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Hansen, Pelle Guldborg; Gahner Larsen, Erik; Modin, Alexander; Gundersen, Caroline; Schilling, Mathilde

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Nudging hand hygiene compliance: a large-scale field experiment on hospital visitors

P.G. Hansen [a,*], E.G. Larsen [b], A. Modin [c], C.D. Gundersen [c], M. Schilling [c]

[a] Roskilde University, Roskilde, Denmark
[b] School of Politics and International Relations, Rutherford College, University of Kent, Canterbury, UK
[c] iNudgeyou — The Applied Behavioural Science Group, Copenhagen, Denmark

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SUMMARY

Background: Hospital-care-associated infections (HCAIs) represent the most frequent adverse event during care delivery, affecting hundreds of millions of patients around the world. Implementing and ensuring conformity to standard precautions, particularly best hand hygiene practices, is regarded as one of the most important and cheapest strategies for preventing HCAIs. However, despite consistent efforts at increasing conformity to standard hand hygiene practices at hospitals, research has repeatedly documented low conformity levels amongst staff, patients and visitors alike.

Aim: The behavioural sciences have documented the potential of adjusting seemingly irrelevant contextual features in order to 'nudge' people to conform to desirable behaviours such as hand hygiene compliance (HHC). In this field experiment we investigate the effect on HHC amongst visitors upon entry of a hospital by varying such features.

Methods: Over 50 days, we observed the HHC of a total of 46,435 hospital visitors upon their entry to the hospital in a field experimental design covering eight variations over the salience, placement and assertion of the hand sanitizer in the foyer, including the presence of the yearly national HHC campaign and a follow up during the COVID-19 pandemic.

Findings: Our experiment found that varying seemingly irrelevant features increased HHC from a baseline of 0.4%–19.7% (47.6% during COVID-19). The experiment also found that the national HHC-campaign had no direct statistically significant effect on HHC.

Conclusion: Varying seemingly irrelevant contextual features provides an effective, generic, cheap and easy to scale approach to increasing HHC relative to sanitizing one's hands at hospitals.

Introduction

Hospital care-associated infections (HCAIs) represent the most frequent adverse events during care delivery affecting hundreds of millions of patients around the world each year [1]. In a highly developed country such as Denmark, it has been estimated that one in every 10 hospitalized patients acquire an infection during their hospitalization [2]. In healthcare settings with more limited resources, the prevalence of HCAIs is reported to be even higher [1]. HCAIs are costly to society as a whole and create additional suffering for the patient which, at

* Corresponding author. Address: Roskilde University, Roskilde 4000, Denmark.
E-mail address: pgh@ruc.dk (P.G. Hansen).

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worst, may lead to death [3]. In the USA alone, almost 100,000 people are estimated to die of HCAIs every year [4].

The good news is that many HCAIs are easily preventable. Implementing and ensuring conformity to standard precautions is one of the most effective and cheapest strategies for preventing HCAIs. In particular, merely improving conformity to best hand hygiene practices in hospitals is among the most promising ways of preventing HCAIs [5]. However, despite continuous efforts to increase conformity to standard hand hygiene practices at hospitals through information, instructions and campaigning, research has repeatedly documented low conformity levels amongst staff, patients and visitors alike [6–8].

This is specifically the case for hand hygiene compliance (HHC) amongst visitors, understood as non-staff at the hospital, but not currently hospitalized. One observational study involving multiple hospitals reported in 2019 that visitors and patients accounted for 15.4% of all entries and exits from patient rooms in the acute-care setting [9]. While many efforts have been made to improve healthcare workers' HHC (e.g., [10,11]), far less has been done in order to maintain high levels of HHC among visitors. This may explain the low levels of visitor HHC, e.g., 0.52% [12], 3% [13], 7% [14], reported in the limited literature on this issue. In fact, despite visitors playing a substantial part in hospital activity, only these three experiments aimed at increasing visitor HHC have, to our knowledge, been published.

All three experiments explore how adjusting seemingly irrelevant contextual features may 'nudge' people to conform to standard hand hygiene practices. Originally proposed by Thaler and Sunstein [15] a nudge is defined here according to Hansen [16] as

> "a function of (a) any attempt at influencing people's judgment, choice or behaviour in a predictable way (b) that is motivated because of cognitive boundaries, biases, routines, and habits in individual and social decision-making posing barriers for people to perform rationally in their own self-declared interests, and which (c) works by making use of those boundaries, biases, routines, and habits as integral parts of such attempts".

Using this definition, nudges may be conceived of as subtle psychologically informed interventions that seek to influence people's decisions in directions which, when used benignly, better fit their declared self-interests [17].

These experiments on nudging HHC have shown great potential in increasing HHC by such simple means as increasing the salience, improving the placement and emphasizing the assertive force of existing hand sanitizers. In one experiment, an increase in HHC from 0.52% to 11.67% was obtained by merely placing a free-standing alcohol-based hand sanitizer (AHS) in front of a security desk with a sign mandating all visitors to use AHS [12]. Another experiment increased HHC amongst visitors from 3% to 67% by placing an AHS in front of the entrance of a hospital section with a sign that read "Here we use HAND DISINFECTANT in order to protect your relative" [13]. A third experiment replicating that by Aarestrup *et al.* [13] found an increase from 7% to 46% in visitors' HHC in terms of using the AHS [14].

However, the three experiments are based on small sample sizes and provide little insight into interaction effects and moderators in the treatments; Birnbach *et al.* [12] had a baseline of 3000, and three treatments each comprising 300 visitors; Aarestrup *et al.* [13] only had a baseline of 30, and each of the two treatments comprising 30 visitors as well; and Mobekk and Stokke [14] had a baseline of 100, and two treatments comprising 100 visitors, respectively. As a result, comparison of treatments beyond the extremes (baseline vs best treatment) in all three experiments fail to show statistically significant differences between treatments. In addition, the small sample sizes together with experimental designs used in these experiments do not allow for (1) exploring specific interaction effects when combining the salience, placement and assertion of AHS; or (2) statistically exploring the potential individual (e.g., gender effects) or contextual (e.g., time of the day effects) moderators otherwise indicated by their observations. Finally, (3) neither of these experiments looks at how treatments interact with the most prevalent existing measure in promoting visitor HHC, namely HHC campaigns.

It is for these reasons that our experiment sets out to estimate the effect of varying the salience, placement and assertion of AHS, including potential interaction effects with a standard HHC campaign as well as gender and time of the day effects. As an extension, we returned during the COVID-19 pandemic one year later and estimated the effect of the most effective treatment which by then had been implemented at the hospital.

Methods

The experiment was conducted in cooperation with Danish Regions (The Danish Interest and Employer organization for the five Danish Regions) and one of Denmark's largest hospitals with 40,000 hospitalized patients each year. More than 46 days of observation (between 2nd April 2019 and 23rd August 2019) over 294 h a total of 41,702 hospital visitors (excluding children, staff and chauffeurs) were observed upon their entry to the main foyer of the hospital by four experienced observers who, in turn, were discretely seated in the waiting areas of the hospital foyer. Visitors were not identified, and no record was kept of individual visitors. No formal inter-observer agreement was conducted, and cases of doubt with regard to status of being a child, staff, or gender was resolved by excluding the observation from the data. Eighteen months later, during the COVID-19 pandemic, we returned and measured the effect of the most effective treatment over four days (25th March to 7th April 2021) which by then had been implemented at the hospital by observing 4733 additional visitors.

Observations covered, besides a baseline period, nine variations (each of four consecutive days), plus a follow up observation one year later during the COVID-19 pandemic of four days, adjusting the salience, placement and assertion of the hand sanitizer in the foyer in combination with the presence of the yearly national hand hygiene campaign. The resulting 11 scenarios observed were as follows (see the Supplementary material for conceptual illustrations):

(1) Baseline: a free-standing AHS was placed in its usual place next to the reception desk and clearly visible to all visitors. The HHC of 5316 visitors was observed over a total of eight days with six consecutive days to begin with ($N = 4000$), plus two additional days ($N = 544$; $N = 772$) inserted after scenarios 2 and 4.
(2) Placement 1: the free-standing AHS was strategically placed approx. 5 m in front of the reception desk so that

visitors had to pass this directly upon entering the hospital foyer. The HHC of 2580 visitors was observed over four consecutive days.

(3) Salience: the free-standing AHS was again placed in its usual place next to the reception desk and clearly visible to all visitors, but made more salient by attaching a pink sign reading "SANITIZER" with white font on the AHS. The HHC of 3242 visitors was observed over four consecutive days.

(4) Placement 1 + salience: the free-standing AHS was strategically placed approx. 5 m in front of the reception desk so that visitors had to pass this directly upon entering the hospital foyer and made more salient by attaching a pink sign reading "SANITIZER" with white font on the AHS. The HHC of 2982 visitors was observed over four consecutive days.

(5) Campaign: the free-standing AHS was again placed in its usual place next to the reception desk and clearly visible to all visitors (and without the sign), but accompanied by a pink roll-up banner and a pink sticker for the AHS from the yearly official HHC campaign both reading "Clean Hands Save Lives" in white font and placed next to the reception. To emphasize, the experimental design was coordinated with this national campaign, such that the treatment coincided with the launch of this throughout Danish hospitals. The HHC of 5320 visitors was observed for a total of six days.

(6) Salience, placement 1 + campaign: the free-standing AHS was strategically placed approx. 5 m in front of the reception desk so that visitors had to pass this directly upon entering the hospital foyer, made more salient by attaching the pink sign reading "SANITIZER" with white font on the AHS, and accompanied by a pink roll-up banner from the yearly standard HHC campaign reading "Clean Hands Saves Lives" in white font and placed next to the reception. The HHC of 3530 visitors was observed over four consecutive days.

(7) Placement 2: the free-standing AHS was placed in front of the entry doors so that visitors had to pass this directly before entering the hospital foyer. The pink roll-up banner was still placed next to the reception inside the building, but difficult to spot from the entrance and the AHS had a small pink sticker on it. The HHC of 5101 visitors was observed over four consecutive days.

(8) Placement 2 + salience: the free-standing AHS was placed in front of the entry doors, but made salient by attaching the pink sign. The pink roll-up banner was still placed next to the reception inside the building, but was difficult to spot from the entrance. The HHC of 4005 visitors was observed over four consecutive days.

(9) Placement 2 + salience + assertion: the free-standing AHS was placed in front of the entry doors, made salient by attaching the pink sign, and a line was laid down in front of the door with pink duct tape matching the sign in order to signal to visitors that certain rules applied when crossing the line – rules that pertained to the use of sanitizer. The pink roll-up banner was still placed next to the reception inside the building, but was difficult to spot from the entrance. The HHC of 5331 visitors was observed over four consecutive days.

(10) Placement 2 + salience + assertion + campaign: this treatment was identical to the previous treatment with the exception that, besides the free-standing AHS being placed in front of the entry doors, made salient by attaching the pink sign, and a line being laid down in front of the door with pink duct tape matching the sign in order to signal to visitors that certain rules applied when crossing the line, the pink roll-up banner was placed next to the

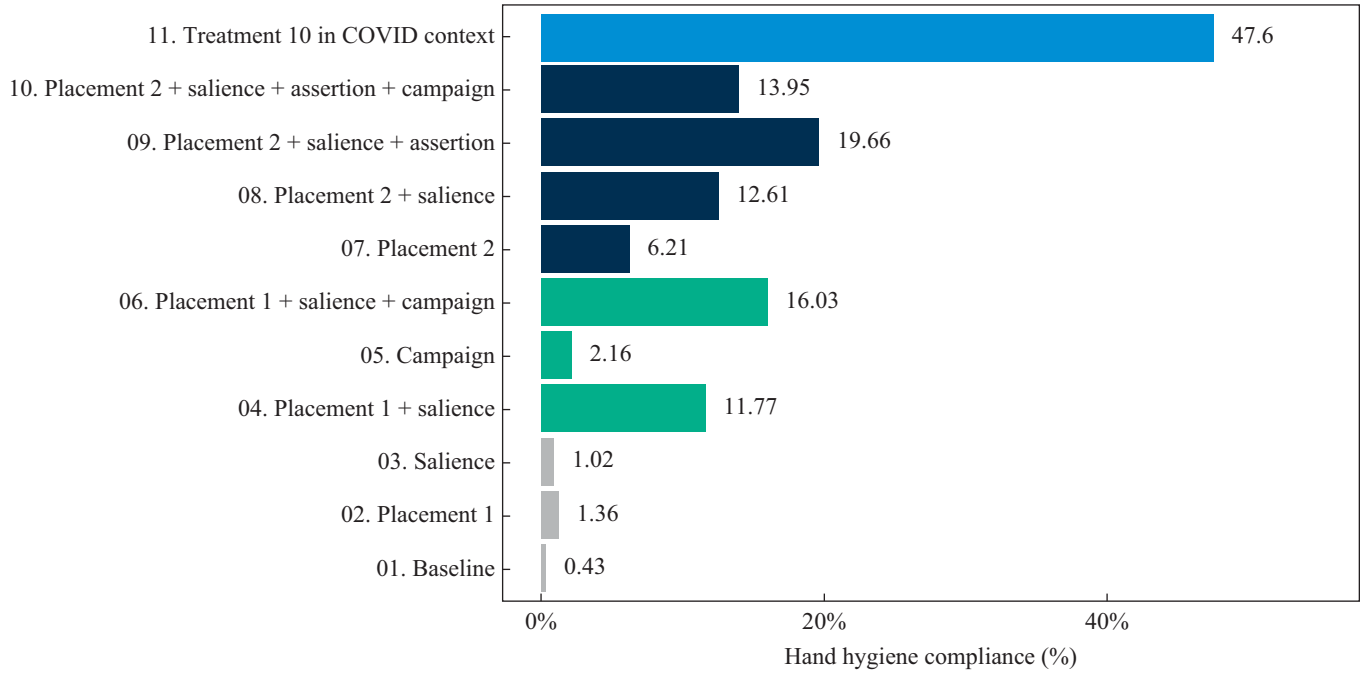

Figure 1. Percentage of people sanitizing their hands upon entering the hospital.

interventions in front of the door. The HHC of 4295 visitors was observed over four consecutive days.

(11) Placement 2 + salience + assertion + campaign following the COVID-19 pandemic: this treatment was implemented by the hospital after the experiment. We returned to measure conformity one year after the COVID-19 pandemic had broken out, but before vaccines had been delivered population wide. The HHC of 4733 visitors was observed over a total of four days.

Results

Our experiment observed the level of HHC amongst a total of 46,435 hospital visitors over 50 days. We found low levels of HHC in the baseline measurements similar to those reported in past studies, with HHC merely being 0.43% ($N = 5,316$). While each of the individual adjustments, salience and placement 1 (scenarios 2, 4 and 5), showed no statistically significant effects and the yearly national campaign only a very modest one, placement 2 showed a significant effect (scenario 7). Interestingly, however, all combinations of the adjustments lead to large improvements in HHC. We saw the largest percentage of people sanitizing their hands in the condition when free-standing AHS was placed in front of the entry doors with the pink sign with a pink line. In addition, the pandemic was also revealed to have a large effect on HHC. Figure 1 presents the percentage of people sanitizing hands upon entering the hospital across all conditions.

In Table I, we estimated the average treatment effects of the different conditions on HHC. The reference group was the baseline. That is, the coefficients should be interpreted as the difference between the specific scenario and the baseline scenario. The model also controls for gender, the day of observation (to capture any seasonal trend) and time of the day (as fixed effects). There are substantial differences across the different treatments in terms of their effects. The smallest effects are the ones with placement 1, that are both less than one percentage point and statistically insignificant. We see the largest effect for placement 2 with salience and assertion. The treatment effect here is close to 20 percentage points.

Figure 2 shows the percentage of men and women sanitizing hands upon entering the hospital. On average, we see that women are more likely to respond positively to the different conditions.

Table II presents the results from interaction models and, in particular, the coefficients from the interaction term (full models are available in the supplementary data). We see that for four of the conditions, the treatment effects are significantly smaller for men than for women. Specifically, the negative coefficients in the table show how men are less likely to comply. The largest difference is for the salience condition, where the treatment effect is 7.35 percentage points greater for women than for men. This is in line with the visual presentation of the average differences provided in Figure 2.

Lastly, for the HHC of the 4733 visitors observed over four consecutive days one year after the outbreak of the COVID-19 pandemic, we found a high level of HHC of 47.6%. Noteworthy, there was a large gender difference here with 53.3% of the women using the hand sanitizer whereas this number was 39.7% for the men.

Table I
The average treatment effects on hand hygiene compliance

	Coefficient (S.E.)
02: Placement 1	0.856 (0.728)
03: Salience	0.369 (0.706)
04: Placement 1 + salience	11.124*** (0.708)
05: Campaign	1.281 (0.816)
06: Placement 1 + salience + campaign	15.485*** (0.787)
07: Placement 2	5.489*** (0.770)
08: Placement 2 + salience	11.774*** (0.850)
09: Placement 2 + salience + assertion	18.882*** (0.907)
10: Placement 2 + salience + assertion + campaign	13.189*** (1.549)
11: Treatment 10 in COVID context	46.214*** (7.849)
Male	−3.438*** (0.288)
Observations	46,435
Adjusted R^2	0.169

The estimates are unstandardized regression coefficients with standard errors (S.E.) in parenthesis. The model further controls for day of study (linear trend) and with hour of day fixed effects.
* $P<0.1$, ** $P<0.05$, *** $P<0.01$.

Discussion

Our results confirm that varying simple, cheap, non-invasive and easily scalable contextual features such as placement, salience and assertion can nudge significant increases in visitor HHC. However, not all interventions are equal and the findings show how specific combinations of the salience, placement and assertion of AHS is likely to increase HHC amongst hospital visitors.

First, our experiment shows that of the four types of treatments tested, the placement of AHS is crucial in order to increase HHC and in particular also to ensure the efficiency of the other treatments of salience and assertion. We found a large treatment effect of around 20 percentage points by implementing the simple nudges before the pandemic, and the compliance rate with this intervention in place increased to around 50% one year into the pandemic. The placement of AHS appears to be the crucial parameter to consider when seeking to increase visitor HHC.

Second, when it comes to moderators, the interventions increase the compliance among both men and women,

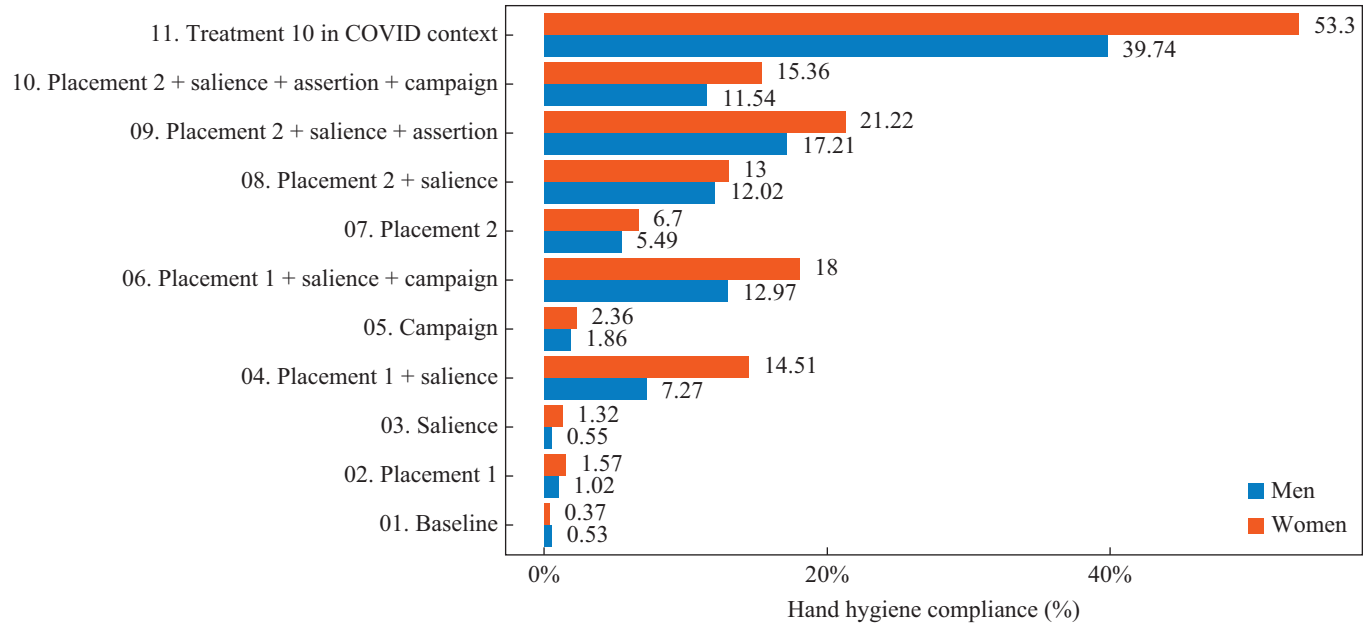

Figure 2. Percentage of people sanitizing their hands upon entering the hospital, men and women.

although — as also indicated by Mobekk and Stokke [14] — the specific interventions increase the compliance more among women than men. We can only speculate why this is so. The treatments besides placement involved the use of the colour pink, chosen to match the main colour of the yearly HHC-campaign. This colour, different from that in Aarestrup *et al.* [13] and Mobekk and Stokke [14] which made use of red, might have appealed more to women due to cultural associations as well as because it is the colour used internationally in campaigns aimed at increasing awareness about female breast cancer [18]. While the observed gender differences might be related to these usages, the experiment provides no clues about what may explain the observed differences. Accordingly, future research should examine how such features might diminish the gender difference in the effectiveness of the interventions. As for a time-of-day effect, it is noteworthy that there is no evidence in our experiment for this. The changes in compliance during the day are small, i.e. within a few percentage points, and are not statistically significant. Thus, we found no decreasing time-of-day effect relative to visitors' HHC as might be hypothesized on the basis of studies such as that by Dai *et al.* [19] focusing on potential fatigue and depletion.

Third, the experiment shows that the most prevalent measures used to promote visitor HHC, namely campaigns, not only seem to have merely modest effects on behaviour, but also that these appear to be non-trivial. That is, while the presence of the campaign significantly boosts visitor HHC for placement 0 and 1 of the AHS, it leads to a significant decrease in visitor HHC for placement 2. We can only speculate why this is so, but none of the possible explanations that come to mind qualify as an intended persuasive effect by the messenger mediated by rational deliberation on behalf of visitors. Thus, one of three possibilities obtain: either we are missing a potential rational explanation, or the result is a fluke albeit a statistically significant one, or the campaign influences its effects by irrational means or preconditions. However, these findings confirm the importance of not only studying simple interventions on their own, but also how the interactions between them shape HHC.

Finally, the observations during the COVID-19 pandemic one year later provide an indication of the effect of the global pandemic. Yet, while visitors' HHC was much higher in this extension, it illustrates the extreme difficulty of ensuring high HHC amongst visitors even during 'optimal' conditions. Noteworthy, it also emphasizes how the context of experiments will affect the baseline level of HHC.

As for the limitations of our experiment, the findings presented above stem from one hospital in Denmark. Future work is needed in order to examine the extent to which the findings will generalize to other hospitals and other hospital settings. Also, background variables, such as educational level and cultural background, were not available in the experiment. Despite being difficult and somewhat intrusive to measure, such characteristics could be studied in future research. A further limitation is that our experiment does not explore the potential further effects of using various persuasive messages such as those in Aarestrup *et al.* [13] and Mobekk and Stokke [14]. In a similar fashion, the experiment did not measure variations over the campaign and potential tweaks of this. Given the funding going into such campaigns, we encourage future research in this direction. Another limitation is that no formal inter-observer agreement was made and that potential serial effects, where one visitors' HHC or lack thereof influences a subsequent visitor observing this.

In conclusion, HCAIs represent the most frequent adverse event during care delivery affecting hundreds of millions of patients around the world each year. Implementing and ensuring conformity to standard precautions such as visitor HHC is one of the most promising, effective and cheapest strategies for preventing HCAIs. Yet, incredibly low conformity levels have been recorded on visitor HHC as in this experiment which recorded a baseline level of merely 0.4%.

Table II
The average treatment effects on hand hygiene compliance, gender differences

	Coefficient (S.E.)
02: Placement 1	−0.643
	(1.489)
03: Salience	−0.891
	(1.377)
04: Placement 1 + salience	−7.325***
	(1.421)
05: Campaign	−0.563
	(1.200)
06: Placement 1 + salience + campaign	−5.112***
	(1.343)
07: Placement 2	−1.294
	(1.210)
08: Placement 2 + salience	−1.078
	(1.292)
09: Placement 2 + salience + assertion	−4.100***
	(1.200)
10: Placement 2 + salience + assertion + campaign	−3.876***
	(1.277)
11: Treatment 10 in COVID context	−13.590***
	(1.229)
Observations	46,435
Adjusted R^2	0.172

The estimates are unstandardized regression coefficients with standard errors (S.E.) in parenthesis. A negative coefficient suggests that men are less likely to show hand hygiene compliance. The model includes parameters for the additive effects of gender and the conditions (not shown). The model further controls for day of study (linear trend) and with hour of day fixed effects.
* $P<0.1$, ** $P<0.05$, *** $P<0.01$.

Recently, the behavioural sciences have documented the potential of adjusting seemingly irrelevant contextual features in order to 'nudge' people to conform to individually as well as socially desirable behaviours such as HHC by means of cheap, non-invasive and easily implementable and scalable interventions. In particular, a small number of initial experiments with nudging visitors' HHC have indicated a potential for significantly increasing this. However, these experiments suffer from a series of limitations: low number of observations; no recording of the interaction effects from combining nudges; no comparison of their effect and interaction with the most prevalent measure for increasing visitors HHC, i.e. persuasive campaigns; no data on potential gender differences and time-of-day effects.

By varying seemingly irrelevant contextual features, our experiment succeeded in nudging significant increases in visitor HHC. Through the combination of three nudges — placement, salience and assertion — we succeeded in increasing HHC from 0.4% to 19.7% in a pre-COVID-19 setting. Returning to the hospital one year into the COVID-19 pandemic, where the best combination had been implemented throughout, we recorded a 47.6% HHC level. Further, the national persuasive hand hygiene campaign showed only a modest, non-trivial, but positive effect if integrated, the reason for which the experiment does not identify. Also, a significant gender difference was observed where women on average were more likely to respond positively to the different treatments, but no time-of-the day effect was found. Thus, on the basis of this large field experiment it may be concluded that nudging is not only a cheap, non-invasive and easily implementable and scalable approach to increasing hospital visitors HHC, but also a highly effective one.

Conflict of interest statement
None declared.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jhin.2021.09.009.

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