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## Major article

## A study of the efficacy of flashing lights to increase the salience of alcohol-gel dispensers for improving hand hygiene compliance

Gianni D'Egidio HBSc, MD, MEng<sup>a,\*</sup>, Rakesh Patel MD, PharmD, MSc<sup>a</sup>,  
Babak Rashidi BCmp, MD<sup>a</sup>, Marlene Mansour MD<sup>a</sup>, Elham Sabri MSc<sup>b</sup>,  
Paul Milgram PhD, PEng<sup>c</sup><sup>a</sup> Department of Medicine, University of Ottawa, Ottawa, ON, Canada<sup>b</sup> Ottawa Research Health Institute, University of Ottawa, Ottawa, ON, Canada<sup>c</sup> Department of Mechanical and Industrial Engineering, University of Toronto, Toronto, ON, Canada

## Key Words:

Infection control  
Human factors  
Hand hygiene  
Flashing lights**Background:** Many interventions have been implemented to improve hand hygiene compliance, each with varying effects and monetary costs. Although some previous studies have addressed the issue of conspicuousness, we found only 1 study that considered improving hand hygiene by using flashing lights.**Method:** Our attention theory-based hypothesis tested whether a simple red light flashing at 2-3 Hz affixed to the alcohol gel dispensers, within the main hospital entrance, would increase hand hygiene compliance over the baseline rate. Baseline and intervention observations were completed over five 60-minute periods (Monday-Friday) from 7:30 to 8:30 AM using a covert observation method.**Results:** Baseline hand hygiene compliance was 12.4%. Our intervention increased compliance to 23.5% during cold weather and 27.1% during warm weather. Overall, our pooled compliance rate increased to 25.3% ( $P < .0001$ ).**Conclusions:** A simple, inexpensive flashing red light affixed to alcohol gel dispensers was sufficiently salient to approximately double overall hand hygiene compliance within the main hospital entrance. We hypothesize that our intervention drew attention to the dispensers, which then reminded employees and visitors alike to wash their hands. Compliance was worse during cold days, presumably related to more individuals wearing gloves.Copyright © 2014 by the Association for Professionals in Infection Control and Epidemiology, Inc.  
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Attention is the ongoing cognitive process of acquiring information from one's environment. In some circumstances, the stimuli that we select to process are inappropriate, resulting in a failure of selective attention. Occasionally, we are unable to focus on one important source of information while ignoring others, resulting in a failure of focused attention. Divided attention is the cognitive process of concurrently distributing one's attention across multiple sources of information within an environment. Here, failure to perceive and process critical cues can be considered a failure of divided attention.<sup>1</sup>

The hospital environment is information-rich and attention-seeking, with many signs, colors, frequent alarms, and public address system announcements. Our hospital's main entrance has

flashing lights at the automated teller machine, auditory cues directing attention to parking payment machines, and many other directions, posters, and signs. In addition, individuals entering the hospital may be easily distracted and/or preoccupied by their cell phones, bags, and coffee mugs. Consequently, hand alcohol gel dispensers, which are inconspicuous objects within hospitals such as ours, are easily ignored.

Errors of omission (ie, omitting necessary tasks) are one of the most common types of human error.<sup>2</sup> In most situations, failure to disinfect hands can be considered an error of omission, consequent to a failure of divided attention. Certain circumstances increase the probability that a particular step or task will be omitted; for instance, tasks in which an item to be acted on is concealed or lacking in conspicuousness are liable to be omitted.<sup>2</sup>

Errors of omission often can be reduced by increasing a target's salience, thereby drawing attention to it. For example, visual attention will be drawn to items that are large, bright, colorful, and constantly changing (eg, blinking).<sup>1</sup> This general concept has been applied in previous hand hygiene studies. In one such study, hand

\* Address correspondence to Gianni D'Egidio, HBSc, MD, MEng, Department of Medicine, University of Ottawa, 501 Smyth Rd, Ottawa, ON, Canada K1H8L6.

E-mail addresses: [degidio.gianni@gmail.com](mailto:degidio.gianni@gmail.com), [gianni.degidio@mail.utoronto.ca](mailto:gianni.degidio@mail.utoronto.ca) (G. D'Egidio).

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hygiene compliance at the front entrance of a large tertiary care hospital at baseline was 0.52% and increased to nearly 12% simply after signage was placed near the existing hand hygiene dispenser.<sup>3</sup> Fakhry et al<sup>4</sup> used motion sensor-triggered audible hand hygiene reminders; compliance improved immediately from 10.6% to 63.7% and was sustained over a 6-month period. However, we found only 1 previous study that evaluated (in a simulated setting) the effect of a flashing light on compliance.<sup>5</sup> That intervention, in combination with improving the line of site of a dispenser, significantly improved preexamination compliance from 37% to 66%.

The purpose of the present study was to evaluate the effect on hand hygiene compliance of a simple, inexpensive, salient red flashing light affixed to hand alcohol gel dispensers at the front entrance of our hospital.

## METHODS

### Setting

The study setting was the main entrance of a large tertiary care academic hospital. We chose the main entrance for observing hand hygiene compliance because numerous observations could be recorded in a relatively short time compared with other locations. Formal approval from our local Research Ethics Board was obtained before study initiation.

Eight hand alcohol gel dispensers were located on 4 sides of 2 separate stands. The stands were located in the main foyer that leads to other halls.

### Properties of the intervention

Four red flashing lights were used. The lights were attached with high-grade organosiloxo polymer (total cost of C\$1.50) to 4 of the 8 alcohol dispensers. The lights were in the line of sight of the majority of pedestrian traffic and operated independent of one another.

Each light lasted up to 15 hours, was rechargeable via a USB cable, and cost \$9.75. In total, our system cost \$40.50 and was installed within minutes.

### Light color

A red light was selected because it conventionally directs individuals to stop or slow down. This would then draw attention to the signage requesting performance of hand hygiene.

### Light frequency

Flashing lights have been shown to be more conspicuous than constant lights.<sup>6,7</sup> The ideal frequency for the present study was deemed to be 2-5 Hz (flashes/second), to ensure greater conspicuousness while not exceeding the threshold of 5 Hz, beyond which epileptiform seizures may be triggered.<sup>8</sup> Our lights had a frequency of 3 Hz.

### Brightness

One potential problem with brightness is annoyance or discomfort. We hypothesized that a flashing red light used to identify bicyclists at night would be adequate for this study, bright enough to catch the attention of passers-by, but not blinding. The lights had a luminous flux of 23 lumens.

### Auditing method

All observers were trained to use the covert observation (ie, "secret shopper") method used at other institutions.<sup>9</sup> Any hand

**Table 1**

Compliance data: percentages during baseline and intervention periods in September 2012,\* January 2013, and April 2013

Period	Compliant	Noncompliant	Total	%
Baseline 1 (September 17-21, 2012)	396	2661	3057	13
Baseline 2 (January 7-11, 2013)	358	2476	2834	12.6
Intervention 1 (January 14-18, 2013)	730	2370	3100	23.5
Baseline 3 (April 15-19, 2013)	360	2699	3059	11.8
Intervention 2 (April 22-26, 2013)	835	2248	3083	27.1

\*No intervention during this period.

hygiene attempt at the moment of entering or exiting the entrance was considered a compliance event, regardless of the quality of the attempt. No identification of the subject as a visitor or an employee was recorded. Over the same time period, all persons entering the hospital were counted. Only children who were judged not capable of using the hand alcohol gel dispenser on their own accord were excluded from this count.

All observations were completed over five 60-minute periods on Monday through Friday, from 7:30 to 8:30 AM.

### Baseline compliance observations

Baseline hand hygiene compliance was determined during 3 separate Monday-Friday inclusive sessions. The initial baseline compliance was evaluated on September 17-21, 2012 (baseline 1) by the principal investigator, with the intention of determining the magnitude of hand hygiene compliance. Subsequent observations of baseline compliance were completed by trained observers (blinded to the study hypothesis and protocol) on January 7-11, 2013 (baseline 2) and April 15-19, 2013 (baseline 3).

### Intervention observations

The first intervention period (intervention 1) was January 14-18, 2013. Trained observers not involved during baseline 1 were used. Of note, a community outbreak of influenza occurred during this intervention period.

Another set of baseline and intervention assessments (intervention 2) was completed on April 22-26, 2013, immediately after baseline 3. This unplanned assessment was performed to determine the effect of cold weather, if any, on compliance during the January observation period.

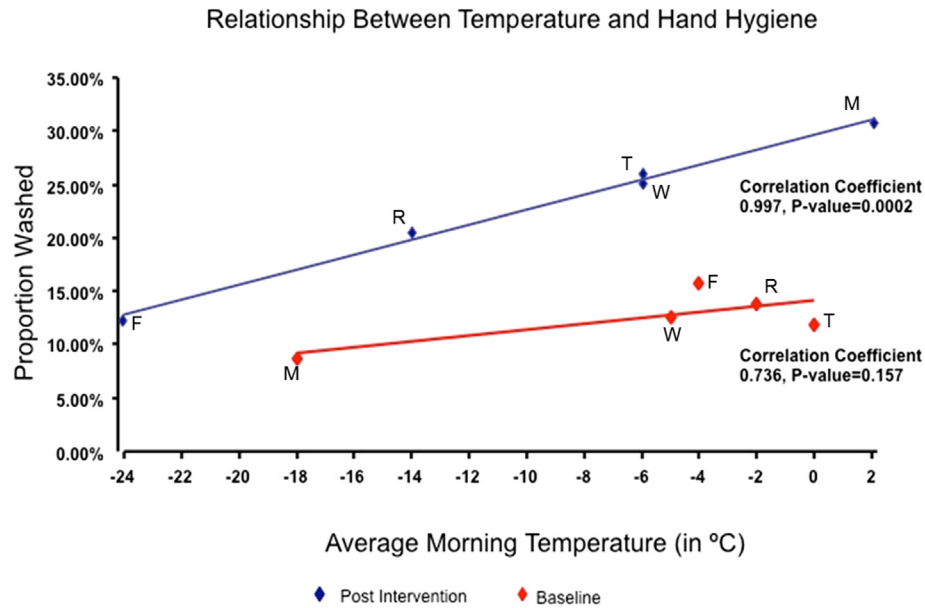
### Statistical analysis

The percentage of observed subjects compliant with hand hygiene was determined by dividing the number of compliant subjects by the total number of subjects deemed eligible to be compliant because they walked past the dispenser stands.

Chi-square analysis was used to determine any statistically significant difference between baseline and postintervention compliance. Post hoc correlation analysis was used to identify any relationship between compliance and morning temperature. (The mean morning temperature for each observation day was calculated by taking the mean of the published values for the 7:00-8:00 and 8:00-9:00 AM time periods from the Environment Canada Web site.) A multivariable linear regression model was applied to determine the adjusted effect of intervention, temperature, and individual days of the week on each day's compliance.

## RESULTS

During this study, we directly observed 15,133 opportunities for hand hygiene. As shown in Table 1, mean hand hygiene compliance



**Fig 1.** Relationship between average morning temperature (in °C) and hand hygiene compliance for baseline 2 and intervention 1 during January 2013. Days of the week are indicated as M-T-W-R-F.

was similar for baseline 1 and baseline 2 (13% and 12.6%, respectively) and increased to 23.5% during intervention 1. The increase was statistically significant ( $P < .0001$ ) relative to the pooled mean baseline compliance of 12.8% (754 of 5891). According to 3 different auditors, the majority of compliant individuals appeared to be visitors, although these data were not formally recorded.

As shown in Figure 1, during intervention 1, compliance decreased from 31.1% on Monday (mean temperature, 2°C) to 20.6% on Thursday (mean temperature, -14°C) and to 12.3% on Friday (mean temperature, -24°C). The observer noted that the majority of individuals were wearing gloves, and that the temperature had decreased substantially during the course of the week. To evaluate the effect of temperature as a confounding factor on hand hygiene compliance, baseline and intervention periods were repeated in April 2013.

Figure 1 also illustrates the correlation between hand hygiene compliance and temperature during baseline 2 and intervention 1. The correlation was significant for intervention 1 ( $r = 0.997$ ;  $P = .0002$ ), indicating that as temperature decreased, so too did compliance.

Our multivariate regression analysis revealed significant effects of intervention ( $P < .0001$ ) and temperature ( $P < .0001$ ) on compliance. There was no interaction effect of individual days of the week and temperature on compliance. As shown in Table 1, mean compliance during baseline 3 was 11.8%, similar to the previous periods. However, compliance increased to 27.1% during intervention 2, a significant difference from the corresponding baseline period ( $P < .0001$ ). In contrast to the baseline 2 and intervention 1 periods, temperature remained relatively constant, and there was no significant relationship between temperature and compliance ( $r = 0.736$ ;  $P = .157$ ).

When results are pooled for the January and April observation periods, intervention compliance was 25.3%, representing a significant relative increase of 104% compared with the pooled baseline compliance of 12.4% ( $P < .0001$ ).

## DISCUSSION

In the present study, we observed that installation of a simple, inexpensive flashing red light increased hand hygiene compliance

at the front entrance of our institution by 12.9% absolutely (104% relatively) compared with baseline compliance.

### Baseline compliance

Baseline hand hygiene compliance at the front entrance of our institution was consistently very low, at 12.4% when all sessions (baselines 1-3) were pooled. Possible explanations for such disappointingly low overall compliance include inconspicuous dispensers; lack of appropriate signage indicating the importance of hand hygiene, objects such as gloves, coffee cups, cell phones, and bags occupying hands; and perhaps a perceived lack of importance of hand hygiene on entry into a health care institution in particular.

Attention theory suggests that weak or ambiguous signals are likely to be ineffective in triggering prescribed actions.<sup>2</sup> We believe that the current hand alcohol gel dispensers located within the main entrance of our institution offer too weak and inconspicuous a signal relative to their competitive environment. To the right of these dispensers are parking payment machines that emit loud computer-generated voices and a banking machine that emits a green light flashing at a rate of 2 Hz, both of which compete with the hand alcohol gel dispensers for an individual's attention. Furthermore, the information on the dispenser stand is in small, difficult-to-read print.

### Effect of flashing lights

One of the most effective countermeasures for reducing errors of omission is the use of reminders. There are five universal criteria for a good reminder: conspicuous, contiguous, context, content, and count.<sup>2</sup> The use of an affixed flashing light should satisfy the conspicuous, context, and contiguous requirements for a good reminder.

The original dispensers, although well placed from a human factors engineering perspective, were not sufficiently noticeable. The addition of the red flashing lights make the dispensers the most conspicuous object at the front entrance, able to catch an individual's attention at a critical time, when entering the hospital (thereby contributing to the context criterion). Furthermore, fixing

the light to the top of the dispenser ensures contiguity; the reminder is positioned as close as possible in time and space to the location of the necessary action.

#### *Comparison with other studies using flashing lights*

One previous study evaluated the effect of flashing lights on hand hygiene compliance before and after physical examination of a standardized patient in a simulated setting.<sup>5</sup> Preexamination hand hygiene compliance nearly doubled, from 37% to 66%, which is similar to our results in relative terms. Interestingly, post-examination compliance did not improve significantly. We agree with Nevo et al<sup>5</sup> that low flashing frequency (1 Hz), the green LEDs, and insufficient light intensity could explain that lack of improvement in postexamination compliance. We speculate that a more conspicuous light, similar to ours, might have had a greater impact. Yet another possible explanation is that their Nevo et al's very high 66% compliance figure might represent something akin to a "saturation effect" (owing to the fact that theirs was a simulator study), and that in reality, compliance figures exceeding this level simply might not be achievable.

#### *Effect of temperature*

Our regression model analysis demonstrated that colder temperatures significantly reduced hand hygiene compliance. The wearing of gloves/mittens was the most likely factor influencing this reduced compliance. Based on the correlation found between temperature and compliance (Fig 1), we speculate that the increased compliance observed during intervention 1 would have been greater had the morning temperature been warmer.

We suggest that if a hospital wishes to increase hand hygiene compliance during the winter months, then signage should explicitly direct individuals to remove gloves/mittens and wash hands on entering the building. In fact, the signs should be placed before the dispensers in an attempt to forewarn individuals, using positive guidance,<sup>1</sup> similar to traffic signs on highways warning drivers of upcoming exits or turns. Furthermore, a surface or small shelf adjacent to the dispensers, on which people could place gloves/mittens, as well as coffee cups, phones, and other objects, while using the dispensers could further increase compliance.

#### *Effect of influenza outbreak*

Coincidentally, during the second study period in January 2013, Ottawa and the rest of Canada were in the midst of one the worst flu seasons in recent history. The outbreak received considerable conventional and social media coverage. Regrettably, we did not find any positive influence of that coverage on hand hygiene compliance, as demonstrated by the similarity of our baseline compliance across the three study periods.

#### *Study strengths and recommendations*

In total, we directly observed 15,133 opportunities for hand hygiene over the 3 study periods. This large number of observations provides greater reliability for baseline compliance and the influence of our intervention. Furthermore, ours was a covert naturalistic study and thus was not affected by the biases seen in overt and/or simulator studies.

The use of highly conspicuous flashing red lights does not require education or training. These lights can be rapidly and easily deployed and replaced, are inexpensive, and are immediately effective. Our

intervention is 10-fold less expensive than the audible reminder system that costs at least US\$500 and takes half a day to install.<sup>4</sup>

#### *Study limitations*

The use of an intense, flashing red light might not be suitable for all hospital locations. For example, placing such a light on a busy ward may promote unfavorable working conditions and annoyance. A flashing light of reduced intensity and frequency may be a feasible alternative, but the trade-off may be a reduction in salience. A motion sensor-triggered visual message has been implemented successfully and also may be suitable for this purpose.<sup>10,11</sup>

Given the short duration of our intervention, we cannot comment on the durability of the effect of the flashing red lights. It may be that individuals who are exposed to the flashing lights over weeks to months may no longer comply as they grow tired of the stimulus or perhaps even resent it. In fact, acclimatization may be another explanation for the declining compliance as the particular observation week progressed. Employees and visitors might have become accustomed to the lights and thus ignored them, thereby compromising compliance.

It should be noted that if the lights are not securely affixed to the dispensers, individuals certainly may manipulate or attempt to steal them. Occasionally, and unexpectedly, our auditors had to instruct visitors or employees to stop tampering with the lights. This action could have resulted in the discovery of an auditor and spuriously increased compliance by visitors and staff if they perceived that they were being observed.

#### **CONCLUSION**

The installation of flashing red lights is a potentially effective way to increase short-term hand hygiene compliance (eg, during infection outbreaks) at the front entrance of a hospital. Cold weather appears to decrease compliance, because more people are likely to be wearing gloves/mittens. We plan on evaluating the long-term effect of flashing lights by permanently fixing the flashing red lights to the dispensers and measuring compliance over the span of weeks.

#### **References**

1. Wickens CD, Hollands JG. *Engineering psychology and human performance*. 3rd ed. Upper Saddle River [NJ]: Prentice-Hall; 2000.
2. Reason J. Combating omission errors through task analysis and good reminders. *Qual Saf Health Care* 2002;11:40-4.
3. Birnbach DJ, Nevo I, Barnes S, Fitzpatrick M, Rosen LF, Everett-Thomas R, et al. Do hospital visitors wash their hands? Assessing the use of alcohol-based hand sanitizer in a hospital lobby. *Am J Infect Control* 2012;40:340-3.
4. Fakhry M, Hanna GB, Anderson O, Holmes A, Nathwani D. Effectiveness of an audible reminder on hand hygiene adherence. *Am J Infect Control* 2012;40:320-3.
5. Nevo I, Fitzpatrick M, Thomas RE, Gluck PA, Lenchus JD, Arheart KL, et al. The efficacy of visual cues to improve hand hygiene compliance. *Simul Healthc* 2010;5:325-31.
6. Gerathewohl SI. Conspicuity of steady and flashing light signals: variation of contrast. *J Opt Soc Am* 1953;43:567-71.
7. Vos JJ, Van Meeteren A. Visual processes involved in seeing flashes. *International Symposium of Imperial College of London. The Perception and Application of Flashing Lights*. London: Adam Hilger Ltd; 1971. p. 3-16.
8. Scadding JW, Losseff N. *Clinical neurology*. 4th ed. London: Hodder Arnold; 2011. p. 285.
9. John Hopkins Medicine. Secret Shopper Method. Available from: [http://www.hopkinsmedicine.org/heic/infection\\_surveillance/hand\\_hygiene.html](http://www.hopkinsmedicine.org/heic/infection_surveillance/hand_hygiene.html). Accessed September 18, 2012.
10. Swoboda SM, Earsing K, Strauss K, Lane S, Lipsett PA. Electronic monitoring and voice prompts improve hand hygiene and decrease nosocomial infections in an intermediate care unit. *Crit Care Med* 2004;32:358-63.
11. Levchenko AI, Boscart VM, Fernie GR. The feasibility of an automated monitoring system to improve nurses' hand hygiene. *Int J Med Inform* 2011;80:596-603.