Out of sight, out of mind: a prospective observational study to estimate the duration of the Hawthorne effect on hand hygiene events

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ABSTRACT

Background Human auditing has been the gold standard for evaluating hand hygiene (HH) compliance but is subject to the Hawthorne effect (HE), the change in subjects' behaviour due to their awareness of being observed. For the first time, we used electronic HH monitoring to characterise the duration of the HE on HH events after human auditors have left the ward.

Methods Observations were prospectively conducted on two transplant wards at a tertiary centre between May 2018 and January 2019. HH events were measured using the electronic GOJO Smartlink Activity Monitoring System located throughout the ward. Non-covert human auditing was conducted in 1-hour intervals at random locations on both wards on varying days of the week. Two adjusted negative binomial regression models were fit in order to estimate an overall auditor effect and a graded auditor effect.

Results In total, 365 674 HH dispensing events were observed out of a possible 911 791 opportunities. In the adjusted model, the presence of an auditor increased electronic HH events by approximately 2.5-fold in the room closest to where the auditor was standing (9.86 events per hour/3.98 events per hour; p<0.01), an effect sustained across only the partial hour before and after the auditor was present but not beyond the first hour after the auditor left. This effect persisted but was attenuated in areas distal from the auditor (total ward events of 6.91*6.32–7.55, p<0.01). Additionally, there was significant variability in the magnitude of the HE based on temporal and geographic distribution of audits.

Conclusion The HE on HH events appears to last for a limited time on inpatient wards and is highly dynamic across time and auditor location. These findings further challenge the validity and value of human auditing and support the need for alternative and complementary monitoring methods.

INTRODUCTION

Accurate measurement of hand hygiene (HH) compliance rates among healthcare providers is a crucial component of HH programmes. Human auditing has traditionally been the gold standard for evaluating HH compliance due to its ease, low cost and potential for immediate feedback.[1 2] However, human auditing is subject to the Hawthorne effect (HE), the change in subjects' behaviour due to their awareness of being observed,[3 4] a bias that often leads to inflation of true HH compliance values. Electronic HH monitoring (e-monitoring) avoids the influence of the HE, but widespread adoption has been limited by costs and technical considerations such as installation and maintenance. With human auditing continuing to be the mainstay of HH measurement, understanding the full impact of the HE is critical to adjust for this bias and appropriately interpret human audit measurements.

Several features of the HE on HH compliance measurement by human auditing have been described in previous studies, with most focusing on its magnitude.[3 5–9] The HE has been shown to follow a time-dependent curve such that longer auditor presence elicits a more significant change effect, with a ceiling effect reached approximately 10–15 min after an auditor's arrival.[10 11] Heterogeneity in the HE among healthcare workers has also been observed between types of healthcare workers and between various units, such as those with high and low baseline performance of HH.[12–14]

Several aspects of the HE on HH event measurement that may have important implications for HH programmes have not been well characterised. First, the duration of the HE once an auditor has left the ward is not well described, that is, once an auditor has left the ward, the persistence of the effect is unknown. This is important for accurate HH event auditing, as temporally close audits may contaminate one another, and for HH campaigns, which could take advantage of the HE by placing auditors on units at regular intervals to boost compliance. Furthermore, although variability in the HE has been established between healthcare workers and units, variability in the HE within units has received less attention, including between locations within the unit, at different distances from auditors within a single unit and between hours of the day.

We therefore aimed to further characterise the magnitude and duration of the HE on HH event measurement by human auditing by comparing e-monitoring HH data collected during the presence and absence of human auditors.

METHODS

Setting and population

The study was prospectively conducted on two transplant wards at a tertiary centre between May 2018 and January 2019. Both wards consisted of three hallways arranged in a 'U' shape. The units that comprised 34 rooms were across the two wards, including a total of 18 private, 14 semiprivate and 2 four-bed rooms. Of the 18 private rooms, eight were medical step-down beds for patients who are more acutely ill. One of the four-person bedrooms was also for step-down patients. Given that our centre performed one of the highest volumes of transplants in North America, both wards had a stable occupancy of 100% throughout the study period.

Measurement of HE on HH event rates by human auditing

HH events and opportunities were measured using the electronic GOJO Smartlink Activity Monitoring System (GOJO AMS), a technology previously used and validated.[4] Alcohol-based hand sanitiser and soap dispensers and infrared sensors were located within and outside of the 34 rooms and hallways across the two wards. All sanitiser and soap dispensers were electronically enabled and recorded each dispensing event, documenting the precise time and location of the event. For this study, HH events were defined as any time soap or hand sanitiser was dispensed. Infrared sensors located at each patient room doorway recorded entries and exits into each patient room, also documenting the precise time and location of the opportunity. For this study, HH opportunities consisted of any person's entry beyond 18" through the doorway into the patient room or passing through the doorway when exiting the room, as identified by the GOJO AMS. Despite the electronic system not discriminating dispense events and opportunities of healthcare workers from non-healthcare workers, the influence of these measures was likely minimal due to their uniform nature throughout the observation period, given the lack of familiarity of visitors and patients with electronic HH auditing.

Non-covert human auditing was conducted throughout the study period by three trained auditors for 1-hour intervals between 07:00 and 19:00 at random locations on both wards, and on varying days of the week (except weekends and holidays) throughout the study period. The median time for audits to take place was around 12:30 (25th and 75th quartiles of 10:40 and 15:00). Auditors stood in different hallways of the wards during different observation periods so that HH compliance could be compared between rooms near auditors with rooms distant from auditors from which auditors could not be seen. Despite being stationed in one location for each audit, one to three or more rooms could be observed and recorded from the auditor's position. Auditors were non-covert observers who stood in a single location on the ward wearing unmarked clothing who manually collected HH opportunity and event data using a paper-based data collection tool. Due to the positioning of handwashing stations on the wards, the majority of the events observed by auditors were hand rubbing events, rather than handwashing (approximately 90%). Auditors documented adherence to HH opportunities (approximately 60 per session) entering and leaving patient rooms only with extremely minimal visibility to in-room dispenser events. Therefore, there were no differences in the auditing protocol for single versus multibed rooms. HH compliance according to human observation, using study definitions of HH events and opportunities, was calculated using simple proportions, comparing observed opportunities to observed HH events.

Statistical analysis

The rate of HH events during auditor presence and absence was estimated using negative binomial regression. The predictor of primary interest was the *audit status*; two separate models were fit in order to estimate an overall auditor effect (audit status coded as a binary yes/no depending on whether an auditor was on the ward at the time of HH event—model 1) and a graded auditor effect (audit status at the time of HH event coded as being local to a particular room, hallway, or ward, vs no auditor present—model 2). In both models, adjustment was made for room number, day of the week, hour of the day, overall temporal trend (as a quintic polynomial in day of data collection, by ward) and number of HH opportunities. We fit restricted cubic spline models with a variety of numbers of knots as well as a range of polynomial functions and selected the model with the lowest Akaike information criterion (AIC). No adjustments were made for multiple comparisons because we only focused on two comparisons: the overall auditor effect (relative to a non-audit day, all else being equal)

Table 1 Marginal (adjusted) auditor effect on hand hygiene events[15 16]

Variable	Hourly event rate	P value	Model
Reference	3.98 (3.83–4.17)	–	
2 hours preaudit	3.77 (3.51–4.04)	0.04	1
1 hour preaudit	4.08 (3.81–4.37)	0.345	1
Partial hour preaudit	5.72 (5.27–6.21)	<0.01	1
Partial hour postaudit	5.60 (5.17–6.07)	<0.01	1
1 hour postaudit	4.06 (3.78–4.35)	0.482	1
2 hours postaudit	3.90 (3.62–4.19)	0.453	1
Room nearest auditor	9.86 (8.22–11.84)	<0.01	2
Same hallway as auditor	6.74 (6.13–7.40)	<0.01	2
Same ward as auditor	6.91 (6.32–7.55)	<0.01	2

and the auditor effect broken down by proximity. Temporal window of observation was treated as an offset term so that HH rates were standardised to dispenses per hour. We report HH rates, 95% CIs and p values relative to a non-audit day for each model as follows: for a non-audit day and the overall auditor effect from the first model; for a non-audit day and for the 2 hours before/after an audit, partial hour before and after audit (rounded to the nearest value above and below) and the three levels of audit intensity from the second model (table 1). The reference was chosen to be a non-audit day, room 1, ward 1, the hour from 10:00 to 11:00, on a Sunday, on the first day of data collection, with nine HH opportunities. This time was selected because the nine opportunities per room per hour represented the overall average in our study and would therefore reflect a typical number of opportunities throughout the study period.

Complete log-scale model coefficient estimates for both models are reported in the online supplementary file. An alpha level of 0.05 was used to assess statistical significance. The analysis was conducted in R V.3.4.4[15] using the MASS package.[16]

RESULTS

Duration of HE

Forty-six human audits were conducted across the two wards between 31 May 2018 and 31 January 2019 (duration of 244 days). During this period, e-monitoring detected 365 674 HH events across both wards out of a possible 911 791 opportunities, leading to an unadjusted adherence rate of 40.1%. Results of human auditing during the same observation estimated compliance at 80% (range 72%–87%). Time trend analysis showed a drop in HH events during the summer months (May to August; data not shown), a finding consistent with previous studies.[17]

Table 2 displays the unadjusted estimation of the HE by comparing e-monitoring data during the presence and absence of human auditing. A total of 4004 events were observed during 46 audits, resulting in 5.13 events per hour (17 room-hours per audit). This resulted in an approximate 1.5-fold increase in HH events per hour across both wards when auditors were present (5.13/3.66). In the adjusted model displayed in table 1, the baseline number of HH events per hour was 3.98; with the presence of an auditor, this increased by approximately 2.5-fold in the room closest to where the auditor was standing (9.86 events per hour/3.98 events per hour). This effect was measured at approximately 1.75-fold greater in the same hallway and ward as the auditor was standing in despite the fact that the auditor could only easily observe external room dispensers in the hallway where they were located, and the auditors were not visible from the other two hallways of the ward. This effect was sustained across only the partial hour before (defined as the period between the exact hour and the start of the audit) and partial hour after the auditor was present (defined as the period between the end of the audit and the exact hour). The effect did not last beyond the first hour after the auditor left (figure 1, table 1). Full results of each model are available in the online supplementary file tables 1 and 2.

The full results of the model are found in the online supplementary materials and include the parameter estimates for all variables in the model, including locations (ward/room/hallway), hours before and after the observation, the individual rooms and the times of the day.

Variability in HE

Figure 2 displays the number of HH events across all rooms and all times of the day, divided according to the presence and absence of the auditor. Comparing the times in which the auditor was present and absent, there is variability in the magnitude of the HE caused by the presence of the auditor based on the auditor's location on the ward, and time of the day. Certain

Table 2 Unadjusted auditor effect, including events and opportunities, by auditor presence and absence

Auditor presence	Total HH events*	HH events per hour	Total HH opportunities†	Dispenses per opportunity
Auditor present	4004	5.13	7107	0.56
Auditor absent	361 670	3.66	904 684	0.4

*Comprise all HH dispensing events, including alcohol hand rub and soap dispensers.
†Include all recorded entrance and exit movements as documented by doorway infrared sensors.
HH, hand hygiene.

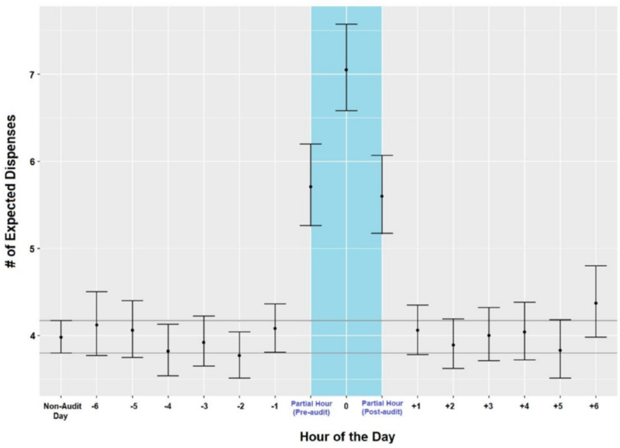

Figure 1 Hourly dispense rate, comparing the period before, during and after auditor presence.

times and locations experienced intense increases in HH events while auditors were present, while others displayed little change.

DISCUSSION

This is the first study to thoroughly examine the duration and magnitude of the HE on HH events following human audit completion. Using e-monitoring HH technology, we concluded that the HE did not last longer than the time an auditor was present on the ward. Additionally, the HE varied over time and auditor location.

Only one study has reported on changes to the HE on inpatient wards after an HH auditor was no longer present; however, this study examined only the period immediately after the auditor left and did not control for temporal and geographic confounding variables, as our study has done.[18] Our findings of a limited duration effect of HE are consistent with previous quantitative research showing that the HE is directly caused by participants' knowledge that they are being observed, in both HH research[10] and non-HH research.[19] The temporally and spatially limited nature of the HE indicates that the presence of auditors cannot be used as a sustainable tool to increase HH events, an approach also known as the 'Hawthorne Strategy',[2 20] because the rise in HH is limited only to the short and rare occasions that auditors are present. This is consistent with campaigns in non-healthcare-related fields such as law enforcement, where authorities have found they can successfully encourage 'good behavior' in citizens using fake observers, but only for as long as the individuals believe they are being observed.[21] The short duration of the HE also implies that individual HH audits are unlikely to contaminate subsequent audits even if performed in close succession. Therefore, rapid auditing cycles, even on an hourly basis, may be performed without concern for confounding by the HE.

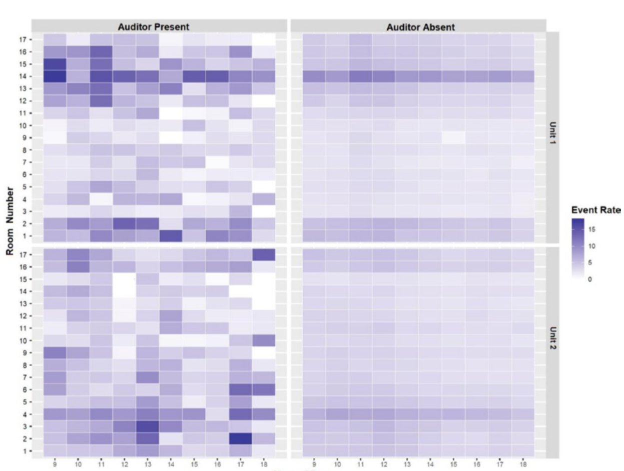

Figure 2 Event rates per hour by room and time of the day comparing presence and absence of auditors. All observations included.

Our study verified the well-established magnitude of the HE in HH events in healthcare,[3 10 22 23] estimated in our study to range approximately 1.75–2.5 times greater than true baseline values. This effect was demonstrated in multiple ways in our data, including the initial observation that the aggregate event and opportunity electronic data estimated the overall HH adherence to be approximately 40%, while human auditing during the same period measured compliance at 72%–87% (values consistent with prior literature in the transplant setting[24]). Furthermore, both the unadjusted and adjusted models using e-monitoring data comparing the presence and absence of human auditors showed a dramatic increase in HH events. These findings align with prior literature corroborating the HE in HH compliance, including a study from our centre confirming the presence of the HE on the same wards using slightly different methodology.[22] Interestingly, contrasting that study, we showed that the HE extended beyond the areas where the auditors were visible to affect the entire ward, although to a lesser degree. This difference may be due to the accumulated effect of several years of HH auditing performed on this ward, potentially resulting in heightened awareness of auditors among healthcare workers, consistent with observations that longer individual observation durations lead to a larger HE.[9 10] For unclear reasons, HH events increased just prior to the arrival of auditors to the wards (the partial prehour). This may have been due to healthcare workers noting the unannounced presence of the auditors as they were stationing themselves to perform the audit but prior to them initiating their observations.

An additional noteworthy result was that the HE was not uniform and affected HH measurements differently across both time and auditor location on the ward. Prior estimation of HE variability in HH has demonstrated differences between wards[12] and types of healthcare professionals,[25] but not within the same ward or between hours of the day. Notably, the variability we observed did not appear to follow a predictable pattern or trend based on time of day or room location. In fact, some rooms showed sustained increase in HH (eg, rooms 1, 2 and 14 on unit 1, and rooms 4, 16 and 17 on unit 2), perhaps due to proximity to the main nursing station. Although the cause of the variability was not immediately clear, it may have been due to other factors not measured in our study, such as bed occupancy and turnover,[26 27] patient acuity,[28] the presence of other healthcare workers in the area[6] and differences in workflow during different times of the day and sections of the wards.[29] This variability suggests that human audit measurements cannot be used to approximate true HH compliance values using a formula or correction coefficient, as the HE is not uniform across time or space. The unevenness in the HE seen in our study raises concerns regarding the accuracy of human auditing and whether it is appropriate to extrapolate audit results to longer periods and larger areas, given the apparently unpredictable differences between the electronic and human auditing compliance numbers. This flaw, in addition to the many other drawbacks of human auditing, which include the need for ongoing training,[30] significant time investment yielding limited sample sizes[4 31 32] and lack of standardisation,[33] has contributed to a perception of inaccuracy by front-line staff.[34] Notably, this perception has recently been shared by healthcare workers regarding e-monitoring systems as well, highlighting the argument that no measurement system is perfect.[35]

Numerous attempts have been made to minimise the HE in order to increase the accuracy of human auditing. Since the HE is rooted in participants' awareness that they are being observed, a covert observer has been the most commonly used method, resulting in variable success in minimising the HE.[30 36 37] Other options for mitigating the HE include minimising the duration of observations,[11] using participant observers,[38] or using indirect outcomes, such as total soap utilisation.[39 40]

Due to the inconsistent success of these attempts to minimise the HE, along with other drawbacks to human auditing previously outlined, alternative methods of conducting HH auditing have gained popularity, such as the use of e-monitoring HH.[41] Advantages of these systems include standardised measurement of dispensing events and opportunities on either individual or aggregate levels, minimal immediate human time investment, data collection across all hours of the day and avoidance of the HE. Diverse e-monitoring technologies are available with varying benefits and drawbacks, which include group monitoring, badge-based systems and video observation.[42] For example, the GOJO AMS used in our study can identify precise times and locations of dispensing events, unlike the group-based monitoring system, but does not distinguish between healthcare workers and patients, visitors or other hospital employees, as a badge-based or video-based system would. No consensus has been reached on which electronic HH monitoring system is best; however, given the concerns regarding the HE outlined in our study, we would advocate for the use of any of the e-monitoring systems as a tool to complement human auditing. Whichever technology is chosen, all affected healthcare workers must be aware of the limitations of its measurement capabilities and the results must be contextualised to each ward and hospital site. Furthermore, regardless of the specific electronic system, institutional administration must recognise that HH compliance is maximised when e-monitoring is combined with a simultaneous HH campaign because e-monitoring is merely the measurement tool while dedicated HH campaigns are the real drivers of change.[43]

Our most significant limitation is that the study was conducted at a single institution on highly specialised medical wards (transplant wards) conducting most observations during work hours. Also, we were unable to control for changes in patient acuity over time and between rooms, for periods of increased patient volumes and for the peer effect of multiple healthcare workers entering rooms together. These variables may interact with the presence of an auditor to modify numbers of HH events. Similar research in other institutions or on other wards may reach different results regarding the duration of the HE, since different wards react differently to human auditors based on their familiarity with the auditors, staff scheduling and underlying culture of the ward. On the other hand, the sample size of nearly a million opportunities across 7 months of observations reduced the likelihood of a spurious finding. Furthermore, the variability across time and auditor location seen in the HE was unlikely to be affected by the single centre design, given that the comparisons were made within wards. A final limitation was our inability to incorporate repeated measures (repeated observations of the same healthcare workers) into our analysis. This was due to the inherent constraint of our study in identifying each healthcare worker entering or leaving the room while also collecting a large amount of data inexpensively and anonymously. This likely resulted in overly narrow CIs due to unmeasured correlation induced by the particular patient and staff; however, this likely did not significantly alter the direction and magnitude of our main effect estimates.

CONCLUSION

In conclusion, the HE on HH events appears to last for a limited time on inpatient wards, implying that human audits are unlikely to contaminate one another and likely have an overall limited effect on HH events. Furthermore, the HE itself is highly dynamic across time of the day and auditor location. Both findings further challenge the use of non-covert auditors to promote sustained HH adherence and support the need for alternative methods to increase HH.

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