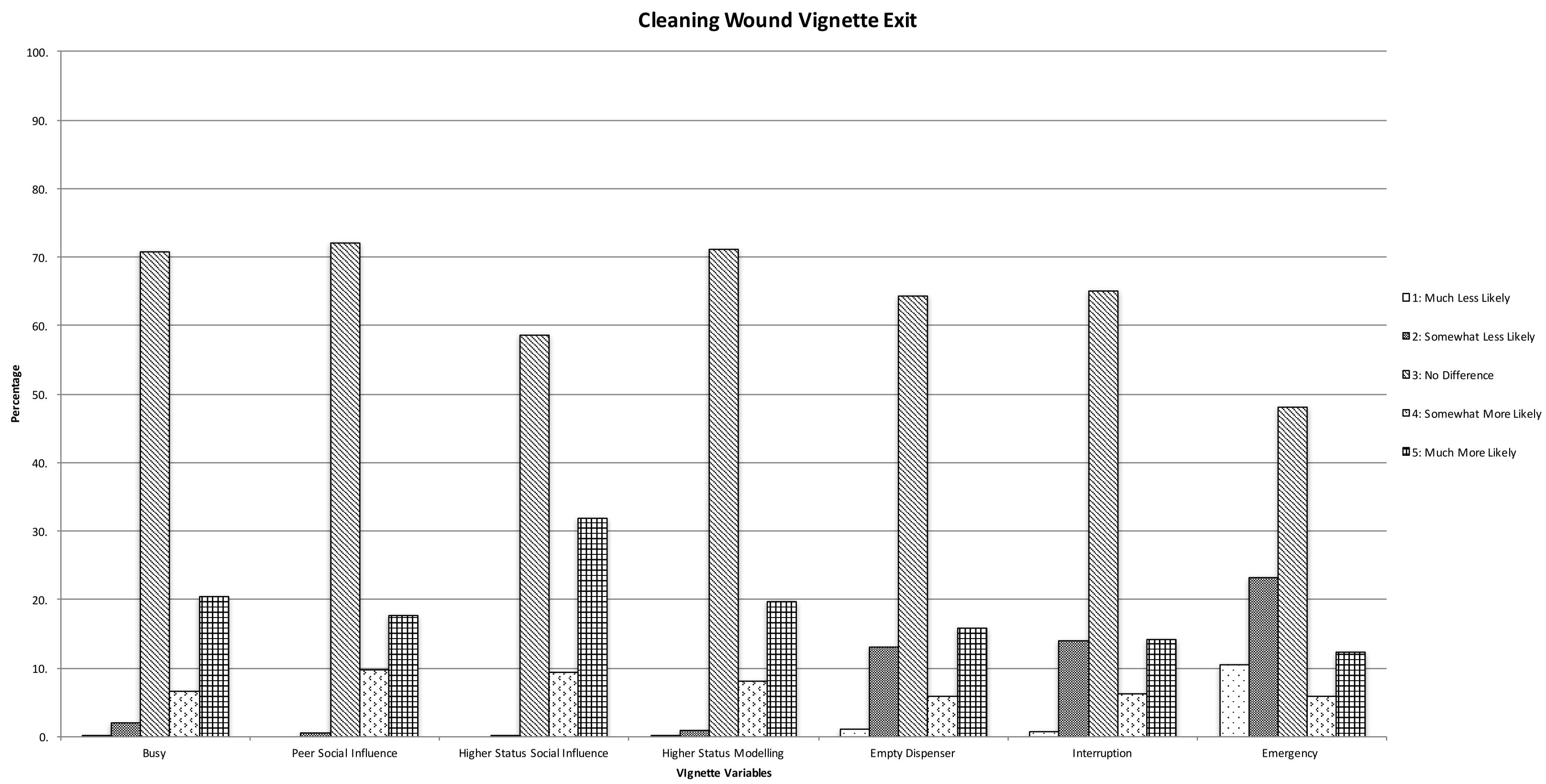


Figure A3- 5: Cleaning wound vignette— Entry

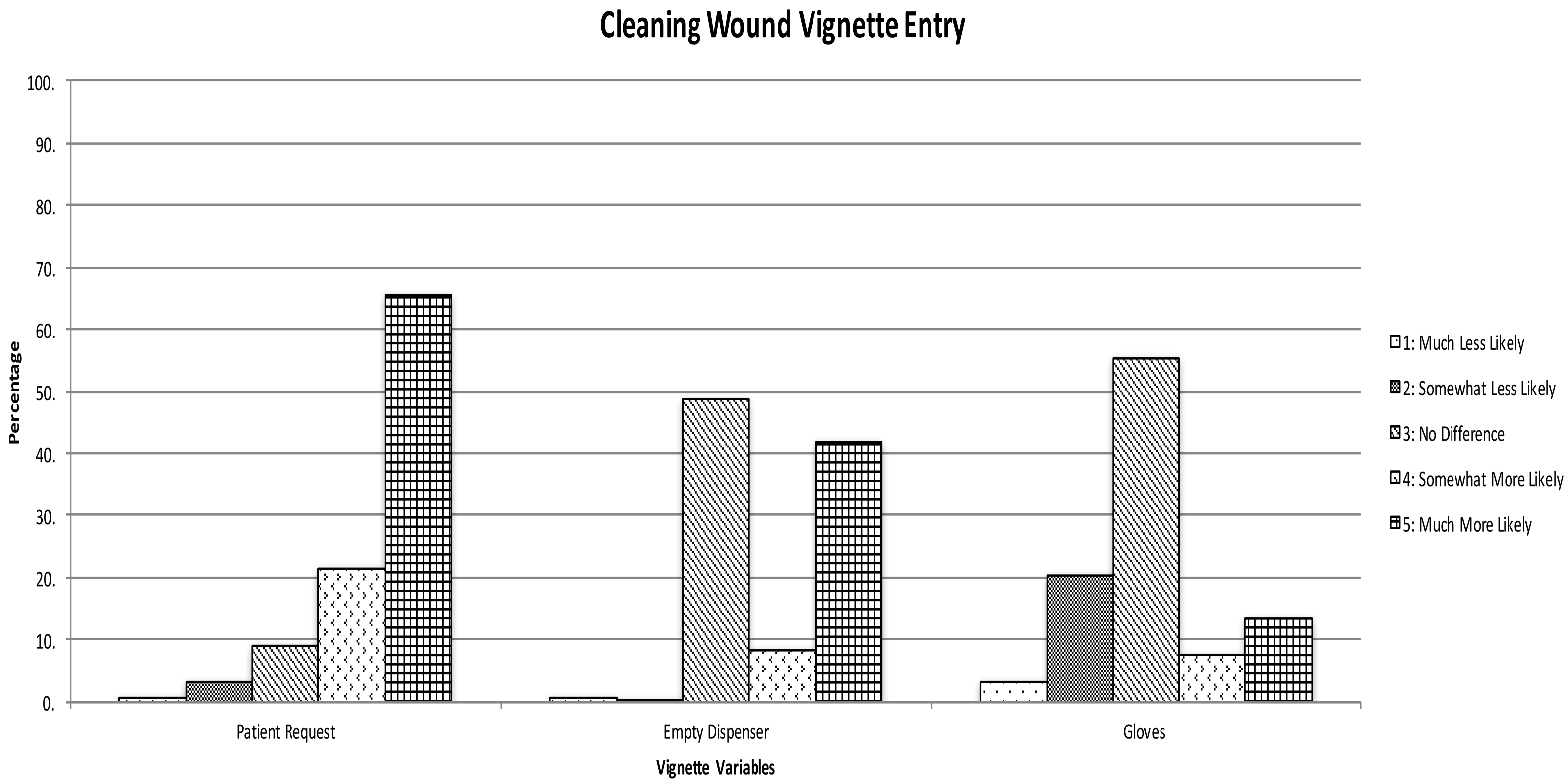


Figure A3- 6: Role— Top 5 most desirable traits

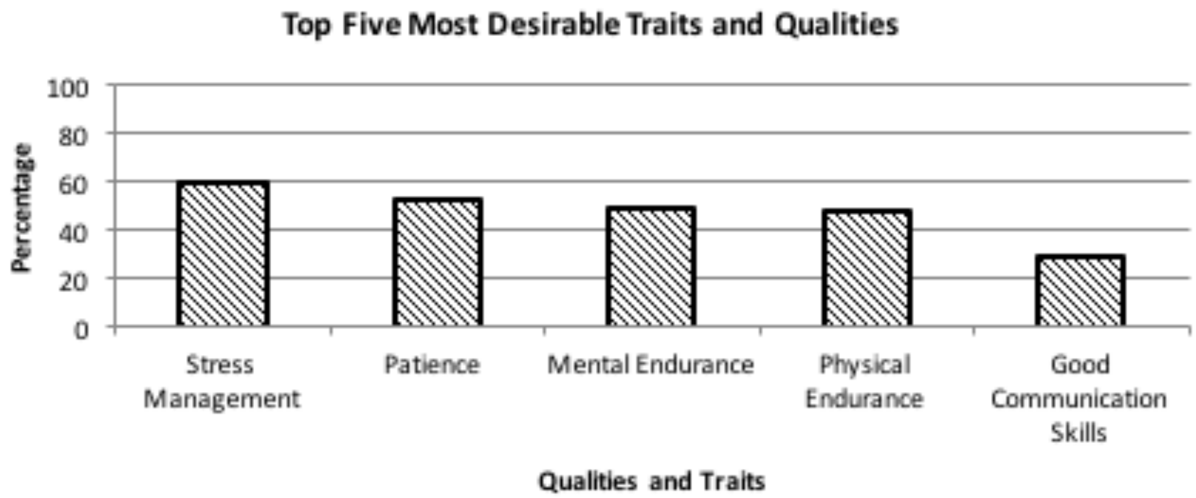


Figure A3- 7: Role— Top five negative statements

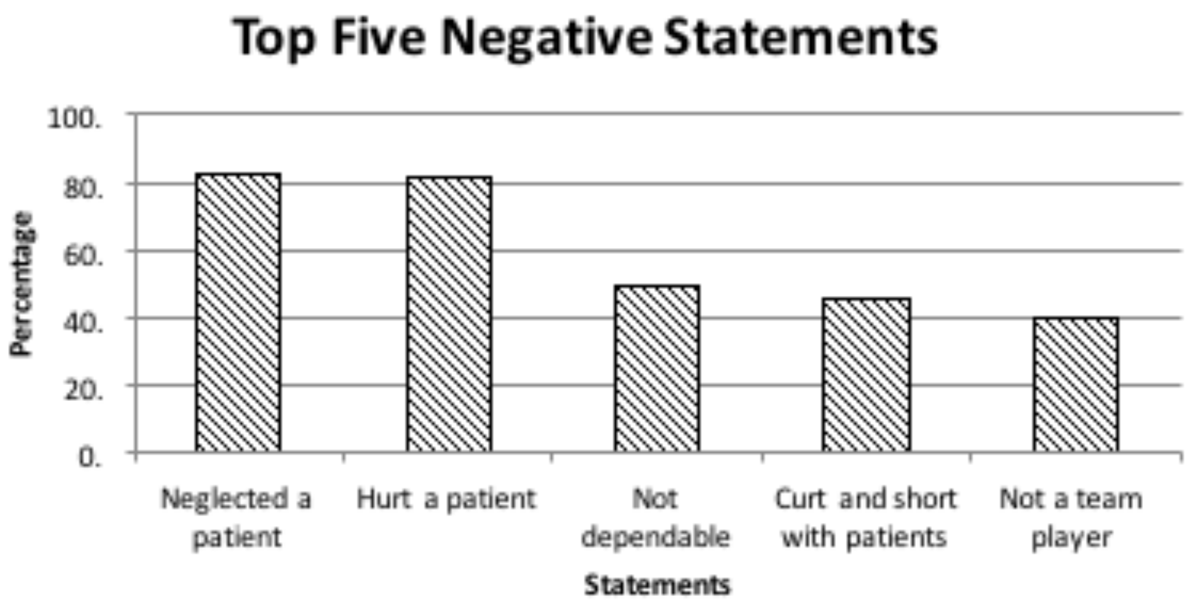


Figure A3- 8: Empirical expectations— Comparison of mean responses

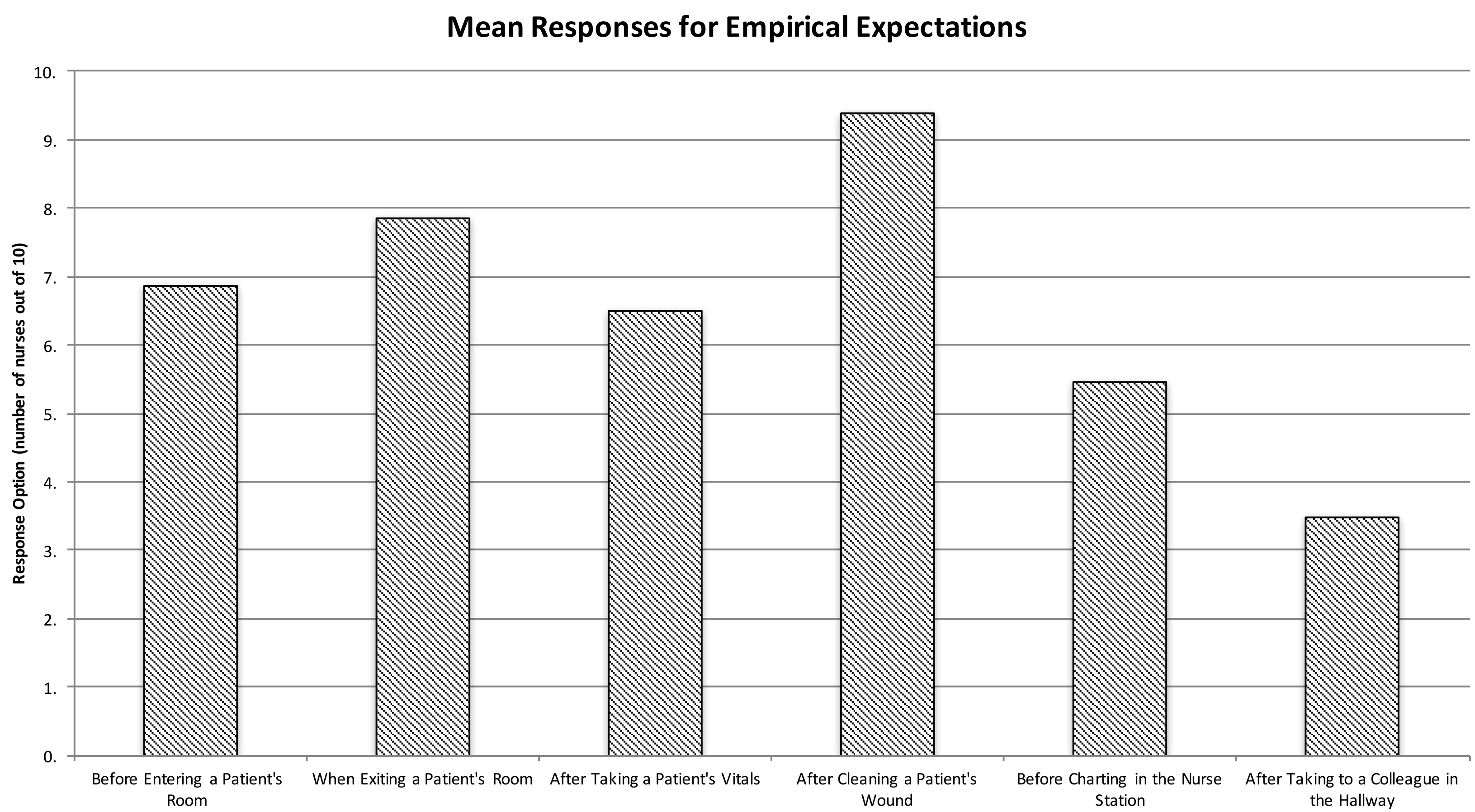


Figure A3- 9: Normative personal beliefs

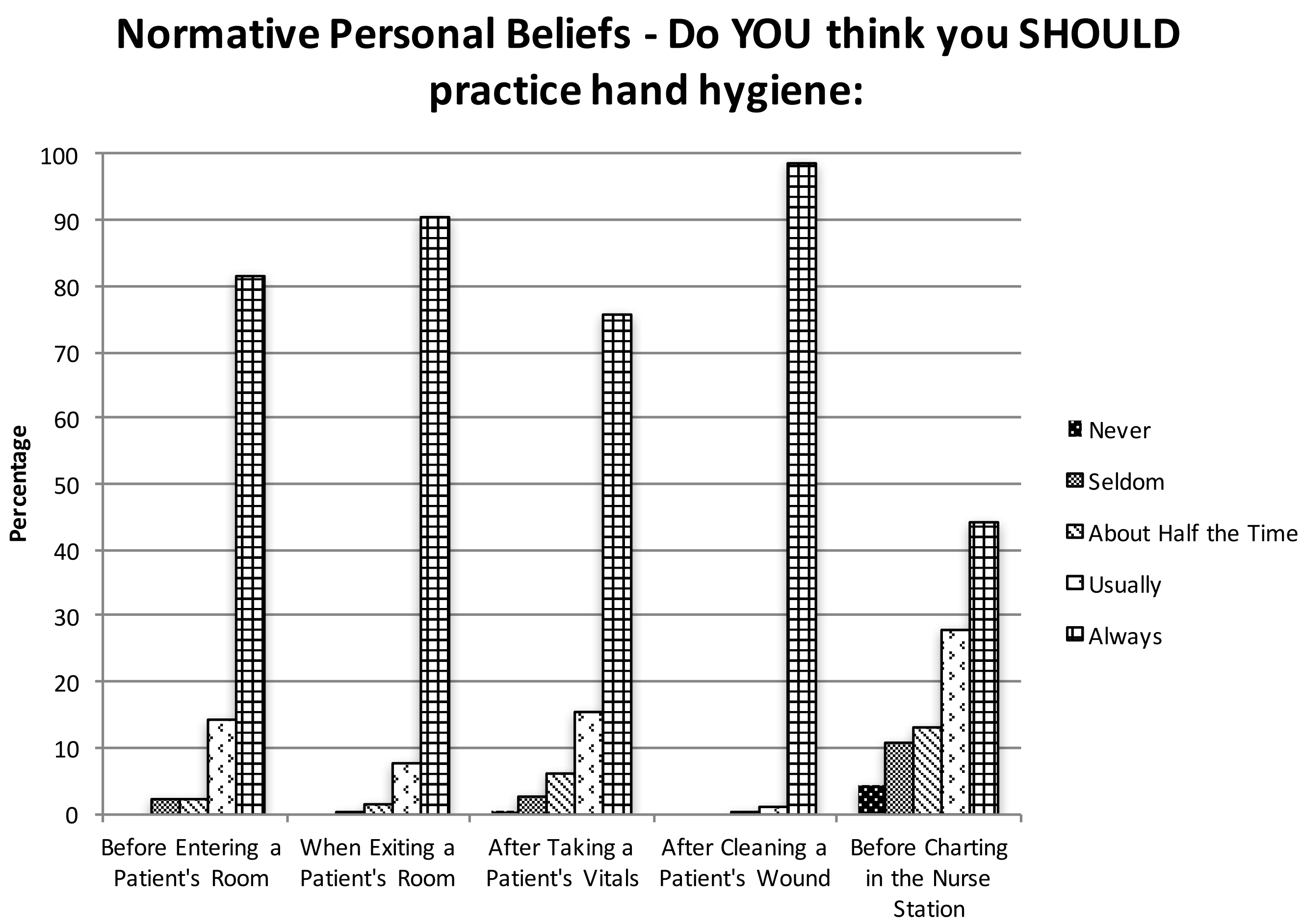


Figure A3- 10: Normative expectations

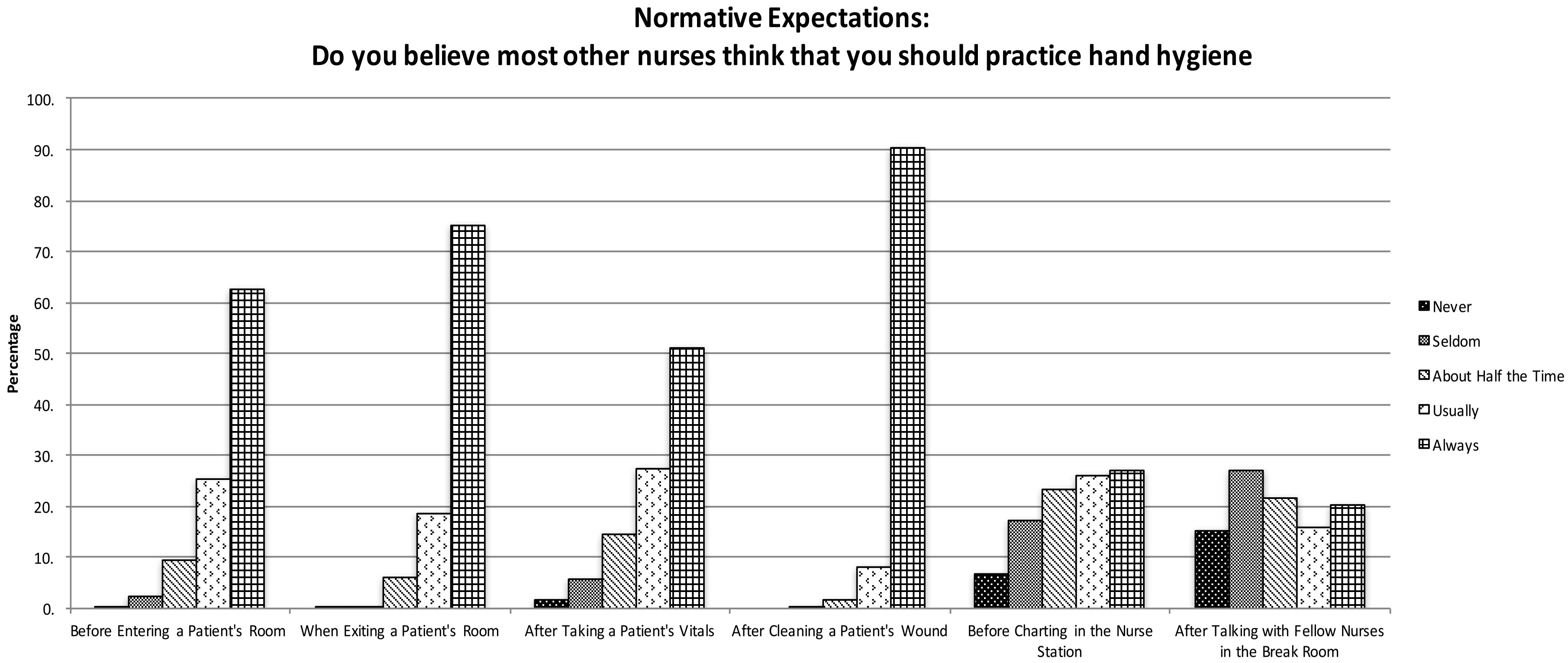
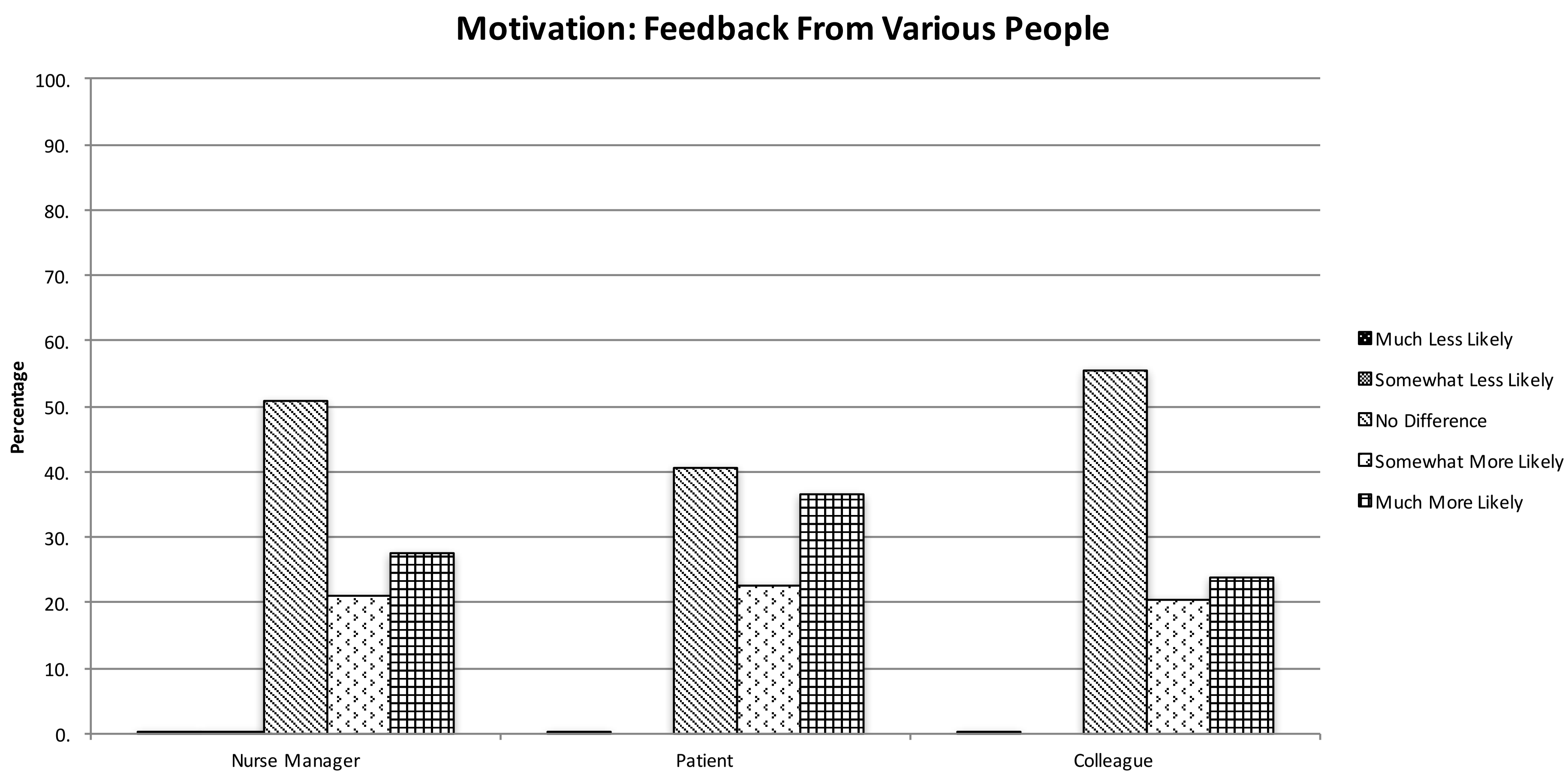


Figure A3- 11: Motivation and feedback



APPENDIX 4-1: TIDieR CHECKLIST FOR INTERVENTION DESIGN

The TIDieR checklist was used to ensure that the intervention had been appropriately described.

TIDieR Template for Intervention Description and Replication

The TIDieR (Template for Intervention Description and Replication) Checklist*:

Information to include when describing an intervention and the location of the information

Item number	Item	Where located ** Primary paper (page or appendix number)	Other † (details)
	BRIEF NAME		
1.	Provide the name or a phrase that describes the intervention.	page 146, 160	
	WHY		
2.	Describe any rationale, theory, or goal of the elements essential to the intervention.	page 160-164	
	WHAT		
3.	Materials: Describe any physical or informational materials used in the intervention, including those provided to participants or used in intervention delivery or in training of intervention providers. Provide information on where the materials can be accessed (e.g. online appendix, URL).	page 146-8 Appendix 4-1 Appendix 4-2	
4.	Procedures: Describe each of the procedures, activities, and/or processes used in the intervention, including any enabling or support activities.	page 163-5 Appendix 4-2	
	WHO PROVIDED		
5.	For each category of intervention provider (e.g. psychologist, nursing assistant), describe their expertise, background and any specific training given.	page 163-5	
	HOW		
6.	Describe the modes of delivery (e.g. face-to-face or by some other mechanism, such as internet or telephone) of the intervention and whether it was provided individually or in a group.	page 163-5	
	WHERE		
7.	Describe the type(s) of location(s) where the intervention occurred, including any necessary infrastructure or relevant features.	page 163-5	

TIDieR checklist

	WHEN and HOW MUCH		
8.	Describe the number of times the intervention was delivered and over what period of time including the number of sessions, their schedule, and their duration, intensity or dose.	page 146-7	______
	TAILORING		
9.	If the intervention was planned to be personalised, titrated or adapted, then describe what, why, when, and how.	page 164-165	______
	MODIFICATIONS		
10.‡	If the intervention was modified during the course of the study, describe the changes (what, why, when, and how).	N/A	______
	HOW WELL		
11.	Planned: If intervention adherence or fidelity was assessed, describe how and by whom, and if any strategies were used to maintain or improve fidelity, describe them.	N/A	______
12.‡	Actual: If intervention adherence or fidelity was assessed, describe the extent to which the intervention was delivered as planned.	N/A	______

** **Authors** - use N/A if an item is not applicable for the intervention being described. **Reviewers** – use '?' if information about the element is not reported/not sufficiently reported.

† If the information is not provided in the primary paper, give details of where this information is available. This may include locations such as a published protocol or other published papers (provide citation details) or a website (provide the URL).
‡ If completing the TIDieR checklist for a protocol, these items are not relevant to the protocol and cannot be described until the study is complete.

* We strongly recommend using this checklist in conjunction with the TIDieR guide (see *BMJ* 2014;348:g1687) which contains an explanation and elaboration for each item.

* The focus of TIDieR is on reporting details of the intervention elements (and where relevant, comparison elements) of a study. Other elements and methodological features of studies are covered by other reporting statements and checklists and have not been duplicated as part of the TIDieR checklist. When a **randomised trial** is being reported, the TIDieR checklist should be used in conjunction with the CONSORT statement (see www.consort-statement.org) as an extension of **Item 5 of the CONSORT 2010 Statement.** When a **clinical trial protocol** is being reported, the TIDieR checklist should be used in conjunction with the SPIRIT statement as an extension of **Item 11 of the SPIRIT 2013 Statement** (see www.spirit-statement.org). For alternate study designs, TIDieR can be used in conjunction with the appropriate checklist for that study design (see www.equator-network.org).

TIDieR checklist

APPENDIX 4-2: INTERVENTION MATERIALS

The intervention was presented in two parts: the first part focused on values the second part delivered the HH message and guided participants through the cue-association activity.

We'd like to learn about values that are important to you. Please answer the following three questions about values.

1. Below is a list of values. We are interested to know which of these values are the most important to you in your everyday life – that is, not necessarily related to work, but important to you personally.
   Write "1" next to your MOST IMPORTANT value.
   Write "2" next to your SECOND MOST IMPORTANT value.
   Write "3" next to your THIRD MOST IMPORTANT value.

   _____ Creativity
   _____ Courage
   _____ Friendship
   _____ Honesty
   _____ Humor
   _____ Justice
   _____ Modesty
   _____ Respect
   _____ Spirituality
   _____ Spontaneity

2. Please think about the value you wrote "1" next to. Why is this value *personally* important to you?

____
____
____
____
____
____

3. Please briefly describe a time in your life (<u>not</u> involving your job/work) when the value you wrote "1" next to was particularly important to you.

____
____
____
____
____
____
____

Thank you for completing this questionnaire!

Please read the information below about hand hygiene.

Proper hand hygiene is one part of a nurse's responsibilities to ensure patient safety. Nurses usually clean their hands after **leaving** a patient's room. Doing so protects the nurse from germs acquired during patient interactions. However, research using advanced methods of observation shows that nurses are less likely to clean their hands when **entering** a patient's room. This means that nurses' hands often carry germs into the patient's room. Thus, nurses are not doing as much to protect their patients from germs as they are doing to protect themselves.

This highlights an important opportunity to improve hand hygiene upon **entry** to patient rooms. That is, we now know that 'entering patient rooms' is a specific situation in which nurses can focus their attention and achieve a noticeable increase in hand hygiene. Nurses should strive to clean their hands more consistently every time they enter a patient room. It is possible that nurses can create mental reminders to help them think about cleaning their hands in this specific situation.

Here's what you can do…

Think about the things/objects in the environment near most patient rooms in your unit. This might include a sign (e.g., a room number), a part of a door, a dispenser, etc. Ideally, identify some object that doesn't move – something that will be present every time you approach most patient rooms. Also, try to identify something distinctive – something with a shape, color, or size that will stand out and catch your attention each time you approach the room.

➔ Please list the object you identified here:

____

Next, make a plan involving the object you identified. Tell yourself, "As soon as I see [*insert name of object*] I will tell myself 'clean your hands!'"

Please fill in the blank in the statement below:

➔ **"As soon as I see ________________________________ I will tell myself 'clean your hands!'"**

Over the next several days:

- Please remember the object you selected
- Whenever you see that object, please use that object as a reminder to clean your hands.

APPENDIX 4-3: DIRECTIONS FOR FACILITATOR

Directions for the in-person delivery.

Mainspring Intervention

Directions for In-Person Delivery by Facilitator

Black text – indicates materials nurses (research participants) will receive and complete
Blue, italic text – indicates descriptions of how/where the intervention will be delivered, instructions the facilitator will provide to the nurses, etc. Nurses will not see these sections in the intervention materials – these sections are just for the research team to consider, but will be removed from materials to be used in the hospitals.

Setting for intervention:

- *Ideally, the facilitator will meet with several nurses in a group and will have 5-10 min to deliver the intervention materials on paper.*
- *This will take place during nurses' work day (during their shift) in each respective unit's break room/ conference room.*
- *Recruitment will be the responsibility of the respective hospitals, units, and nurse mangers.*

Introduction:

- *We'll give a brief description of who we are and what we're asking nurses to do.*
- *Maybe something like this…*
    - *I'm a researcher [from XXX]. We're partnering with the hospital to learn about hand hygiene.*
    - *In a minute I'll give you some information on hand hygiene.*
    - *First, I'd like to ask you to complete a brief questionnaire. We're trying to learn about values that are important to people in the healthcare field. Today, I'd like to ask your help answering a couple brief questions.*
    - *Materials we fill out today won't be shared with anyone at the hospital.*

Next, pass out a 1-page questionnaire containing the 3 questions below:

Thank you for participating! Please answer the following three questions about values.

1. Below is a list of values. We are interested to know which of these values are the most important to you.
   Write "1" next to your MOST IMPORTANT value.
   Write "2" next to your SECOND MOST IMPORTANT value.
   Write "3" next to your THIRD MOST IMPORTANT value.

_____ Creativity
_____ Courage
_____ Friendship
_____ Honesty
_____ Humor
_____ Justice
_____ Modesty
_____ Respect
_____ Spirituality
_____ Spontaneity

2. Please think about the value you wrote “1” next to. Why is this value *personally* important to you?

____
____
____
____
____
____

3. Please briefly describe a time in your life (not involving your job/work) when the value you wrote “1” next to was particularly important to you.

____
____
____
____
____
____
____
____

Thank you for completing this questionnaire!

Next, we’ll pass out a page or two containing the information below…

Please read the information below about hand hygiene.

Proper hand hygiene is one part of a nurse’s responsibilities to ensure patient safety. Nurses usually clean their hands after **leaving** a patient’s room. Doing so protects the nurse from germs acquired during patient interactions. However, research using advanced methods of observation shows that nurses are less likely to clean their hands when **entering** a patient’s room. This means that nurses’ hands often carry germs into the patient’s room. Thus, nurses are not doing as much to protect their patients from germs as they are doing to protect themselves.

This highlights an important opportunity to improve hand hygiene upon **entry** to patient rooms. That is, we now know that ‘entering patient rooms’ is a specific situation in which nurses can focus their attention and achieve a noticeable increase in hand hygiene. Nurses should strive to clean their hands more consistently every time they enter a patient room. It is possible that nurses can create mental reminders to help them think about cleaning their hands in this specific situation.

Here's what you can do…

Think about the things/objects in the environment near most patient rooms in your unit. This might include a sign (e.g., a room number), a part of a door, a dispenser, etc. Ideally, identify some object that doesn't move – something that will be present every time you approach most patient rooms. Also, try to identify something distinctive – something with a shape, color, or size that will stand out and catch your attention each time you approach the room.

Please write the object you identified here:

____

Next, make a plan involving the object you identified. Tell yourself, "As soon as I see [*insert name of object*] I will tell myself 'clean your hands!'"

Please fill in the blank in the statement below:

"As soon as I see _________________________________ I will tell myself 'clean your hands!'"

To concludes the session, deliver the information below verbally after the nurses have completed the questionnaires.

- *I'd like to ask you to do two things over the next several days:*
  - *(1) please remember the object that you selected*
  - *(2) whenever you see that object, please use the object as a reminder to clean your hands*
- *Thank nurses for their time*

APPENDIX 5-1: PROCESS EVALUATION NURSE QUESTIONNAIRE

Process Evaluation Nurse Questionnaire

Question 1: Did you participate in the survey project? 1=a, 2=b, 3=c, 4=d

[a] Yes, I completed the survey
[b] Yes, I started the survey but didn't finish it
[c] No, I didn't participate [Skip to end]
[d] Not sure/Can't remember [Skip to end]

Question 2: Do you remember seeing this information? 1=a, 2=b, 3=c

[a] Yes
[b] No
[c] Not sure [Skip to end]

Question 3: Did you know (before the survey) that nurses are less likely to clean their hands when entering a patient's room than when exiting a patient's room? 1=a, 2=b, 3=c

[a] Yes
[b] No
[c] Not sure

Question 4a: I believe it is true that nurses are less likely to clean their hands when entering a patient's room than when exiting a patient's room. 1=a, 2=b, 3=c, 4=d, 5=e

Strongly Disagree a	Somewhat Disagree b	Neutral c	Somewhat Agree d	Strongly Agree e

[a] strongly disagree
[b] somewhat disagree
[c] neutral
[d] somewhat agree
[e] strongly agree

Question 4b: I was irritated when I read that nurses are less likely to clean their hands when entering versus when exiting a patient's room. 1=a, 2=b, 3=c, 4=d, 5=e

[a] strongly disagree
[b] somewhat disagree
[c] neutral
[d] somewhat agree
[e] strongly agree

Question 4c: It is useful for nurses to know that they may be less likely to clean their hands when entering versus exiting a patient's room. 1=a, 2=b, 3=c, 4=d, 5=e

[a] strongly disagree
[b] somewhat disagree
[c] neutral
[d] somewhat agree
[e] strongly agree

Question 4d: I'm glad I learned that nurses are less likely to clean their hands when entering versus exiting a patient's room. 1=a, 2=b, 3=c, 4=d, 5=e

[a] strongly disagree
[b] somewhat disagree
[c] neutral
[d] somewhat agree
[e] strongly agree

Question 5: The survey asked you to choose an object to help you remember to clean your hands when entering a patient's room. Do you recall what object you chose? 1=a 2=b 3=c

[a] Yes
[b] No [Skip to end]
[c] Not sure [Skip to end]

Question 6: Did you try to use the object as a reminder for yourself to clean your hands when entering patients' rooms? 1=a 2=b 3=c

[a] Yes
[b] No [Skip to end]
[c] Not sure [Skip to end]

Question 7: Did the object help you to remember to clean your hands when entering patients' rooms?

1	2	3	4	5
It didn't help me at all				It helped me a lot

Question 8: Do you still use the object to remind yourself to clean your hands? 1=a 2=b 3=c

[a] Yes
[b] No
[c] Not sure

Question 9: In a typical work day, how often do you use the object to remind yourself to clean your hands? 1=a 2=b 3=c 4=d 5=e

[a] Almost always
[b] Often
[c] Sometimes
[d] Rarely
[e] Almost never

Question 10: After you completed the survey, have you cleaned your hands more often, less often, or about the same as you did before you completed the survey? 1=a 2=b 3=c 4=d 5=e

[a] A lot more often
[b] A little more often
[c] About the same
[d] A little less often
[e] A lot less often

APPENDIX 5-2: PROCESS EVALUATION FACILITATOR QUESTIONNAIRE

Process Evaluation Facilitator Questionnaire

Hospital	
Unit	
Date of Intervention	
Date of Process Evaluation	

DELIVERY

How did delivery of the intervention in this unit compare to the other deliveries? What were similarities and differences?

To what extent were all materials designed for use in the intervention used? (What materials did you use in the intervention?)

To what extent were all the activities of the intervention completed by the participants?

How long did the complete intervention take? How long did each activity take?

Did you develop any techniques or approaches during this delivery that you think may help you get the best results? Can you explain this?

Any recommendations for how to change the delivery for next time?

RECEPTION

Do you think there was any activity that could have led to the nurses feeling like they were singled out or could have made them feel defensive? Did you sense that the nurses actually felt this way?

To what extent were participants engaged in the activities? Did participants seem excited? Were they listening and writing?

REACH

What proportion of the target population participated in the intervention? (How many nurses participated in the intervention and what is the total number of nurses in the unit?)

How did the number of nurses working compare to the number of nurses who actually attended the event? Do you have an explanation for why this might be the case?

RECRUITMENT

When you initially reached out to the hospital, what did you explain about the intervention?

Did you make suggestions of who should attend? If so, how did your point of contact (please specify if it was the IP director or nurse manager) respond to these particular requests?

Did you discuss with the IP director/nurse manager where the intervention would be carried out (where the venue would be)? What were the factors that helped determine the venue?

Did you experience any difficulties during the recruitment stage? If so, what?

APPENDIX 5-3: BACKGROUND ON SPC

Statistical Process Control

Statistical process control (SPC) is the graphical and statistical analysis of data for the purpose of understanding and monitoring process performance.[1,2] SPC charts can be used to determine whether changes in processes are making a real difference in outcomes.

Repeated measures of the same parameter often yield slightly different results— for example, repeatedly measuring HHC rates in a hospital unit using an electronic compliance monitoring (ECM) system may produce variation in rates— even if there is no fundamental change.[187] This inherent variability can be due to various factors with an example being the imperfections in the ECM data gathering process. SPC allows for the identification of the variability inherent within the process so that the interventions' impact and sustainability can be understood and evaluated. SPC methods combine time series analysis methods with graphical presentation of data to detect changes and trends.

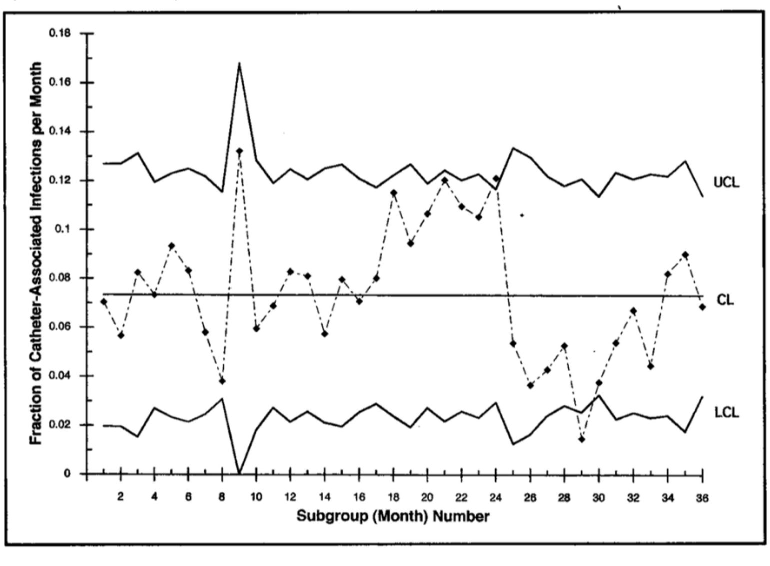
Theory of Statistical Process Control

The basic premise is that repeated measurements from a process will exhibit variation. There is natural variation in a process, referred to as *common cause variation.*[1,3] Variation will occur according to an underlying statistical distribution if the parameter remains constant over time. This variation is predictable within a range that can be described by one of the several statistical models of distribution.[3] *Special cause variation* is the unnatural variation due to events, changes, or circumstances that are not inherent in the regular process.[1] The measured values will deviate from the random distribution models. Special cause variation can result from deliberate action, such as a HH intervention that changes HHC rates. Generally, if the process is in statistical control (meaning the underlying distribution is stable) then almost all data falls within ±3 SD of the mean. The SPC control chart defines what the process is capable of producing given its current design and operation.[3] This project seeks to implement an intervention that deliberately attempts to introduce special causes of variation. By establishing statistical limits and testing for data that deviate from predictions, the research team can provide statistical evidence of a change.

The Control Chart

In the SPC control chart, the series of measurements are plotted in time order. The chart has three horizontal lines called the centre line (the mean), the upper control limit (UCL), and the lower control limit (LCL). The UCL and LCL values are calculated from the inherent variation in the data. Data that fall outside the control limits or display abnormal patterns are indications of special cause variation.[3] Data that fall between the upper and lower control limits are attributed to common cause variation. An example is show in Figure A5-1.

Figure A5- 1: Trial p control chart



Based on unequal subgroup sizes (unequal number of monthly catherizations). Abbreviations: CL, centre line; LCL, lower control limit; UCL, upper control limit. Reprinted from Benneyan, 1998.[1]

Statistical Process Control in this Project

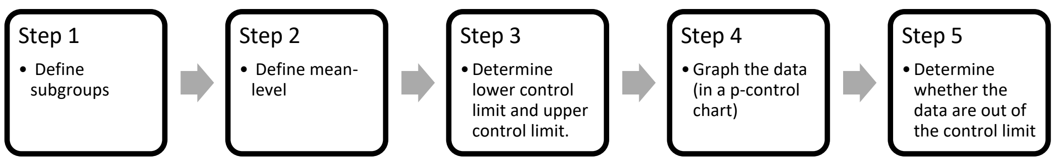
Baseline assessment of the stability of a process is helpful not only for understanding and managing present variability but also for predicting the future performance of the process. The selection of an appropriate control chart for any situation is based directly on identifying which type of process data is being investigated.[3] In this project, the data are discrete. There are four possible control charts for discrete counts (Table A5-1).

Table A5- 1: The various control charts for discrete data

Control Chart Type	Description of Uses and Limitations	Subgroup Size
p	Discrete— Binomial Distribution	Unequal
np	Discrete—Binomial Distribution	Equal
u	Discrete—Poisson Distribution	Unequal
c	Discrete— Poisson Distribution	Equal

If the data were discrete and followed a Poisson distribution, then the *u*- and *c*-control charts would be best to use. However, in this project the outcome is a dichotomous event. There can only be one of two outcomes: either hand hygiene is practiced or it is not. This is a Bernoulli trial. An *np*- or *p*-control chart is most appropriate. As there are variable subgroup sizes due to the varying number of opportunities to wash hand each days and week, a *p*-chart will be most accommodating. It should be noted that a *p*-chart will be created for each of the hospital units.

Figure A5- 2: SPC data analysis plan



APPENDIX 5-3 REFERENCES

[1] Benneyan JC. Statistical Quality Control Methods in Infection Control and Hospital Epidemiology, Part I Introduction and Basic Theory. Infection Control. 1998; 19:194-214.

[2] Birnbaum D, Benneyan JC. Statistical quality control methods in infection control and hospital epidemiology, Part II: chart use, statistical properties, and research issues. Infection Control. 1998; 19:265-83.

[3] Benneyan J, Lloyd R, Plsek P. Statistical process control as a tool for research and healthcare improvement. Quality and Safety in Health Care. 2003; 12:458-64.

APPENDIX 5-4: MULTIPLE BASELINE DESIGN POWER CALCULATIONS

Multiple Baseline Design's Interrupted Time Series Analysis— Power Calculations

The power calculations were based on monitored HH events, opportunities, and calculated compliance rates for two hospitals that have the ECM system that will be used in the hospitals recruited for this study. The Project Funder provided the data presented in Table A5-2. It was assumed that the mean and SD of events and opportunities were normally distributed in the data provided.

The mean baseline HHC was similar in the two hospitals. Hospital 1 had a baseline compliance rate of 12% (SD=3.2%) and Hospital 2 had a baseline compliance rate of 11% (SD=2.5%). Hospital 1 had a slightly higher mean event rate per month (7524, SD=1425) than Hospital 2 (5980, SD=1673). The graph for the baseline HHC rates of the two hospitals has been provided in Figure A5-3.

Table A5- 2: HHC data from Jan-Jun 2015

Hospital	Months	Events	Opportunities	HHC Rate
Hospital 1	Jan 2015	7328	80224	9.10%
	Feb 2015	6874	64258	10.70%
	Mar 2015	8802	80441	10.90%
	Apr 2015	8681	76795	11.30%
	May 2015	5078	27580	18.40%
	Jun 2015	8383	70175	11.90%
	Totals	45146	399473	12.05%
Hospital 2	Jan 2015	7195	70230	10.20%
	Feb 2015	7757	69811	11.10%
	Mar 2015	6619	98548	9.70%
	Apr 2015	6151	43367	14.20%
	May 2015	5005	44005	11.40%
	Jun 2015	3155	25082	12.60%
	Totals	35882	351043	11.53%

Simulations were conducted to estimate the power of segmented logistic regression models when the main intervention effect size was 25%, 50%, and 75% and the interaction between time and intervention were -0.0025, -0.005, and -0.0075, respectively. We conducted 5000 simulations for each scenario and estimated that for all numbers of time points we examined, we had 85-99% power to detect these effects (alpha - .05). Graphs are provided in Figure A5-4 and Figure A5-5.

Figure A5-4 displays the power to detect an effect (alpha = .05) across varying numbers of time points measured and 3 effect-size levels. *Time points measured* indicates the number of samples measured during each of the control and treatment periods. We conducted 5000 simulations for each combination of effect-size and number of time points, assuming that the baseline percentage of HHC and opportunities for HH both followed truncated normal distribution with mean and standard deviation the same as those observed in the data and truncated at 0. The dotted red line indicates the 80% power used as a threshold for a well-powered study. For all simulations in this graph, we assumed a constant interaction effect between time and the intervention equal to -.005.

Figure A5-5 displays the power to detect an effect (alpha = .05) across varying numbers of time points measured and interaction effect-size levels. *Time points measured* indicates the number of samples measured during each of the control and treatment periods. We conducted 5000 simulations for each combination of effect-size and number of time points, assuming that the baseline percentage of HHC and opportunities for HH both followed truncated normal distribution with mean and standard deviation the same as those observed in the data and truncated at 0. The dotted red line indicates the 80% power used as a threshold for a well-powered study. For all simulations in this graph, we assumed a constant main effect of the intervention equal to a 50% increase from baseline (approximately 6 percentage points).

Figure A5- 3: Baseline HHC rates

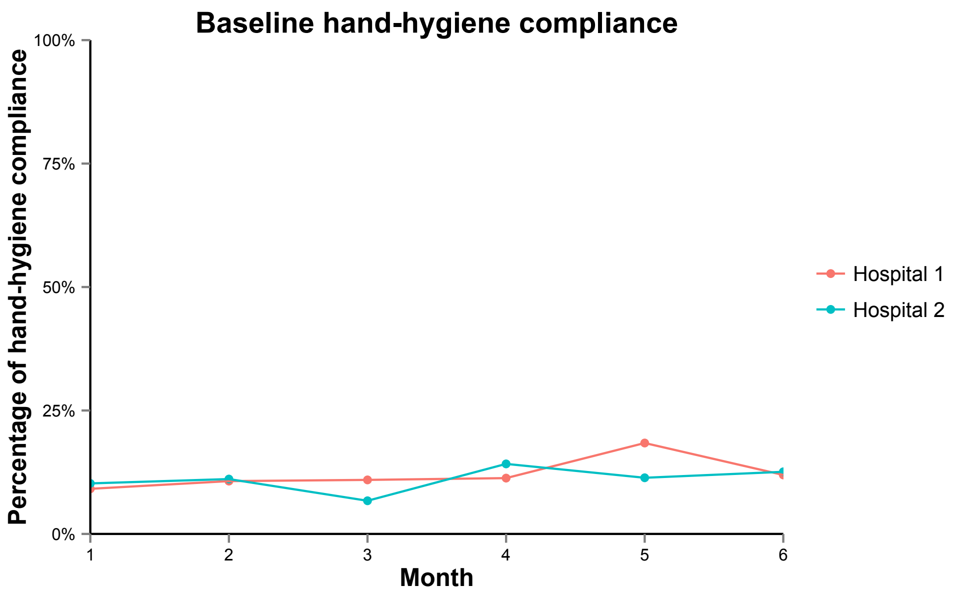


Figure A5- 4: Power simulations for main intervention effect

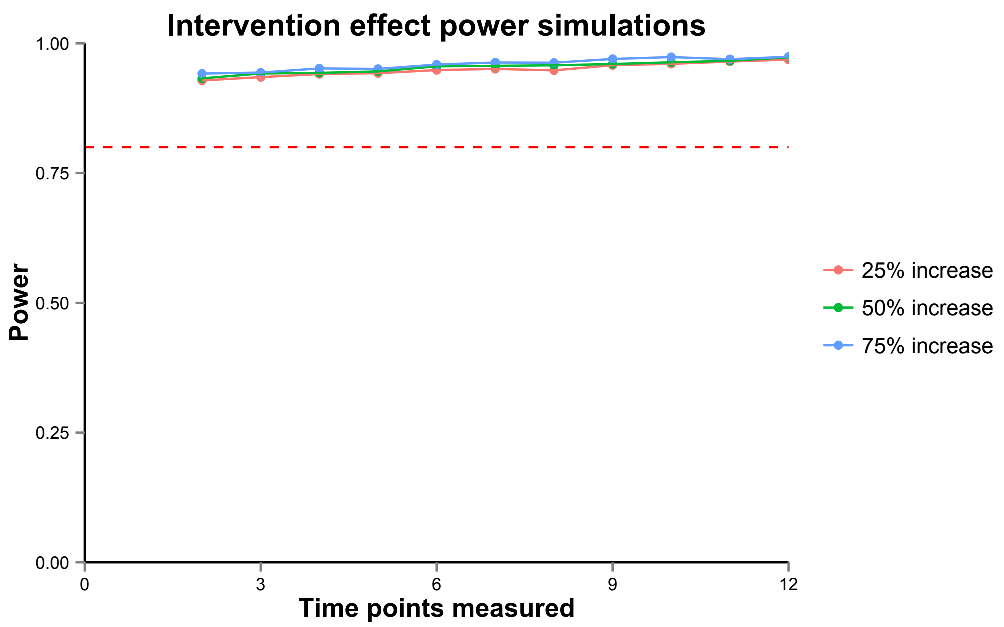
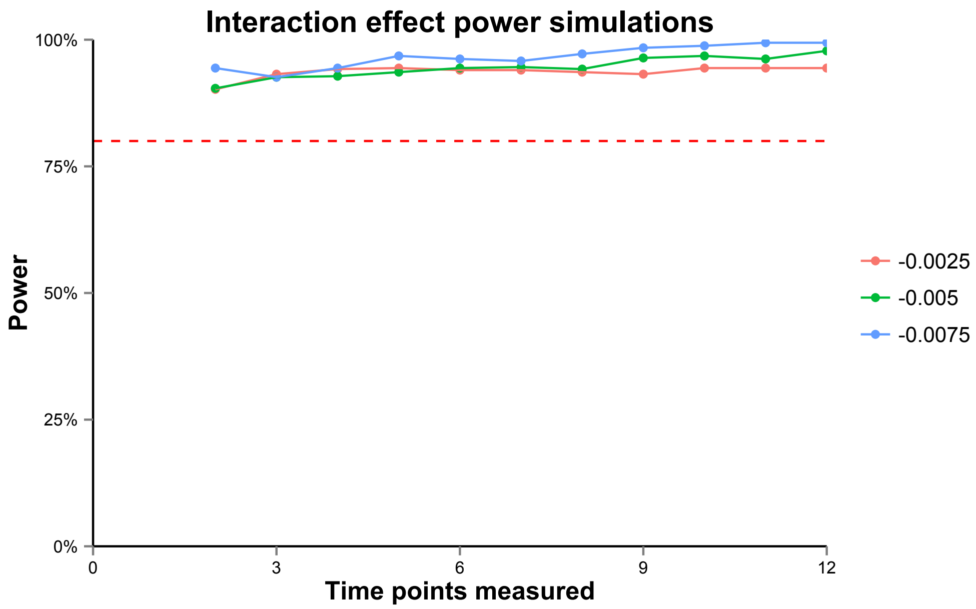


Figure A5- 5: Power simulations for interaction between time and intervention



APPENDIX 5-5: PROJECT FUNDERS LETTER TO LSHTM'S ETHICS COMMITTEE

GOJO Industries, Inc.
One GOJO Plaza, Suite 500
Tel: 330-255-6000 Fax: 330-255-6119
www.GOJO.com

Mailing Address:
P.O. Box 991, Akron, Ohio 44309-0991

Dear Committee:

GOJO Industries will conduct a set of market research studies with LSHTM researchers Robert Aunger and Madeline Sands acting as technical advisors. The market research studies will examine the opinions of acute care nurses who work in US hospitals toward a package of services offered by GOJO that provide hospitals with data on the frequency with which hospital staff perform hand hygiene behaviors (e.g., dispensing and using hand sanitizer) along with training and recommendations regarding how to improve hand hygiene frequency among the staff members. The purpose of these studies will be to improve the package of services offered by GOJO, not to develop or contribute to generalizable knowledge. Thus, as is the case with most market research activities, this work does not meet the US Department of Health and Human Services definition of *human subjects research* and is exempt from the requirement of approval by an Institutional Review Board (IRB).[1] Instead, the research will be conducted in compliance with guidelines established by several commercial industry organizations (e.g., Market Research Association, ESOMAR, Qualitative Research Consultants Association) to promote ethical behavior in market research and to protect research participants. Codes of market research standards from these organizations are available online at the web addresses listed in Note 2 below.

Sincerely,

[redacted]

Sue Powell
Vice President of Market Research
GOJO Industries

[1] Department of Health & Human Services code of federal regulations can be found online at the following web address: http://www.hhs.gov/ohrp/humansubjects/guidance/45cfr46.html#46.

[2] Interested readers can explore the following websites to receive a full description of the ICC/ESOMAR international code on market and social research (https://www.esomar.org/uploads/public/knowledge-and-standards/codes-and-guidelines/ICCESOMAR_Code_English_.pdf), the Market Research Association's code of marketing research standards (http://www.marketingresearch.org/issues-policies/mra-code-marketing-research-standards), and the Qualitative Research Consultants Association's ethics and practices (http://www.qrca.org/?page=ethics_practices).

APPENDIX 5-6: LSHTM ETHICS APPROVAL

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LONDON SCHOOL of HYGIENE &TROPICAL MEDICINE

Observational / Interventions Research Ethics Committee

Miss Madeline Sands

LSHTM

22 September 2017

Dear Madeline,

Study Title: Determining the effectiveness of a novel intervention to improve nurse hand hygiene compliance in US hospitals

LSHTM ethics ref: 14411

Thank you for your application for the above research, which has now been considered by the Observational Committee.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation, subject to the conditions specified below.

Conditions of the favourable opinion

Approval is dependent on local ethical approval having been received, where relevant.

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

Document Type	File Name	Date	Version
Local Approval	Letter_LSHTM-GOJO	15/07/2015	1
Protocol / Proposal	Sands and Aunger. Study Protocol	06/07/2016	1
Protocol / Proposal	Hospital A- Intervention Materials	05/07/2017	1
Protocol / Proposal	Hospital B- Online Intervention Survey Screenshots	19/07/2017	1
Investigator CV	Sands-CV-UK	19/07/2017	1
Protocol / Proposal	Process Evaluation survey	20/07/2017	1

After ethical review

The Chief Investigator (CI) or delegate is responsible for informing the ethics committee of any subsequent changes to the application. These must be submitted to the Committee for review using an Amendment form. Amendments must not be initiated before receipt of written favourable opinion from the committee.

The CI or delegate is also required to notify the ethics committee of any protocol violations and/or Suspected Unexpected Serious Adverse Reactions (SUSARs) which occur during the project by submitting a Serious Adverse Event form.

An annual report should be submitted to the committee using an Annual Report form on the anniversary of the approval of the study during the lifetime of the study.

At the end of the study, the CI or delegate must notify the committee using an End of Study form.

All aforementioned forms are available on the ethics online applications website and can only be submitted to the committee via the website at: http://leo.lshtm.ac.uk

Additional information is available at: www.lshtm.ac.uk/ethics

Yours sincerely,

[redacted]

Professor John DH Porter
Chair

APPENDIX 6-1: DESCRIPTION OF INTERVENTION (PER TIDieR CHECKLIST)

WHAT

Name: *Mainspring* study

Target behaviour: Practicing hand hygiene before entering a patient's room

Target population: Nurses in acute care hospital units

WHY

Rationale: Healthcare associated infections (HAIs) are the most common complications in hospital care and are associated with high morbidity, mortality, and healthcare costs for patients, their families, and healthcare systems alike.[1-4] Hand hygiene (HH) is the most effective measure for reducing the incidence of HAIs.[3, 5] Unfortunately, healthcare workers' compliance to HH recommendations are generally low. [3, 6-11] Strategies to improve adherence to practice guidelines have been successful in producing immediate changes in compliance, but long-term behaviour changes are typically not maintained. [4, 8, 12-16]

Theoretical Underpinnings: The intervention was developed using in the Behaviour Centred Design approach.[17] The *Mainspring* study centred on the use of threat to professional identity to prompt change. The health message, which explained that nurses were less likely to perform HH at room entry than at room exit, drew attention to the incongruity between the nurses' current HH practice and their required practice. This message was intended to surprise the nurses. To decrease defensiveness and, in turn, increase openness to the message, a values affirmation exercise was included as the first part of the intervention. This made it an example of a 'wise' intervention, a brief intervention that seeks to disrupt a recursive process, and thus facilitate a positive experience that leads to later positive outcomes.[18]

Goal: To increase the HHC rates of nurses in each of the hospital units by 50% over the units' respective baseline HHC rate for a 3-month period.

WHERE AND HOW

Where: The intervention is intended to be delivered to nurses in acute care hospital units. Necessary infrastructure must include a way to observe and monitor HHC rates, specifically HH opportunities upon entering and exiting a patient's room.

Recruitment: The hospital administration and each of the unit's nurse managers oversee recruitment efforts. The hospital and managers are encouraged to email nurses regarding participation and to discuss the study at staff meetings.

Materials and Timing: The intervention is to be presented to participants in two separate parts in one day. The intervention is a self-guided activity and takes less than thirty minutes to complete. It is divided into two sections: the first part is the values affirmation activity and the second is the HH messaging with the implementation cue activity. Participants must complete the affirmation activity before being presented with the HH messaging. Participants are given a brief survey six-weeks later—as part of the process evaluation— testing their recall of the HH message, their use of the intention-cue association, and their feelings regarding the intervention.

Modes of Delivery: Given the constraints of "taking nurses off the floor" to participate, the intervention could be administered either in-person in the hospital unit or online. How the intervention is administered is at the hospital administration's discretion. For the in-person delivery, the two parts of the survey are presented on separate sheets of paper. Respondents only receive the second page from the facilitator dependent on the completion of the values affirmation on the first page. When administered online, respondents complete the first exercise before being allowed to continue to the following activity. Intervention materials provided upon request.

Facilitator: The facilitator oversees the delivery of the intervention in-person and ensures that the procedures are adhered to. No formal training is required for the facilitator and there are prompts and written directions for the facilitator to follow (provided upon request). The facilitator does not need expertise or background in the topic of HH, and minimal training is required for the delivery of the intervention.

IN PRACTICE

Where: Hospitals were selected by GOJO based on specific inclusion criteria: the hospitals needed to have a specific electronic compliance monitoring (ECM) system and could not have participated in a hand hygiene intervention program within the last six months. The intervention was staged in two university research hospitals situated in the Midwestern United States.

Mode of Delivery: The mode of delivery in Hospital A was to directly hand questionnaires and forms to nursing staff during shift changeovers or staff meetings. In Hospital B, nurses were alerted to the questionnaire task via an email from the facilitator—with follow-up emails from the units' nurse managers— which presented them with a link to the questionnaire itself, hosted on a website.

Facilitator: When the intervention was delivered in this study, the facilitator was a research psychologist employed by the company funding the project with experience conducting research in healthcare. The facilitator delivered the intervention in each unit of Hospital A and notified nurses of the intervention in Hospital B Unit 1.

APPENDIX 6-1 REFERENCES

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APPENDIX 7-1: PROCESS EVALUATION CODES

Table A7- 1: Definition of codes used in process evaluation analysis

Codes	Definitions
feasibility of delivery	facilitators and barriers
recruitment	how nurses were asked to participate
participant engagement	acceptability as well as the positive and negative impacts
reach	headcount of participants
context	factors in the intervention setting that could have affected uptake

APPENDIX 7-2: ADDITIONAL FIGURES FOR PROCESS EVALUATION RESULTS

Additional figures for the Results sections of the process evaluation paper (Chapter 7).

Figure A7- 1: Percent of nurses reached

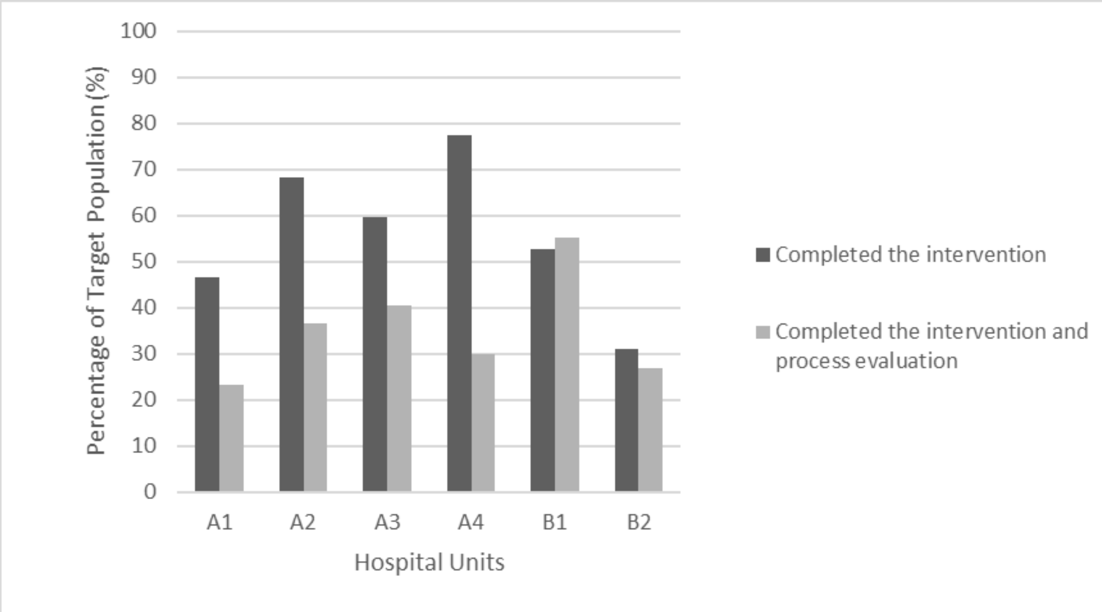


Figure A7- 2: Participant's recall of HH message and object

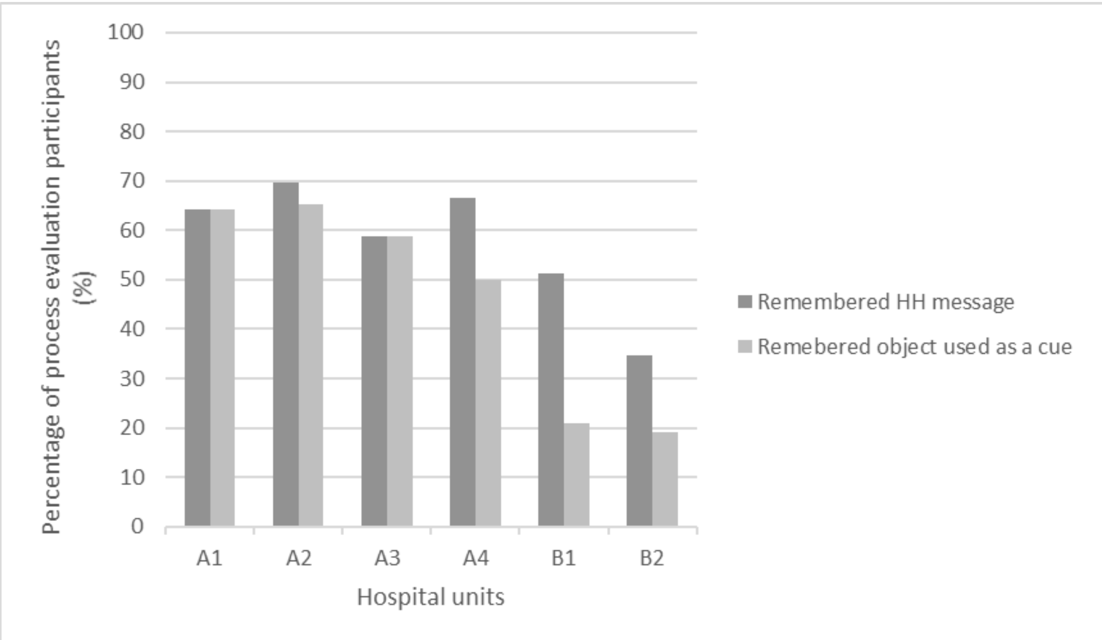


Figure A7- 3: Reactions to key HH message

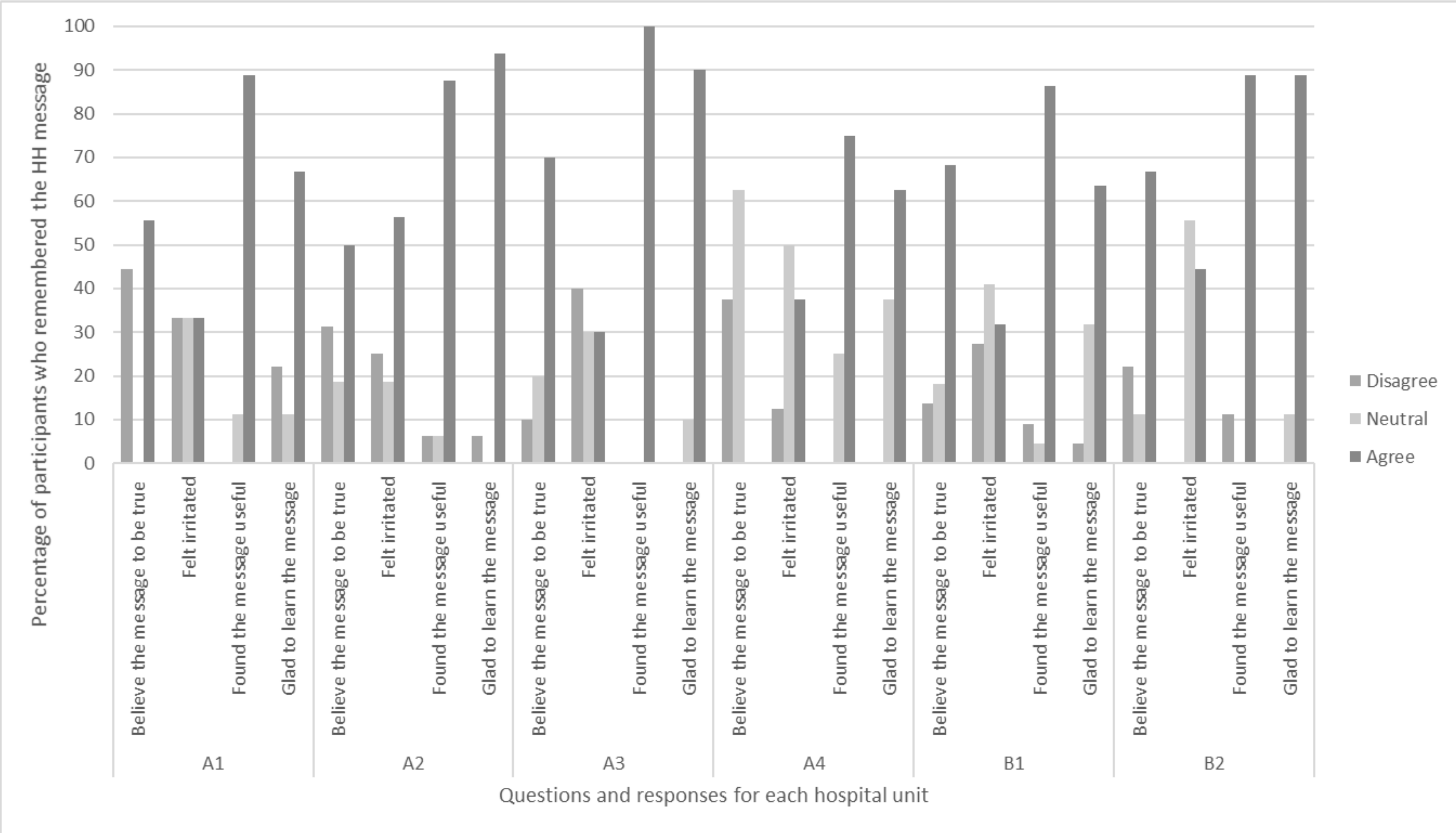
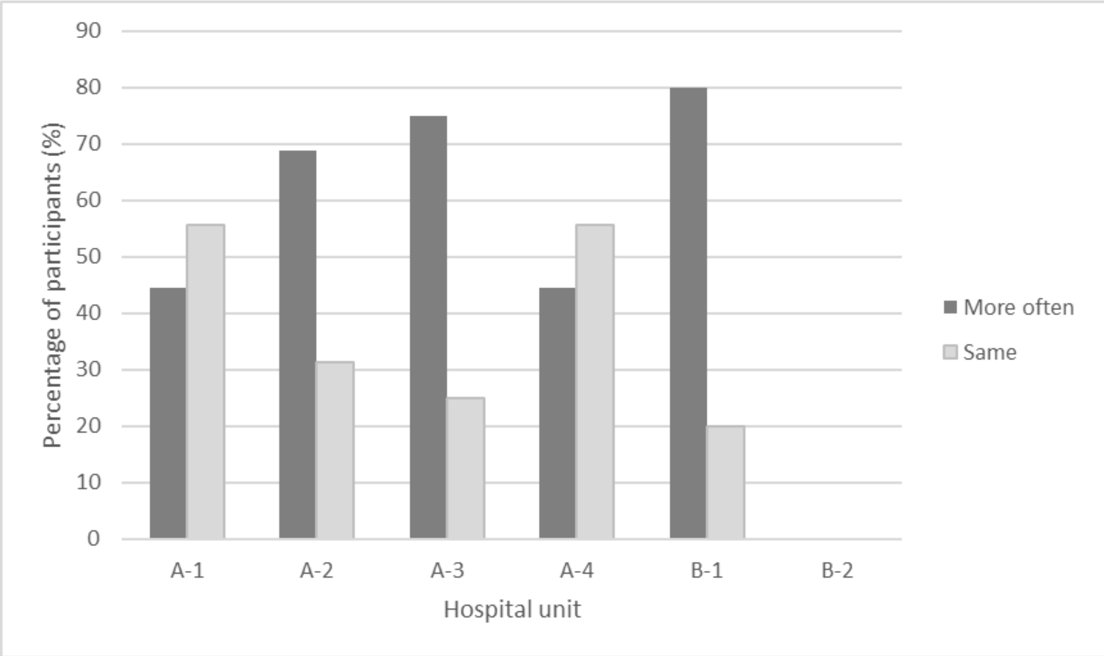


Figure A7- 4: Self-reported frequency of HH behaviour pre- and post-intervention



Only participants who remembered the HH message were considered.

Figure A7- 5: Participants who had not heard the message before

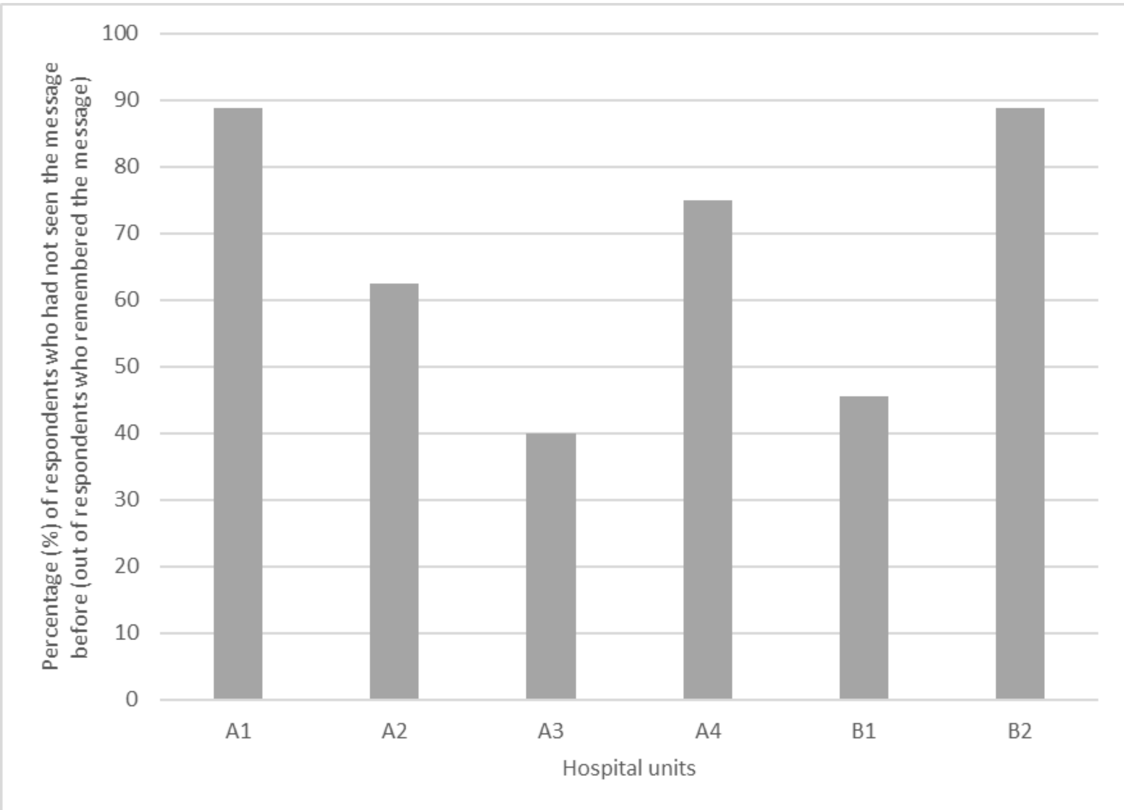
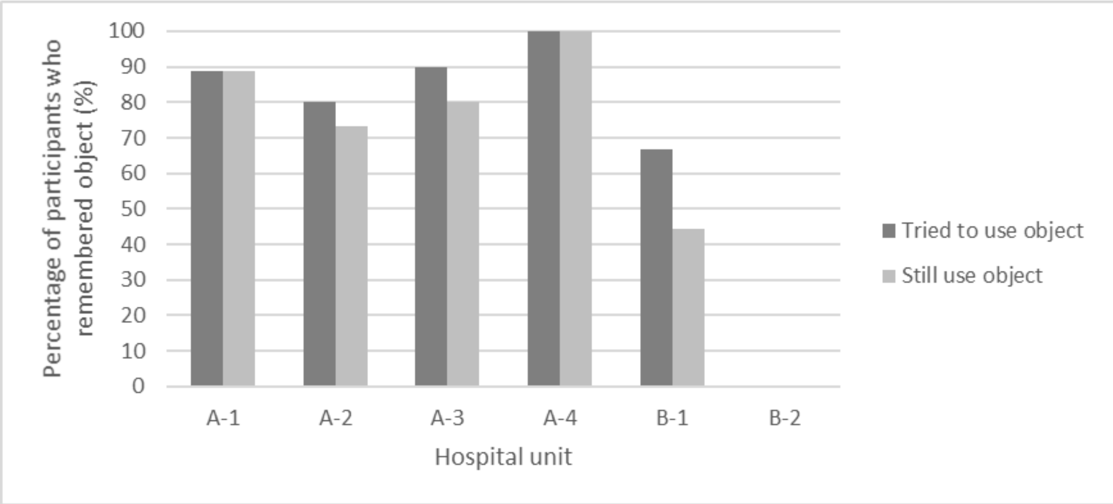


Figure A7- 6: Use of cue-association object



Only participants who recalled the object were considered.