The Hawthorne Effect in Hand Hygiene Compliance Monitoring

by

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A thesis submitted in conformity with the requirements for the degree of Master of Science (Health Services Research) Institute of Health Policy, Management and Evaluation University of Toronto

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Abstract

Introduction: The Hawthorne effect, or behaviour change due to awareness of being observed, is believed to inflate directly observed hand hygiene compliance rates, but evidence is limited.

Methods: A real-time location system tracked hospital hand hygiene auditors and recorded alcohol-based hand rub and soap dispenses. Rates of hand hygiene events per dispenser per hour within sight of auditors were compared to dispensers not exposed to auditors.

Results: The event rate in dispensers visible to auditors (3.75/dispenser/hour) was significantly higher than unexposed dispensers at the same time (1.48) and in prior weeks (1.07). The rate increased significantly when auditors were present compared to five minutes prior to arrival. There were no significant changes inside patient rooms.

Conclusions: Hand hygiene event rates increase in hallways when auditors are visible and the increase occurs after the auditors’ arrival, consistent with the existence of a Hawthorne effect localized to areas where auditors are visible.
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Chapter 1

Introduction

1.1 Healthcare-associated Infections

Healthcare-associated infections (HAIs) are the most frequent adverse event experienced by patients during medical care. The most common HAIs include urinary tract infections (UTIs), surgical site infections (SSIs), bloodstream infections (BSIs), pneumonia, and *Clostridium difficile* infection (CDI). HAIs may be caused either by patients’ endogenous bacteria or by pathogens acquired in hospitals, including antibiotic-resistant organisms (AROs) such as methicillin-resistant *Staphylococcus aureus* (MRSA), vancomycin-resistant enterococci (VRE), and multi-drug resistant Gram negative bacteria (MDRGN). Patients may also acquire AROs in hospital and remain asymptotically colonized rather than developing an infection.

HAIs cause significant morbidity and mortality, affecting 10.5% of hospitalized patients and resulting in an estimated 8,000 deaths per year in Canada. HAIs also add a substantial burden to the health care budget, although Canadian economic data are limited. MRSA alone was estimated to account for $42 to $59 million in direct costs per year in Canada over a decade ago, and rates of MRSA have increased since then. In the United States, the direct cost of treating all HAIs is estimated to be between 28.4 and 45 billion dollars per year.
morbidity, mortality and costs associated with HAIs are further increased when they are caused by AROs.  

1.2 Importance of Hand Hygiene

AROs, *C. difficile*, and other pathogens can be transmitted on the hands of health care workers (HCWs), either directly from patient to patient or via an intermediate stage of environmental contamination. Multiple studies have demonstrated that HCWs can transmit organisms between patients on unclean hands due to transient colonization. HCW hand hygiene at appropriate times during patient care, including before and after contact with patients or their environment, before aseptic procedures, and after potential exposures to body fluids, can interrupt this chain of transmission and potentially reduce HAI risk.

Many years of research and experience have established HCW hand hygiene at appropriate times during patient care as one effective strategy to reduce HAIs. One of the earliest and most elegant studies of hand hygiene was conducted by Ignaz Semmelweis in 1847 on two maternity wards in Vienna. The mortality rate from postpartum infections was much higher on the ward attended by doctors, who frequently went directly from the autopsy suite to deliver babies, than on the ward attended by midwives. Semmelweis conducted an experiment in which all the doctors washed their hands prior to delivering babies and the mortality rate on their ward dropped from 15% to 1%, comparable to the midwifery ward.
Health care has become enormously complex since the 1800s, and it is difficult to demonstrate such a direct link between hand hygiene and HAIs in modern studies. Although hand hygiene is frequently advocated as the most important way to prevent HAIs, it is not a panacea since HAIs are multifactorial in etiology and the transmission of organisms on HCW hands is only one contributing cause. There are many other factors that increase HAI risk, such as invasive devices, portable medical equipment, and immunosuppressant drugs.\(^1\) Regardless, many studies have demonstrated that improving hand hygiene reduces HAI rates.\(^8\) For example, in a landmark before and after study, implementation of a hospital-wide multimodal hand hygiene program led to a statistically significant decrease in overall HAI rate from 16.9\% to 9.9\%.\(^11\) In one of the few randomized studies, strict hand washing reduced HAI rates in pediatric solid organ transplant recipients from the pre-intervention baseline of 4.9 per 100 patient days to 3.0 per 100 patient days.\(^12\) One systematic review attempted to determine whether hand hygiene interventions led to a reduction in HAI rates and found limited evidence, but the authors note this finding might be attributable to methodological limitations of the primary studies.\(^13\) A Cochrane review to assess whether hand hygiene interventions improve compliance found only four studies that met methodological criteria for inclusion, and three did not assess HAI rates as an outcome.\(^14\) The one study that did report HAI rates was an interrupted time series analysis that found a correlation between alcohol-based hand rub (ABHR) consumption and MRSA incidence but not CDI.\(^15\)

Despite concerns about evidence quality, there is a strong theoretical basis for hand hygiene as an important factor in preventing HAIs and it is widely accepted by infection control
professionals and major health care organizations that hospitals should have hand hygiene programs in place to promote compliance.\textsuperscript{8,9} Although there are strong recommendations from numerous guidelines and mounting pressure from regulatory bodies, HCW hand hygiene compliance rates remain suboptimal. A systematic review of hand hygiene studies found that the median compliance was 40%, which may in fact be an overestimate of true compliance since the included studies were subject to numerous biases.\textsuperscript{16} More recent studies that use novel hand hygiene monitoring technology, such as electronic and video systems, have reported much lower rates of compliance. For example, a video camera-based hand hygiene auditing system was able to observe 60,542 hand hygiene events in a 16-week pre-intervention period, during which time the compliance rate was 6.5%.\textsuperscript{17}

Poor HCW compliance with hand hygiene is likely contributing to the fact that HAI and ARO rates continue to increase or, at best, stabilize.\textsuperscript{5,18} As a result, improving HCW hand hygiene is a major patient safety goal worldwide. A multifaceted approach is recommended to attain this goal, with the components of hand hygiene programs typically including provision of soap and ABHR at point of care, training and education, reminders, administrative support, and measurement of compliance rates.\textsuperscript{8,9} Measurement is necessary in order to assess changes over time, and feedback of compliance rates to HCWs can be an effective strategy to increase hand hygiene.\textsuperscript{19}
1.3 Measuring Hand Hygiene Compliance

Hand hygiene can be monitored using self-report, direct observation, measurement of soap and ABHR consumption, and video or electronic monitoring systems. The most commonly used method to measure compliance is direct observation, which typically involves an auditor observing HCWs during the provision of patient care and recording their compliance using a standardized paper or computer tool. Direct observation is currently considered to be the “gold standard” for hand hygiene compliance measurement, and it does have some advantages that include the ability to assess technique and provide immediate feedback to HCWs. However direct observation has significant limitations: it is labour intensive, can only assess small samples of hand hygiene opportunities, has questionable inter-rater reliability, and is potentially subject to biases. If the resulting data are publicly reported, as is the case in Ontario, the potential for bias may be even greater. For example, the currently reported average compliance rate in Ontario is 85.6% before patient contact and 91.2% after patient contact, which is significantly higher than the median rate of 40% reported in the literature. Moreover, despite the apparently high compliance rates in Ontario, which represent a significant and sustained increase since public reporting began in 2009, there has been no corresponding reduction in HAI incidence.

Sources of bias in direct observation include observer bias, selection bias, and the Hawthorne effect. Observer bias occurs because there is subjectivity in interpreting hand hygiene opportunities and HCW actions that may systematically differ across auditors. Selection bias refers to non-random sampling of situations and HCWs, since auditors can choose who to
observe and record. The existence of these biases is supported by the observation that unit-based observers, who presumably have an allegiance to the unit being audited, consistently report higher hand hygiene compliance rates than outside observers.\textsuperscript{23}

The Hawthorne effect, also called observation bias, refers to the tendency of people to change their behaviour when they are aware of an observer, which would lead to increased hand hygiene compliance rates compared to the baseline when there is no auditor present.\textsuperscript{8,20} It is widely assumed that the Hawthorne effect transiently increases HCW hand hygiene compliance rates, but the evidence is not conclusive. The existence of the Hawthorne effect in general has been extensively debated, and the studies that examine the Hawthorne effective specifically in hand hygiene behaviour have significant methodological limitations. Furthermore, there is little known about the temporal and spatial boundaries or additional factors that may affect the magnitude of the Hawthorne effect if it does exist.

The recent development of electronic systems for hand hygiene monitoring, including video monitoring and real time locating systems (RTLS), offers an alternative approach to direct observation.\textsuperscript{24} These systems use a variety of technologies to monitor HCW hand hygiene on a constant, real-time basis, making them a promising tool for determining whether the Hawthorne effect exists and characterizing the nature of the effect. Since HCWs are under constant surveillance by these systems, it is hypothesized that they will not have the same awareness of being observed as if there was a person watching them. Furthermore, the systems apply consistent algorithms to measure hand hygiene events and compliance rates, eliminating many of the biases inherent to direct observation.
1.4 Study Question and Hypothesis

Given that the existing evidence for the impact of observation on compliance is inconclusive, this study will use a RTLS to determine whether there is a Hawthorne effect in hand hygiene compliance monitoring by direct observation, as well as the magnitude of the effect if it exists. The primary research question is: does the presence of an auditor significantly increase the hand hygiene event rate compared to when there is no auditor present?

The null hypothesis is that there will be no significant change in HCW hand hygiene compliance in the presence of an auditor. However there is some suggestion from the hand hygiene literature that a Hawthorne effect does exist, and thus the alternate hypothesis is that HCW hand hygiene will increase in the presence of an auditor.

Understanding the nature of the Hawthorne effect in hand hygiene compliance monitoring is necessary in order to more accurately assess data quality, particularly when it is publicly reported. For example, the existence of the Hawthorne effect could provide a plausible explanation as to why HAI rates have not decreased in Ontario despite significant increases in reported hand hygiene compliance. Furthermore, if the magnitude and moderating factors are elucidated, it may be possible to use the Hawthorne effect as a tool to increase compliance by enhancing surveillance in hospitals.25
Chapter 2

The Hawthorne Effect

2.1 Definition and Related Constructs

Although it is widely accepted that the Hawthorne effect plays a role in hand hygiene compliance monitoring, the evidence is not conclusive. In fact, there is much debate over whether the Hawthorne effect exists at all, exacerbated by confusion in the literature around the construct and lack of consensus on a definition. For the purposes of this study, the Hawthorne effect refers to a change in behaviour related to awareness of an observer.26 However, a review of 21 industrial-organizational psychology and organizational behaviour textbooks found 13 unique definitions of the Hawthorne effect.27 All definitions included behaviour change as a key component but attributed the effect to a variety of factors, including awareness of being observed, awareness of being in a research experiment, the attention provided by research personnel, or a nonspecific positive response to a novel stimulus. This inconsistent operationalization of the construct presents challenges to finding and interpreting studies that purportedly assess the Hawthorne effect.

The situation is further complicated by similar constructs that are used interchangeably in the literature. Research participation effects or experiment effects are broader terms that encompass the Hawthorne effect as well as other types of behaviour changes that may be
seen in research subjects.\textsuperscript{28} One of the most frequently studied research participation effects is known as demand characteristics, which refers to changes in the behaviour of research subjects due to their awareness of the study hypothesis.\textsuperscript{29} Demand characteristics and the Hawthorne effect are often used synonymously by researchers, even though they refer to different underlying causes of research participant behaviour change.\textsuperscript{28} The Hawthorne effect has also been equated to the placebo effect in some textbooks and research studies, which is not an accurate description since the placebo effect implies that the participant receives an intervention whereas the Hawthorne effect occurs only because of observation.\textsuperscript{30} Because of this confusion over what it means and how it differs from other similar constructs, some have proposed that the use of the term “Hawthorne effect” be avoided altogether.\textsuperscript{30}

### 2.2 Original Hawthorne Studies

The Hawthorne effect got its name based on studies that were conducted between 1924 and 1932 at the “Hawthorne works” plant of the Western Electric Factory in Illinois, a supplier of telephone equipment. Six experiments were conducted to determine how changes in working conditions affected productivity, which was landmark research that established industrial psychology as an area of study.\textsuperscript{31} Although the term “Hawthorne effect” was never used by the original researchers, the idea arose from the results of the first two Hawthorne experiments, the illumination studies and the relay assembly test room study.\textsuperscript{32}
The illumination studies attempted to define how changes in lighting affected productivity. A control group worked in a room lit by candles that were ten feet high, while the candles in an experimental room were successively decreased in one-foot increments. The researchers noted that both groups steadily increased their performance during the study, until the experimental group candles were three feet high and the workers had difficulty seeing what they were doing.\(^{33}\)

The relay assembly test room study took place from 1927 to 1929 and was designed to test the effects of multiple variables on employees assembling telephone equipment. Five female employees were moved from the main area of the plant to a separate room, where the researchers sequentially changed their working conditions and monitored their output. The manipulated variables included the method of determining wages, length and timing of breaks, length of the work day and week, and provision of food and/or beverages. The productivity of the workers seemed to increase consistently throughout this period regardless of how the variables were manipulated.\(^{34}\)

The original Hawthorne researchers, while noting the increased productivity throughout their experiments, did not draw any conclusions about this observation.\(^{33,34}\) The term “Hawthorne effect” was first proposed in 1950 and was widely accepted after its inclusion in a textbook on research methodology in 1953.\(^{32}\) The effect was originally described as the influence of the experiment itself on the measured results, but it was never specified how the Hawthorne studies supported this assumption. Although the Hawthorne effect continues to be widely
accepted as fact, the construct has come into question many times and it is not clear that the original Hawthorne studies actually demonstrated a Hawthorne effect.\textsuperscript{31,32}

Many authors have detailed the methodological weaknesses of the Hawthorne studies and the inaccuracies that have been perpetuated in the literature. For example, the relay assembly test room experiment did not include a control group and there were numerous uncontrolled variables that could have contributed to the increase in productivity, including the novel physical environment into which the employees were placed, freedom from their strict supervisor, new ways of interacting with their colleagues, or increased control over work procedures. It cannot necessarily be assumed that participation in the experiment or the presence of an observer was the cause.\textsuperscript{30,32} Furthermore, there was limited statistical analysis of the relay assembly test room study data by the original researchers, and subsequent analyses have not supported the existence of a Hawthorne effect.\textsuperscript{35,36} As for the illumination studies, the data were never fully reported.\textsuperscript{32} Despite the lack of empirical support from the original Hawthorne studies, the idea of the Hawthorne effect has intuitive appeal and the question of whether it exists has been extensively investigated in several fields, including psychology, education, and medicine.

2.3 Evidence for the Hawthorne Effect

A review was conducted in 1984 to identify studies that attempted to control for Hawthorne effects as well as those designed to produce Hawthorne effects.\textsuperscript{32} After a challenging literature search, 40 studies were identified in which the experiment included a control group
for the Hawthorne effect, mainly from the education research literature. The specific variables which were controlled fell into the categories of attention being paid to the subjects, awareness of being in an experiment, and novelty, highlighting the fact that the cause of the Hawthorne effect is still not clear. Although seven of the studies claimed to demonstrate Hawthorne effects, the evidence to support those claims was weak. An additional 13 studies were identified that attempted to produce Hawthorne effects in research subjects, of which four showed a Hawthorne effect and nine did not. The author of the review pointed out two main differences between the positive and negative studies. First, those that demonstrated a Hawthorne effect were conducted in adults, whereas seven of the nine negative studies involved children. Although the explanation for this is not clear from the research, one hypothesis is that the Hawthorne effect is caused by a desire to conform to social norms, of which children are less aware. Second, the positive studies measured novel skills or knowledge as the dependent variable while all of the negative ones measured well-practiced skills, suggesting that there may be a ceiling effect in performing routine tasks that prevents the occurrence of a Hawthorne effect.\textsuperscript{32}

A more recent study was conducted to attempt to demonstrate the Hawthorne effect using the rigorous methodology of a randomized controlled trial.\textsuperscript{37} The researchers randomized dementia patients to receive either intensive follow-up, with comprehensive assessments at baseline and every two months, or minimal follow-up consisting of an abbreviated assessment at baseline and a full assessment at the end of the study. The group receiving intensive follow-up had significantly higher cognitive function scores than the minimal follow-up group, which the authors suggest is proof of a Hawthorne effect. However they
noted that there are other possible explanations for this finding, such as learning effects from more frequent exposure to the cognitive test in the intensive follow-up group or the lack of blinding causing a “nocebo effect” in the minimal follow-up group who may have felt they received suboptimal care.\textsuperscript{37} Similar to the earlier research, this study again highlights the uncertainty around the construct itself and its etiology.

A systematic review was published recently that evaluated the effect of demand characteristics on participants in non-laboratory experiments.\textsuperscript{28} Although the construct of demand characteristics is not exactly the same as the Hawthorne effect, many of the included studies made reference to the Hawthorne effect and equated the two terms. The authors of the review found only seven studies that provided some evidence to suggest that awareness of the study hypothesis had an effect on the behaviour of research participants, but the included studies were limited by weak study designs, small sample sizes, and heterogeneous definitions of the construct. The authors aptly summarize the literature on the Hawthorne effect when they state, “It is almost as if the construct has been accepted without being thoroughly interrogated in empirical investigations” (p. 5).\textsuperscript{28}

Given the lack of evidence in many fields of research, the question of whether the Hawthorne effect exists in hand hygiene compliance monitoring warrants further investigation, particularly since hand hygiene differs from the behaviours described in the original Hawthorne studies and subsequent investigations. The Hawthorne studies involved the effect of observation on workers who were in situations where improvements in skill performance and productivity were possible. Many of the later studies on the Hawthorne effect used tests
of math or language skills as the outcome,\textsuperscript{32} which could also improve with repeated practice. Hand hygiene, in contrast, may be a more complex and heterogeneous behaviour. There are at least two types of hand hygiene behaviour: inherent, which is an instinctive desire to wash hands when they are noticeably dirty, and elective, encompassing hand hygiene opportunities in which hands do not appear dirty.\textsuperscript{38} Most hand hygiene in health care falls into the elective category, such as washing hands before taking a patient’s pulse or after touching a patient’s bed to adjust the blankets. Elective hand hygiene behaviour has many determinants, including knowledge, attitudes, perceived threat to self, ability to carry out the behaviour, cues or reminders, and social norms.\textsuperscript{38,39} In light of this complexity, the magnitude and determinants of the Hawthorne effect in other settings may not apply to hand hygiene. Furthermore, although the Hawthorne effect is assumed to affect hand hygiene behaviour, the evidence supporting this assumption does not appear to have been reviewed in any detail to date.
Chapter 3

Literature Review

3.1 Search Strategy and Results

A literature review was conducted to identify studies assessing whether the Hawthorne effect exists in hand hygiene behaviour. Database searches were performed in Medline (1946 – May 2013 Week 1; In-Process & Other Non-Indexed Citations), EMBASE (1947 – 2013 Week 18), and PsycINFO (1806 – April Week 5 2013). The search strategy was developed using medical subject headings (MeSH) and text words related to hand hygiene and the Hawthorne effect. The detailed search strategy can be found in Appendix A. The reference lists of relevant studies were also searched.

The search identified 3,850 citations. Based on title and abstract review, 16 studies of the Hawthorne effect in hand hygiene were identified. No additional studies were identified by reviewing reference lists of the relevant studies. Eight studies were conducted in non-health care settings, including 6 in public washrooms, one in petting zoos, and one in homes. An additional 8 studies focused on the Hawthorne effect in hospital hand hygiene compliance monitoring.
3.2 Non-Health Care Settings

The psychology literature contained 6 studies that assessed hand hygiene behaviour in public washrooms.\textsuperscript{40-45} Five of these 6 studies found that the presence of another person in the washroom increased hand hygiene compliance, although the term Hawthorne effect was rarely used to describe the results.

Three studies were conducted in women’s washrooms and all found that significantly more people washed their hands when an observer was visible, but the magnitude of the increase was variable. Two of these studies used similar methodologies, in which a research associate was either visible near the sinks in a public washroom or was hidden in a stall with their legs not visible and then determined whether people who used the toilets washed their hands afterwards. Hand hygiene compliance increased from 16\% in the unobserved group to 90\% in the observed group in one study, and from 39\% to 77\% in the other.\textsuperscript{1,2} The third study used a slightly different methodology, in which the researcher stayed in a stall and recorded whether or not another person was near the sinks after the subject used the toilet.\textsuperscript{43} This study found that 55\% of subjects washed their hands when they thought they were alone, compared to 91\% when another person was standing at the sinks.

A study conducted in a men’s washroom reported similar findings. The researcher observed from inside a stall, which had an “out of order” sign on it in the control condition to hide the fact that someone else was present in the washroom. Subjects who thought they were alone,
washed their hands 44% of the time, as opposed to 90% when it was apparent that one of the stalls was occupied, even though that person was not visible.\textsuperscript{44}

Another study took place in both men’s and women’s washrooms and found an increase in hand hygiene compliance from 70% to 90% when a researcher was visibly present rather than inside a stall.\textsuperscript{42} Logistic regression was conducted to determine factors associated with hand hygiene. Race and time of day were not significant predictors, but female gender and presence of an observer both increased the likelihood of hand hygiene being performed.

Many of these studies suggest that hand washing is a social norm, and that conformity to social norms is increased in the presence of another person.\textsuperscript{40,41} The reason for this is not definitively known and may relate to a desire to be perceived as more attractive, to enhance feelings of self-worth by engaging in behaviour deemed to be positive by others, or to display behaviour consistent with higher social status.\textsuperscript{46}

The final study in public washrooms differed from the others in that no statistically significant difference was found between the groups, with 79% of observed subjects and 73% of apparently unobserved people washing their hands.\textsuperscript{45} It is not clear why the results of this study differed from the others since the methodology appeared to be the same and it was conducted by the same group of researchers that had previously found a significant increase in compliance among observed subjects.\textsuperscript{42} The authors imply that the study took place around the time that severe acute respiratory syndrome (SARS) emerged and thus there may have been more awareness of the importance of hand hygiene among all subjects. Other
Authors have hypothesized that if hand washing is believed to be important on a personal level, compliance with the norm would occur regardless of whether others were present,\(^{40}\) which could explain why the observer had no effect during the SARS outbreak.

Further evidence for the existence of the Hawthorne effect was reported in a study of hand hygiene in petting zoos.\(^{47}\) Researchers paid unannounced visits to 13 petting zoos with hand hygiene stations and observed whether visitors washed their hands after exiting the animal contact areas. Overall, 37\% of subjects performed hand hygiene, and the compliance rate was significantly higher when a staff member was present at the exit (59\%) compared to when no staff was present (23\%). Although the term Hawthorne effect was not used, the authors note that the presence of an authority figure was associated with an increase in hand hygiene compliance. The study did not assess whether the presence of other visitors at the hand hygiene station had an effect, which would have helped to clarify whether the status of the observer affects the magnitude of the Hawthorne effect.

Although the aforementioned studies support the hypothesis that the presence of an observer increases hand hygiene, they are all subject to similar limitations. Direct observation was used to assess compliance in all studies, a method that is subject to selection and observer bias. Some studies imply that all people entering washrooms were counted for the purposes of the study, but most do not describe how the subjects were chosen. Furthermore, in many cases the researchers were the observers and were therefore not blinded to the study hypothesis, which could increase the potential for bias.
The final study from a non-health care setting overcomes some of these methodological limitations. The study was conducted in rural Bangladesh, where childhood mortality is high and hand hygiene may reduce the risk of gastrointestinal and respiratory illnesses. The goal was to determine whether observation was a valid measurement technique to assess the outcome of hand hygiene interventions, and specifically whether the presence of an observer in households altered behaviour. To accomplish this, the researchers embedded acceleration sensors in bars of soap, which quantified soap movement. The soap was distributed to 50 households that had at least one child under the age of 2, and, after several days of soap use, researchers returned to conduct 5 hours of structured observation in those same households.

The results showed that the median number of soap movements during the observation period was 5.0 (range 0-18.0), compared to 3.7 (range 0.3-10.6) during the same time period on pre-observation days. This represented a statistically significant 35% increase in soap movements. The researchers noted that 62% of households demonstrated increases of at least 20% in soap movement during observation periods and 22% increased by 100% or more, so they went on to compare households in the highest quartile of increased soap movement (termed “reactors”) to the lowest 3 quartiles (“non-reactors”). Bivariate analysis showed that reactor households were more likely to own mobile phones and watches, were more likely have defecation places not shared with other households, and the primary caregivers had significantly more years of education than non-reactors. This suggests that people at higher socioeconomic levels may be more likely to be aware of hand washing as a social norm and thus conform more frequently in the presence of other people.
This study provides supporting evidence for the Hawthorne effect based on a measurement technique other than direct observation, although it has other limitations. The sensor was not able to determine whether the soap was used for hand hygiene or who was using it, and the study cannot assess whether reactivity was only due to observation or whether it was a combination of the special soap and observation. Participants knew that the soap had a sensor in it for detecting movement and that may have motivated them to use the soap more during the observation periods than if they had a regular bar of soap. The study also elucidates some of the factors that may affect the magnitude of the Hawthorne effect and it supports the hypothesis that conformity to social norms may be an underlying motivator for the change in behaviour; however, the extent to which these findings are generalizable to health care settings is unknown.

3.3 Hospitals

Eight studies have reported evidence for the Hawthorne effect in hand hygiene compliance monitoring in hospitals using various methodologies.¹⁸⁻⁵⁵ One group of researchers analyzed over 100,000 hand hygiene observations collected as part of an auditing program in a university hospital.⁴⁹ Observations were grouped based on the order in which they occurred during audit session, and compliance rates were compared. Compliance was found to increase as the audit sessions progressed, with rates of 86% for the first five observations compared to 95% for the thirty-fifth to forty-third observations. The authors attribute this finding to the Hawthorne effect, suggesting that more HCWs become aware of the observer’s presence as the audit progresses and thus compliance rates increase. However the study was
not designed to assess the reason for the increase in compliance so the Hawthorne effect is at best a hypothesis, and furthermore there is no mention of whether the increase in compliance rates was statistically significant.

Three studies have compared hand hygiene audits that were announced to units in advanced to unannounced audits. All studies reported increased compliance in the announced audits compared to unannounced. The first study found compliance rates of 12.4% before patient contact and 10.6% after patient contact among medical residents in an intensive care unit (ICU) during a baseline period of unannounced audits, which increased to 32.7% and 33.3% following an announcement to all medical staff that audits would be taking place. Two other studies of all HCWs in ICUs reported increases in compliance rates from 29% and 47.1% when audits were unannounced to 45% and 55.2%, respectively, after announcements.

Similarly, two studies compared audits conducted by observers who were known to HCWs to audits by covert auditors. The first of those studies reported significant increases in compliance from 79% to 98% and 56% to 71% on two out of three units when the auditors were known, but the third unit showed no significant change. The unit that did not exhibit a Hawthorne effect was noted to have lower baseline compliance rates than the other units, so the authors hypothesized that HCWs on higher performing units take more pride in what they do and are more motivated to demonstrate their behaviour to observers. An alternative explanation is that the Hawthorne effect was the reason for higher baseline compliance on certain units to begin with and the effect was magnified when auditors were known to the
HCWs, although the reason for the different magnitudes of the Hawthorne effect cannot be determined from this study. The other study using this methodology trained medical students on clinical rotations to be covert hand hygiene auditors.$^{55}$ The compliance rate measured by the medical students (44.1%) was significantly lower than those measured by infection control nurses (74.4%) and unit HH ambassadors (94.1%), both of whom were known to the units as auditors.

Although these five studies support the existence of a Hawthorne effect, both of the study designs, whether comparing announced to unannounced audits or known to covert auditors, are limited by the biases inherent to direct observation. In particular, none of the studies specified whether the auditors were blinded to the study hypothesis. Given the subjective nature of hand hygiene auditing, awareness of the hypothesis could enhance the potential for bias on the part of the auditor in choosing which HCWs to observe and in assessing their hand hygiene practices.

Another study consisted of direct observation of 163 physicians, but it avoided some of these limitations by administering a follow-up survey to assess awareness of being observed.$^{48}$ Hand hygiene compliance was higher when physicians reported having been aware of an observer (61%) than when they had not been aware of being observed (44%), with an odds ratio (OR) of 2.24 (95% confidence interval [CI], 1.35 to 3.74). Awareness of being observed remained a significant predictor of compliance in multivariate analysis (OR 3.55, 95% CI 2.00-6.28). This study is limited by the potential for inaccuracies and bias in self-reported data, but it eliminates the possibility of observer bias related to awareness of the hypothesis.
An alternative approach to measuring the Hawthorne effect by direct observation is to use an indirect method of hand hygiene compliance monitoring to reduce the potential for bias. One study monitored soap and paper towel consumption in two intensive care units (ICUs) as an estimate of HH events. The estimated hand hygiene event rates were established during a baseline period when there were auditors present on the units. This was followed by an intervention period in which the auditors no longer visited the ICUs and instead, the estimated hand hygiene events were displayed graphically as feedback to HCWs on the units. Overall, the event rates were found to drop significantly on both units after the observers left and then returned to baseline when observers came back. However, the results were not entirely consistent because the event rate in one of the ICUs initially dropped but then increased back to baseline in the middle third of the intervention period. Furthermore, because there was a feedback intervention in addition to the withdrawal of live auditors and there was no control group, it is impossible to know which component was responsible for the apparent drop in hand hygiene or if it was related to external factors. Finally, although this indirect measurement of HH is more objective than direct observation, the authors caution that the estimates of HH were imprecise. Soap and paper towels may have been used for reasons other than HH, and it is impossible to know whether HH was performed at the indicated times before and after patient care.

3.4 Summary of Evidence

In summary, there is evidence in the literature that awareness of being observed increases hand hygiene in non-health care settings as well as in hospitals, although most of
the published studies have significant methodological limitations. Five of the 6 studies conducted in public washrooms found that subjects who were aware of the presence of another person, whether visible or not, were significantly more likely to wash their hands than those who presumably thought they were alone. The study of petting zoos reported that visitors were more likely to wash their hands when a staff member was visible. These findings support the existence of the Hawthorne effect in hand hygiene behaviour, and it may be that the presence of another person increases conformity to social norms. In contrast, the one study in public washrooms that did not find a significant difference between the observed and unobserved groups suggests that if a social norm is intrinsically believed to be of personal value, such as for protection during an outbreak, compliance will not be dependent on the presence of others. These studies are limited by the biases inherent to direct observation, but the study conducted in households using soap with embedded acceleration sensors provides supporting evidence that hand hygiene occurs more frequently in the presence of an observer and that conformity to social norms may be the underlying reason.

In hospitals, much of the evidence for the Hawthorne effect comes from comparing announced to unannounced audits or known to covert observers. Five studies using this approach have shown that compliance rates are higher when audits are announced in advance or the auditors are known to the units. However, the potential for observer and selection bias is high, particularly since it is not known whether the observers were blinded to the study hypothesis. Supporting evidence comes from survey data showing that physicians who were aware of being observed were more likely to perform hand hygiene and from the study showing that soap and paper towel consumption decreased after auditors were removed from
ICUs, although these studies are limited by potential inaccuracies and inability to attribute causation.

Given the limitations in the existing evidence, particularly related to direct observation, using an alternative methodology to confirm the existence and magnitude of the Hawthorne effect in hospital hand hygiene compliance monitoring is warranted. The recent development of electronic hand hygiene monitoring systems provides a unique opportunity to do so, and it is an approach that does not yet appear to have been utilized based on this literature review.
Chapter 4

Methods

4.1 Setting

A real-time locating system (RTLS) was installed on two multi-organ transplant units, an intensive care unit, and a step-down unit at Toronto General Hospital. Data were collected by the RTLS between July 18, 2012, and March 11, 2013. The RTLS used small tags worn by HCWs and patients, each of which was identified by a unique number. The tags emitted ultrasound signals at regular intervals, which were picked up by a network of 618 wireless receivers situated in patient rooms, hallways, and above all 257 ABHR and 148 soap dispensers. Batteries in the tags were changed regularly by research personnel. Signals from the receivers were processed by a geographical information systems (GIS) engine, which computed movement, location, and proximity of tags to each other.

The RTLS measured hand hygiene events by counting all times that ABHR and soap dispensers were used. Tags installed on the dispensers transmitted a signal to a receiver mounted above the dispenser each time the lever was pushed and a hand hygiene event was counted. The events were time-stamped and recorded in a centralized database. An event could potentially be attributed to a participating HCW if there was an ultrasound tag detected in direct proximity to the receiver above the dispenser or in an adjacent receiver zone.
Attributable HCW hand hygiene events that occurred on entry to and exit from patient rooms could be used to calculate hand hygiene compliance rates by dividing by the total number of HCW room entries and exits, which is a proxy for hand hygiene opportunities before and after patient contact.

Participants were recruited through presentations on the participating units by study personnel to explain the RTLS technology, the study, and the consent process. Posters describing the RTLS and the study were also displayed on the units. After the presentations, HCWs who agreed to wear tags contacted the research assistant. HCWs provided written informed consent and patients provided verbal consent, as part of a larger research study of the RTLS. The participant consent form for HCWs can be found in Appendix B. Research ethics board (REB) approval was obtained from the University Health Network for the overall study, which included studying the Hawthorne effect. Administrative approval from the University of Toronto Office Of Research Ethics was also obtained specifically for this study.

There were 82 HCWs and 344 patients tagged during the time that the system was active. Due to resource limitations, tags were provided to approximately one-third of HCWs on the study units who were distributed across multiple shifts. HCWs had to voluntarily clip the tag to their uniform in order to be detected by the RTLS. In contrast, patient tags were attached to the hospital wrist bands by research personnel and typically tracked patients for the duration of their admission.
4.2 Study Design

The Hawthorne effect can be conceptualized as an exposure-outcome relationship, in which the exposure is the presence of a hand hygiene auditor and the outcome is hand hygiene events. The causal relationship between exposure and outcome can be depicted with a directed acyclic graph (DAG) as shown in Figure 1.

**Figure 1: The Hawthorne effect on hand hygiene**

Figure 1 illustrates the hypothesis that the presence of an auditor will increase the likelihood of HCWs performing hand hygiene. The null hypothesis is that there will be no significant change in the hand hygiene event rate when the auditor is visibly present. The “Unmeasured” box refers to numerous factors influencing the decision to perform hand hygiene that cannot be assessed in this study; for example, HCW profession, type of care activities being provided, and proximity to ABHR dispensers or sinks.⁸

This study used a retrospective cohort design. The cohort was defined as the ABHR and soap dispensers on the two multi-organ transplant units. The primary outcome was the hand
hygiene event rate, defined as the combined number of ABHR and soap dispenses per dispenser per hour. Separate event rates were calculated for dispensers in the hallways, which would be within eyesight of auditors, and dispensers inside patient rooms, which are typically not seen by auditors.

4.3 Exposed Group

In order to calculate the event rate in the exposed cohort, the four auditors who rotated through the two study units wore RTLS tags to track the exact time of auditing and their location. The auditors were blinded to the study hypothesis. They conducted audits as per usual practice in accordance with the Ontario Just Clean Your Hands program, once or twice monthly on each unit from November 29, 2012, to March 11, 2013. Audits typically occur once per unit per month, but auditors were asked to visit the study units twice per month on different days during the study period in order to increase the sample size. No more than two audits were conducted per unit per month, so as to prevent HCWs from noticing an increased frequency of auditing and changing their hand hygiene behaviour as a result.

Audits were conducted during the day, between 8:30 am and 1:00 pm. The usual practice of auditors is to remain on the unit until they observe 60 hand hygiene opportunities, so the duration of each audit is variable. Auditors are instructed to remain in the hallways in order to maintain patient privacy during health care interactions and thus they may not be able to evaluate all hand hygiene opportunities that happen inside patient rooms.
The auditor’s movement was tracked by sequentially locating on a map each of the receivers that detected the auditor tag during the time of the audit. When the tag was localized within a straight section of the hallway (i.e. where all dispensers would be within eyesight) for at least five minutes, the number of dispenses in that area were determined during that time period. The time period started when the auditor tag was first detected in that area, and ended when the auditor turned a corner or left the unit. The outer boundaries of the area were defined as the two receivers furthest from each other that had picked up a signal from the auditor’s tag in that time period and were within eyesight of each other. The number of dispenses were counted for all dispensers inside the patient rooms within those boundaries and in the hallways outside those rooms during the defined time period. The count was then converted into an event rate per dispenser per hour. This procedure was repeated for the duration of each audit, so that each audit was divided into a variable number of time periods in which the auditor was visible within a defined location. The dispensers within these time-location blocks made up the exposed group.

4.4 Unexposed Groups

Event rates in the exposed dispensers were compared to three separate unexposed groups. The first comparison group was another area of the unit that would not have been visible to the auditor at the same time period during the audit. The second was the same area where the auditor was located at the same time of day, but at 1, 2, and 3 weeks prior to the audit. The final comparison was the same area where the auditor was located from one to five minutes prior to auditor’s arrival on the day of the audit. The one minute immediately prior to the
The auditor's arrival was excluded because the auditor often would have been coming into view during that time and may have already been visible. For each exposed time-location block, hand hygiene event rates in all three of the corresponding unexposed comparison groups were determined.

4.5 Data Analysis

Hand hygiene event rates in the exposed group were compared to each of the other three groups using the Wilcoxon signed rank test, a non-parametric test that compares two related samples. The samples were assumed to be related since they were taken from a fixed group of dispensers on the two study units. Data were analyzed using SPSS Statistics, version 20 software (IBM Corp.). A 2-sided $p$ value of 0.05 was considered to be statistically significant.
Chapter 5

Results

5.1 Summary of Audits

There were twelve audits conducted between November 29, 2012, and March 11, 2013 by three auditors. Seven audits took place on one unit (designated "A") and five on the other ("B"). The audits were divided into 37 time periods when the auditor was in a fixed location for at least 5 minutes. The median duration of these time periods was 9 minutes, with a range from 5 to 39 minutes. The median duration of the time periods was 9 minutes on unit A and 12 minutes on unit B.

The median number of dispensers included in each location was 20 (range 8-34), with a median of 6 in hallways and 13 inside patient rooms. Table 1 shows the time periods in each audit and the number of dispensers included in each period.
<table>
<thead>
<tr>
<th>Unit</th>
<th>Date</th>
<th>Audit Time(s)</th>
<th>Time Period</th>
<th>Duration (minutes)</th>
<th>Hallway Dispensers (n)</th>
<th>Room Dispensers (n)</th>
<th>Total Dispensers (n)</th>
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</table>
5.2 Exposed Group

During the entire data collection period, a total of 562,304 ABHR dispenses and 218,473 soap dispenses were recorded. Of these, there were 230 hand hygiene events that occurred in the exposed group during audits, with 31 occurring inside patient rooms and 199 in hallways. Because there were few events inside patient rooms and more dispensers in rooms compared to hallways, the modal event rate in rooms was 0. The median event rates per dispenser per hour were 0 in patient rooms, 3.75 in halls, and 1.43 overall. Table 2 shows the median event rates in the exposed and unexposed groups, with the Wilcoxon signed rank test results where applicable.
Table 2: Event Rates in Exposed and Unexposed Groups

<table>
<thead>
<tr>
<th></th>
<th>Median Rate in Rooms (events/dispenser/hour)</th>
<th>IQR of Rooms (events/dispenser/hour)</th>
<th>Wilcoxon Signed Rank*</th>
<th>Median Rate in Halls (events/dispenser/hour)</th>
<th>IQR of Halls (events/dispenser/hour)</th>
<th>Wilcoxon Signed Rank*</th>
<th>Median Overall Rate (events/dispenser/hour)</th>
<th>IQR Overall (events/dispenser/hour)</th>
<th>Wilcoxon Signed Rank*</th>
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<tr>
<td>Exposed</td>
<td>0</td>
<td>0-0.48</td>
<td>-</td>
<td>3.75</td>
<td>2.23-5.45</td>
<td>Z=-3.39 (p=0.001)</td>
<td>1.43</td>
<td>0.79-2.41</td>
<td>Z=-2.65 (p=0.008)</td>
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<tr>
<td>Unexposed location</td>
<td>0</td>
<td>0-0.61</td>
<td>Z=-0.13 (p=0.90)</td>
<td>1.48</td>
<td>0.46-2.79</td>
<td>Z=-3.70 (p&lt;0.001)</td>
<td>0.67</td>
<td>0.29-1.58</td>
<td>Z=-3.70 (p&lt;0.001)</td>
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<td>Unexposed 1 week prior</td>
<td>0</td>
<td>0-0.50</td>
<td>Z=-0.04 (p=0.97)</td>
<td>1.07</td>
<td>0.37-2.45</td>
<td>Z=-4.53 (p&lt;0.001)</td>
<td>0.58</td>
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<td>Unexposed 2 weeks prior</td>
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<td>0-0.51</td>
<td>Z=-0.30 (p=0.77)</td>
<td>1.5</td>
<td>0.65-2.30</td>
<td>Z=-4.13 (p&lt;0.001)</td>
<td>0.63</td>
<td>0.29-0.94</td>
<td>Z=-3.70 (p&lt;0.001)</td>
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<td>Unexposed 3 weeks prior</td>
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<td>0-0.78</td>
<td>Z=-0.63 (p=0.53)</td>
<td>1.25</td>
<td>0.38-2.22</td>
<td>Z=-4.45 (p&lt;0.001)</td>
<td>0.65</td>
<td>0.32-1.17</td>
<td>Z=-3.70 (p&lt;0.001)</td>
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<td>Unexposed prior to auditor</td>
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<td>0-0</td>
<td>Z=-1.76 (p=0.08)</td>
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<td>0-5.00</td>
<td>Z=-2.60 (p=0.009)</td>
<td>0.6</td>
<td>0-1.67</td>
<td>Z=-3.00 (p=0.003)</td>
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</table>

IQR = interquartile range
* Compared to exposed group
5.3 Location Comparison

In the unexposed group consisting of areas of the ward not visible to the auditors during the time of the audits, there were 26 hand hygiene events inside rooms and 112 in hallways. The median event rates per dispenser per hour were 0 and 1.48, respectively. The total median event rate was 0.67.

Figure 2 illustrates the results of the location comparison. A Wilcoxon signed rank test showed that the exposed group had significantly higher event rates in hallways ($Z=-3.39$, $p=0.001$) and overall ($Z=-2.65$, $p=0.008$) compared to the unexposed group in a different location. There was no significant difference between the exposed and unexposed groups inside patient rooms ($Z=-0.13$, $p=0.90$).

![Figure 2: Median event rates in exposed group and unexposed location](image-url)
5.4 Time Comparison

The second unexposed group consisted of the same areas of the ward where the auditors were visible at the same time of day measured at one, two, and three weeks prior to the audit. One week prior to the audits, there were 34 hand hygiene events inside rooms and 58 in hallways in the unexposed group. The median event rates per dispenser per hour were 0 in rooms and 1.07 in halls, with the total rate being 0.58.

The time comparison for one week prior to the audit is shown in Figure 3. The exposed group had significantly higher event rates in hallways ($Z=-4.53$, $p<0.001$) and overall ($Z=-3.70$, $p<0.001$) compared to the unexposed group one week prior to the audit, but there was no significant difference inside patient rooms ($Z=-0.04$, $p=0.97$). This pattern of findings was identical for the unexposed groups two and three weeks prior to the audits, with the exposed group having significantly higher rates in hallways and overall but no difference inside rooms. The event rates at 1, 2, and 3 weeks prior to the audits were not significantly different from each other.
Figure 3: Median event rates in exposed group and unexposed time one week prior to the audits

5.5 Prior to Auditor Arrival

The final unexposed group was made up of the locations where the auditors were located but in the time period one to five minutes prior to auditors’ arrival. The median event rates per dispenser per hour in this group were 0 inside rooms, 1.50 in hallways, and 0.60 overall. The event rates in the exposed group were significantly higher after the auditors’ arrival in hallways ($Z=-2.60, p=0.009$) and overall ($Z=-3.00, p=0.003$), but there was no significant difference inside patient rooms ($Z=-1.76, p=0.08$). Figure 4 shows the comparison of event rates before the auditors’ arrival and during the audit.
Figure 4: Median event rates in exposed group and unexposed time prior to auditors’ arrival
Chapter 6

Discussion

6.1 Summary of Results

This cohort study showed that the hand hygiene event rate in soap and ABHR dispensers visible to auditors was significantly higher than dispensers not visible to the auditors during the same time period and significantly higher than the same dispensers at the same time in prior weeks. This effect was seen only in hallways, where the auditors were located, and not inside patient rooms. Furthermore, the hand hygiene event rate increased significantly when auditors were present compared to one to five minutes prior to the auditors' arrival, suggesting that the arrival of the auditor preceded the increase in hand hygiene. These results are consistent with the existence of a Hawthorne effect that is localized to areas where the auditor is visible to HCWs.

6.2 Comparison to Existing Literature

The Hawthorne effect is widely assumed to exist in hospital hand hygiene compliance monitoring, but the evidence for this is relatively weak. There have been 16 studies published to date that attempt to determine whether the presence of an observer increases hand hygiene compliance. All 8 of the studies conducted in hospitals were consistent with the existence of a Hawthorne effect, with the exception of one study that failed to show an increase in
compliance on one out of three units when overt auditors were compared to covert auditors. Of the 8 studies in non-health care settings, 7 out of 8 studies demonstrated a Hawthorne effect, but one study in public washrooms found no difference between observed and unobserved groups.

Although these studies do support the existence of a Hawthorne effect in hand hygiene behaviour, they have significant limitations due to the fact that most of them used direct observation to measure compliance in the observed and “unobserved” groups. Direct observation is subject to selection and observer bias, which may have been enhanced if the observers were not blinded to the study hypotheses. None of the studies indicated that the observers were blinded, and in some cases, the researchers acted as observers so they were almost certainly aware of the study hypotheses. This creates the possibility of information bias, which occurs when there are systematic differences in how the two groups are assessed.

Two studies in hospitals retrospectively assessed whether the HCW was aware of being observed, which eliminates the need for observer blinding. However one made an unsubstantiated assumption that awareness of the observer increases as the audit progresses, and the other was limited by using a survey to determine self-reported awareness of being observed. Two other studies avoided the biases of direct observation by using alternative methods to monitor hand hygiene, one of which measured soap and paper towel consumption and the other used acceleration sensors in soap. These provided supporting evidence, but
were potentially inaccurate due to the inability to determine exactly how many hand hygiene events occurred.

Although these studies provide evidence that the presence of an observer changes hand hygiene behaviour, the limitations of the studies and the weak evidence for the Hawthorne effect in general from psychology and other fields introduce doubt as to whether it truly does exist or under what conditions it is likely to be present. It is likely that the biases of direct observation are largely responsible for the positive results seen in most of the hand hygiene studies. Publication bias is another possibility; studies that do not show a Hawthorne effect may be less likely to get published.

This study is consistent with previous research that supports the existence of a Hawthorne effect, but it adds strong confirmatory evidence using a novel methodology and suggests that the effect occurs only in hallways that are within eyesight of the auditor. Previous studies were not able to localize the effect, so it was not clear whether hand hygiene compliance increased on the entire ward due to awareness of the auditor’s proximity or whether the auditor had to be visible in order to bring about a change in hand hygiene behaviour. This study shows that hand hygiene event rates were significantly increased in the dispensers visible to the auditor compared to other areas of the ward at the same time, suggesting that the effect is highly localized.
6.3 Study Strengths

The primary strength of this study is the use of RTLS to measure hand hygiene events, which is not subject to the same biases as direct observation. The RTLS applied a consistent algorithm to count ABHR and soap dispenses regardless of whether the auditor was present or absent, which increases the precision of the measurement and eliminates the risk of information bias. The RTLS also allowed for more precise localization of the effect due to its ability to track auditors’ movements.

As with any observational study, the possibility of confounding has to be considered as a limitation. There are numerous factors influencing the decision to perform hand hygiene that cannot be assessed in this study; for example, HCW profession, type of care activities being provided, and proximity to ABHR dispensers or sinks. Although many of these unmeasured factors could be associated with the outcome, it is not likely that they would be associated with the exposure and thus should not be confounders. However, hand hygiene is highly variable depending on the time of day and the day of the week (weekday versus weekend); this may be a proxy for workload, which is known to be inversely correlated with compliance rates and may be a confounder in this study. Workload may be associated with both exposure and outcome, in that auditors are likely to go to areas of the ward where more patient care activities are taking place so that they can reach their target of observing 60 hand hygiene opportunities per audit. Although higher workload is associated with decreased hand hygiene compliance, there would be more hand hygiene opportunities and the event rate may be increased. Workload thus meets all three criteria for confounding: it is a determinant of hand hygiene, it is associated with the
presence of the auditor, and it is not on the causal path.\textsuperscript{57} The potential confounding due to workload is an example of reverse causation bias, since the outcome of hand hygiene events can potentially cause the exposure of auditor’s presence.\textsuperscript{58} In other words, auditors typically move to locations where more activities are taking place in order to observe more HCWs, and it is the increase in hand hygiene events (outcome) that causes the auditor to be present (exposure). This would be the opposite causal direction to the Hawthorne effect, in which the presence of the auditor results in an increase in hand hygiene event rate.

The use of three unexposed comparison groups addresses this potential for bias due to workload and other unmeasured factors, and it represents an additional strength of the study. The first group was from the same time period during the audit but in an area of the unit not visible to the auditor. Since the day and time was the same, the comparison accounts for any differences in hand hygiene patterns that might be attributable to temporal factors. The second group, which consisted of the same dispensers at the same time but in previous weeks, addresses the fact that workload may be variable depending on location on the ward. For example, patients who are more severely ill and therefore require more hands-on care may be located closer to nursing stations. The final comparison group was the same dispensers at one to five minutes prior to the auditor’s arrival, which was designed to investigate the potential for reverse causation. If the event rate was similar in that group as in the exposed group, it would suggest that the auditor was moving to areas of the ward where there were more hand hygiene events occurring. However, since the rate increased after the auditor’s arrival, this supports the attribution of causality to the presence of the auditor.
The case for a causal relationship is further strengthened based on Hill’s criteria, which consist of nine factors that support causal attribution when present. This study meets the criteria of strength, consistency, temporality, and plausibility. The association between the auditors’ presence and hand hygiene events is strong, with increases of 250% to 350% seen in the exposed group. The results show a consistent increase in hand hygiene events in the exposed group compared to three different unexposed groups. The fact that the increase in event rate occurred after the auditors’ arrival confirms that cause precedes effect, meeting the temporality criteria. Finally, studies from the psychology literature have established a plausible mechanism for the increase in hand hygiene, related to the fact that conformity to social norms is more likely in the presence of other people. Although Hill’s criteria do not definitively prove causation, they provide additional support to the finding that the presence of an auditor leads to an increase in HCW hand hygiene compliance, while the three unexposed comparison groups provide evidence that confounding is not the explanation.

6.4 Limitations

The primary limitation of this study is the use of hand hygiene events as the outcome rather than compliance. The RTLS was able to measure the number of times that dispenser levers were pushed, which is a proxy for hand hygiene event rate. However it is not possible to know whether the people who used the dispensers actually performed hand hygiene or whether hand hygiene was performed at an indicated moment (e.g. before or after patient contact). Furthermore, all dispenses were counted and it was not possible to determine whether it was HCWs or other people using them.
As a result, the magnitude of the Hawthorne effect seen in this study cannot be compared to the existing literature. The event rate in the exposed group increased by between 250% and 350% when compared to different unexposed times and locations, but it is not known whether the denominator of hand hygiene opportunities also changed and thus whether there was a difference in compliance. However, in order for there to have been no change in compliance, the number of hand hygiene opportunities would have had to increase by a similar magnitude. This degree of variation in opportunities is possible, as shown in a study using electronic sensors that reported a wide range from 2 to 196 entries or exits per room during day shifts.\(^6\) It might be plausible to see a consistent increase in opportunities if the auditors were moving to areas where more activity was taking place, but the lack of increased event rate in the unexposed group prior to the auditors’ arrival shows that this is not the case. Therefore, it is less likely that the number of hand hygiene opportunities coincidentally increased by such a significant amount every time auditors arrived.

The ideal way to confirm the existence of the Hawthorne effect would be to measure hand hygiene compliance as an outcome. Hand hygiene compliance would assess HCWs at moments during which hand hygiene is indicated in order to reduce transmission of microorganisms to patients. However, it was not feasible to determine compliance rates in this study since it would require all staff to wear RTLS tags in order to calculate an accurate denominator. Due to resource limitations, tags were provided to approximately one-third of staff on the study units, although the proportion of tagged staff on the unit at any given time was much lower since HCWs were distributed across different shifts and they may have forgotten to wear the tags. As an alternative to measuring compliance rates, an estimated number of hand hygiene opportunities
could have been used as the denominator, but estimates are typically based on 12-hour shifts and may not be accurate for the short period of time that the auditor was present.\textsuperscript{61}

A second limitation is the fact that the RTLS itself may have resulted in a Hawthorne effect, in that HCWs were aware of the fact that the system was monitoring their hand hygiene compliance. However, it is frequently said that the Hawthorne effect wanes over time,\textsuperscript{62} although there is a lack of evidence to support this. If it is true, the RTLS had been operational for approximately four months prior to the start of this study so it is likely that the impact of the Hawthorne effect would have decreased. In addition, any Hawthorne effect related to the RTLS should have impacted both the exposed and unexposed groups equally and thus the magnitude of difference between them would not change.

A third limitation is the possibility of technical problems with the RTLS, which are difficult to quantify. Some of the potential issues would lead to an underestimate of the event rate, such as battery failures in the dispenser tags, receiver failure, and partial dispensing (pushing the dispenser lever less than halfway). Other issues would cause overestimation of the event rate, including empty dispensers and stuck dispenser levers. These technical problems may cause inaccuracies in the event rates, but should not lead to systematic differences between the exposed and unexposed groups because they occur randomly within both groups.

Finally, another limitation of the study relates to external validity. This study was conducted on solid organ transplant units in an academic acute care hospital, and a relatively small number of audits were observed. It is not known whether the findings would be generalizable to other health
care settings involving different patient and HCW populations. The units in this study may be more concerned about infection prevention than other units due to the immunocompromised patient population, potentially increasing the magnitude of the Hawthorne effect as HCWs want to be seen complying with the social norm of hand hygiene for patient protection.

The fact that this study was conducted during winter months also may affect the generalizability of the results. The incidence of respiratory infections is higher in the winter, as are rates of CDI due to the increase in antibiotic use. This may lead to a seasonal increase in hand hygiene compliance as HCWs become more aware of the need to protect themselves from communicable diseases. Similar to the study in public washrooms that took place during the SARS crisis, the magnitude of the Hawthorne effect may be decreased in the winter.

### 6.5 Implications

HCW hand hygiene compliance has long been a focus of infection prevention and control programs, and more recently it has captured the attention of governments and organizations such as the Canadian Patient Safety Institute and Public Health Ontario. Ontario and several other provinces now mandate public reporting of HCW hand hygiene compliance rates in hospitals. At the individual hospital level as well as on a population level, increases in hand hygiene compliance are often taken at face value and celebrated as successes. However, it is important to recognize the limitations inherent to direct observation of hand hygiene compliance, including the Hawthorne effect, so as not to be falsely reassured by the high reported rates. Despite the apparent improvement in hand hygiene compliance rates in Ontario since public reporting started
in 2009, HAI rates have not shown a corresponding decrease.\textsuperscript{18} One possible explanation is that the apparent increase in compliance is related to bias rather than a true improvement. Ongoing quality improvement efforts are necessary to improve hand hygiene compliance if, as expected, the true rates are lower than currently reported.

Increased understanding of the Hawthorne effect may also help to explain some commonly observed patterns in the hand hygiene literature. For example, physicians are consistently shown to have lower hand hygiene compliance than other HCWs.\textsuperscript{8} However, it is possible that their true compliance rates are not significantly worse than other groups but rather they are less susceptible to the Hawthorne effect. There has been a significant investment of time and resources put towards improving physician hand hygiene compliance, but these resources may be misdirected if the discrepancy can be explained by the Hawthorne effect. Similarly the decrease in hand hygiene compliance that has been seen in situations of increased activity, such as understaffing, overcrowding, and working in ICUs,\textsuperscript{8} may in fact reflect a decreased magnitude of the Hawthorne effect when HCWs are busy. Understanding how the Hawthorne effect may play a role in the determinants of hand hygiene compliance will potentially allow for improved hand hygiene interventions that are targeted to address the factors most in need of improvement.

Despite the limitations of the existing literature, the Hawthorne effect is widely accepted as fact and there have been calls to use it as a tool to improve HCW hand hygiene.\textsuperscript{25} The theory is that enhancing the amount of surveillance in hospitals may lead to an increase in compliance due to the Hawthorne effect. In order to optimize an intervention based on the Hawthorne effect, it is necessary to understand what the magnitude of the effect is, how long it lasts, and what factors
may modify its impact. If, as this study suggests, the effect is localized to HCWs within eyesight of the auditor, then it may not be feasible to bring about widespread increases in compliance simply by having more frequent audits. This type of intervention also may not be sustainable if the Hawthorne effect truly does wane over time, as is thought to occur. Furthermore, since the magnitude of the effect may differ depending on the HCW group and the clinical setting, interventions based on increased observation of hand hygiene may not be universally effective.

6.6 Future Research

Electronic and video monitoring systems for hand hygiene are relatively recent developments that provide a valuable tool for measuring the Hawthorne effect. It would be instructive to replicate the findings of this study in other settings, including different types of units and other times of year, and by using different systems. Ideally hand hygiene compliance should be used as an outcome in order to confirm the existence and clarify the magnitude of the Hawthorne effect. If compliance is calculated based on HCWs wearing system tags, it would be important to take into account the differences between people who agree to wear tags and those who refuse. There have been two studies examining acceptability of electronic hand hygiene monitoring systems among HCWs, although both were based on focus group discussions of hypothetical scenarios rather than using a system. However, it is likely that there are significant differences between HCWs who accept or refuse to participate, and that could represent an important limitation of future studies that use hand hygiene compliance rates as an outcome.
Even if it is assumed that the Hawthorne effect exists, the magnitude of the difference between observed and unobserved groups has varied widely in the published literature. In studies that included measurement of compliance, the increase in the observed group ranged from 20% to 74% in non-health care settings\textsuperscript{40-42,44,47} and from 8% to 50% in hospitals.\textsuperscript{48,51-55} Some of this variability may be related to differences in methodology and the resulting risk of bias, but there are also likely to be factors that modify the magnitude of the Hawthorne effect. The study that employed acceleration sensors to detect soap use found significant differences in households that were highly reactive compared to non-reactors, suggesting that awareness of social norms plays a role.\textsuperscript{46} However, other than the study reporting that the Hawthorne effect may be related to increased baseline compliance rates,\textsuperscript{54} there is little known about what enhances or suppresses the Hawthorne effect in health care settings. Future research with a larger sample size and increased number of tagged staff could determine which factors may modify the magnitude of the effect, such as HCW profession, staff to patient ratios, type of unit, and time of day. It was not possible to stratify the observations in this study because of the relatively small sample size and the fact that only a minority of HCWs were wearing RTLS tags. Future research using a similar methodology to this study could also determine whether the Hawthorne effect does in fact wane over time.

Another aspect that could be studied is whether characteristics of the observer modify the effect; for example, whether auditors are known to HCWs on the unit and how conspicuous they are. It is also possible that social cues other than a human observer could bring about a Hawthorne effect. One study showed that an image of human eyes placed over a collection box in a university lounge led to students paying more money for their drinks.\textsuperscript{66} A similar intervention
could be conducted in which images of eyes are placed over soap and ABHR dispensers to
determine if this leads to an increase in hand hygiene compliance.

Finally, it would be valuable to conduct further research into the cause of the Hawthorne effect.
The hypothesis that the Hawthorne effect occurs because of increased compliance to social
norms in the presence of another person could be tested using an electronic monitoring system.
One way to do that would be to compare the magnitude of the Hawthorne effect on different
units and simultaneously measure the hand hygiene norms of the unit using a questionnaire, and
then determining whether norms account for any of the variance in the Hawthorne effect.

6.7 Conclusion

In conclusion, this study used a RTLS to determine that there is a Hawthorne effect in hand
hygiene compliance monitoring, with a significant increase in the hand hygiene events during
audits compared to a different location during the audit, different weeks prior to the audit, and
the time immediately preceding the auditors’ arrival. This is a novel approach, and the study
design has been optimized to address the issues of confounding and reverse causation bias. The
results of this study further the understanding of the Hawthorne effect, which will enable more
accurate assessment of true hand hygiene compliance rates and will potentially contribute to the
development of effective interventions to achieve the ultimate goal of reducing HAIs.
References


Appendix A: Search Strategy

Database: Ovid MEDLINE(R) In-Process & Other Non-Indexed Citations and Ovid MEDLINE(R) <1946 to Present>

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1 exp hawthorne.mp (1036)
2 exp research participation effect*.mp (7)
3 exp demand characteristic*.mp. (1243)
4 exp experiment effect*.mp. (282)
5 exp effect modifier*.mp. (3027)
6 exp observe*.mp. (4464445)
7 exp audit*.mp. (422926)
8 exp hand hygiene.mp. (4606)
9 exp hand disinfection.mp (4967)
10 exp hand asepsis.mp. (11)
11 exp hand wash*.mp. (9739)
12 exp standard precautions.mp. (781)
13 exp handwashing.mp (2919)
14 exp sanitation.mp (31844)
16 (or/1-7) and (or/8-14) (3850)
Appendix B: Participant Consent Form

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

Title
The use of Hospital Watch Live and front line staff empowerment as a quality improvement strategy to reduce healthcare associated infections

Investigator
Dr. Michael Gardam, Director, Infection Prevention and Control (IPAC), University Health Network, 416-340-3758

Co-Investigators
Dr. Susy Hota. Infectious Disease and IPAC, University Health

Sponsor
Canadian Health Innovation (CHI) and Infonaut Inc.

Introduction
You are invited to participate in a research study. Please read this description of the study before you decide if you would like to take part. You should take as much time as you need to make your decision. You should ask the study investigator or study staff to explain anything that you do not understand and make sure that all of your questions have been answered before signing this consent form. Before you make your decision, feel free to talk about this study with anyone you wish. Participation in this study is voluntary.

Background and Purpose
Hospital Watch Live is a communications system developed to track infections and show how they spread in hospitals.

Hospital Watch Live uses safe ultrasound signals to communicate between the tags (worn by staff and patients and placed on hospital equipment) and receivers located in participating patient units (patient wards) to indicate where and how infections spread. We want to determine if this early notification system will reduce the risk and spread of healthcare associated infections.

Study Design
This study measures several process and outcome indicators, including staff attitudes towards the Hospital Watch Live system. This study will enroll 60 health care workers over a period of 18 months.

If you participate you will be requested to (voluntarily) wear a tag when you are caring for your patients. The tag is attached to your hospital badge.
Hospital Watch Live uses tags, to track how and where infections are spread. These tags transmit silent ultrasound signals that are picked up by wireless receivers located in patient rooms and hallways. The tags will also be attached to patient ID bracelets, if the patient agrees and will be placed on hospital equipment.

This new technology allows hospitals to:

- Identify the potential spread of infection;
- Predict who is most at risk of catching a bug;
- Track the spread of infections;
- Chart how often and how well hand hygiene is done;
- Verify when equipment has been cleaned;
- Display equipment on a floor plan so staff can access it quickly and easily.

If you choose to participate you will also be asked take part in an interview, which will last for approximately 30 minutes – 1.5 hrs. This interview will be conducted to find out about your experience in uncovering solutions aimed to improve hand hygiene outcomes using information generated from the Hospital Watch Live (HWL) system. We plan to ask you general questions about any changes in hand hygiene practices within your unit, since the launch of HWL. We will also be exploring your opinion on staff behaviour changes since the project was implemented. Additionally we wish to be informed about how this quality improvement pilot project compares with others you may have experienced.

Approximately 60 staff participants will be enrolled in this study and interviewed by two members of our research team. These members of the study team have been educated in the Positive Deviance process and in conducting the interviews. The interview will be tape recorded and transcribed at a later date. It is our intent to publish stories from these interviews, and to include your job affiliation. You will have the right and opportunity to review the summary of your interview. Your name will not be kept and the tapes identified using a coded study ID number. You name will not appear in any publications. Only the researchers that are part of the interview team will have access to your study information.

**Voluntary Participation**

Your participation in this interview is voluntary. There are no apparent risks involved in participating in this study. There are no direct benefits in participating in this study; however your participation will help to inform future positive deviance projects and will increase knowledge in the area of infection control. You may decide not to be interviewed, or to be interviewed now and then change your mind later. You may leave
the study at any time. You may refuse to answer any question you do not want to answer or remove the tag from your badge. Anonymity, through study coded ID will be assigned to your tag. Any third party names mentioned will be anonymized for publication. In no way does signing this consent form waive your legal rights nor does it relieve the investigators, sponsors or involved institutions from their legal and professional responsibilities.

You may leave the study at any time without affecting your employment status or, if you are a student, your academic standing. You may refuse to answer any question you do not want to answer, or not answer an interview question by saying “pass”.

We will give you new information that is learned during the study that might affect your decision to stay in the study.

Confidentiality

The information that is collected for the study will be kept in a locked and secure area by the study doctor for 10 years. Only the study team or the people or groups listed below will be allowed to look at your records. Your participation in this study also may be recorded in your medical record at this hospital.

The following people may come to the hospital to look at the study records to check that the information collected for the study is correct and to make sure the study followed proper laws and guidelines:

- The study sponsor or its representatives/partner companies.
- Representatives of the University Health Network Research Ethics Board.

Study Information That Does Not Identify You

Some study information will be sent outside of the hospital to the Sponsor. Any information about you that is sent out of the hospital will have a code and will not show your name or address, or any information that directly identifies you. Taped interviews that may identify you will not leave the hospital and will be erased after data analysis at the end of the study period.

The Sponsor may use the study information and share it with its partner companies or with national and international regulatory agencies to help answer the study question, or to develop future studies on this product or for research related to this study.

All information collected during this study, including your personal health information, will be kept confidential and will not be shared with anyone outside the study unless required by law. You will not be named in any reports, publications, or presentations that may come from this study.
If you decide to leave the study, the information about you that was collected before you left the study will still be used. No new information will be collected without your permission.

**Questions About the Study**

If you have any questions, concerns or would like to speak to the study team for any reason, please call the University Health Network, Infection Prevention & Control research team member at:
(416) 340-4800 ext. 8422

If you have any questions about your rights as a research participant or have concerns about this study, call the Chair of the University Health Network Research Ethics Board (REB) or the Research Ethics office number at 416-581-7849. The REB is a group of people who oversee the ethical conduct of research studies. These people are not part of the study team. Everything that you discuss will be kept confidential.

**Consent**

This study has been explained to me and any questions I had, have been answered. I know that I may leave the study at any time. I agree to take part in this study.

Print Study Participant’s Name ______________________ Signature ______________ Date 

(You will be given a signed copy of this consent form)

My signature means that I have explained the study to the participant named above. I have answered all questions.

Print Name of Person Obtaining Consent ______________________ Signature ______________ Date

☐ The consent form was read to the participant. The person signing below attests that the study as set out in this form was accurately explained, and has had any questions answered.

Print Name of Witness ______________________ Signature ______________ Date

Relationship to Participant