

# BMJ Open Quality Nudging healthcare professionals to improve treatment of COVID-19: a narrative review

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## INTRODUCTION

The COVID-19 pandemic has placed unprecedented stress on healthcare systems worldwide and disrupted routine care. Healthcare professionals (HCPs) have had to quickly improvise and adapt to cope with a novel deadly virus with uncertain treatment options, lack of evidence, and a shortage of medical supply and personal protective equipment.

In an ideal world, clinicians would base their decisions on scientific evidence and best practices. In practice, however, behavioural science shows that decisions are affected by emotional and cognitive biases, especially under stress.<sup>1 2</sup> Understanding the behavioural nature of decision-making is essential for designing processes that mitigate risks and improve the quality of care. This is particularly important because of the fast-paced developments characterising the COVID-19 pandemic.

One effective strategy in improving decision-making is nudging: subtle changes to the design of the environment or framing choices without restrictions to encourage a given behaviour.<sup>3</sup> These strategies are often easy to scale and implement at a low cost, making nudging a practical approach to behaviour change.<sup>4</sup> Nudging interventions have been widely effective,<sup>5-15</sup> but often patient directed, and less attention has been given to the use of behavioural insights to support HCPs in making appropriate medical decisions.

In this review, we synthesise the available literature on how nudging techniques can be used to affect the behaviour of HCPs in clinical settings in order to see if these can be useful in the prevention and treatment of COVID-19. The results are intended to guide and inspire quick implementation of cost-effective solutions that can improve the quality of care.

Our objective was to identify interventions using nudge theory<sup>3</sup> to affect the behaviour

of HCPs in clinical settings, focusing on target groups, nudging techniques, delivery systems and empirical evidence.

## METHODS

We conducted a narrative review to explore the role of nudging in supporting HCPs in the prevention and treatment of COVID-19.

Studies eligible for inclusion were: (1) interventions conducted in a clinical setting targeting healthcare personnel, (2) behavioural interventions using the term nudging, (3) randomised controlled trials, quasi-experimental or longitudinal (before-after) studies, (4) original research articles published in English and in peer-reviewed journals between 2010 and 2020.

Articles were searched by an information specialist at the university library on two electronic databases: PubMed and PsycINFO. We searched the term 'nudging', 'nudges', or 'nudge' in the titles or abstracts of articles published from January 2010 to December 2020. Two of the authors performed individual blinded screening of titles and abstracts from the search using the Rayyan QCRI systematic review tool.<sup>16</sup> Studies were selected in three phases: (a) removing duplicates, (b) screening titles and abstracts, and (c) screening full-text articles.

Articles that described an intervention to change the behaviour of HCPs in a clinical setting and deemed relevant to COVID-19 were included. Reviews, opinion letters, editorials, and publications that were not published in English were excluded and nudging interventions not relevant to the treatment of COVID-19 (The table is in the repository Zenodo. <https://doi.org/10.5281/zenodo.5545926>).

The blind was then lifted, and any disagreements between authors were discussed with a third author until a consensus was reached.

The included articles were then reviewed to extract key information about each

intervention, including purpose, target behaviour, measured outcomes, key findings, nudging strategies used and their theoretical underpinnings. The characteristics of the nudging strategies that would allow for systematic grouping were identified. Several grouping approaches were discussed until the most appropriate grouping was selected. The studies were categorised and characterised using descriptive analysis.

Nudging is often referenced to two modes of thinking: the automatic system (system 1) and the reflective system (system 2).<sup>3 17</sup> However, the underlying behavioural strategies that give rise to different interventions are not always described or easy to characterise. Therefore, we categorised the nudging strategies according to two practical dimensions:

- ▶ Synchronous versus asynchronous: an intervention strategy is synchronous if its delivery coincides with the decision or behaviour it intends to affect, while an asynchronous strategy can be performed anytime. For example, providing alternative options when a clinician is prescribing antibiotics in the electronic system is a synchronous strategy: alternative options (nudge) are presented when the prescription (target behaviour) is taking place. A poster providing information on sound antibiotic prescribing is an asynchronous strategy not connected to a specific prescription.
- ▶ Active versus passive: an active strategy cannot be completed without action from the targeted clinician, while a passive strategy does not require any action. For example, requesting written justifications for an antibiotic prescription to complete the order is active strategy: the prescription (target behaviour) cannot be completed without justification (nudge), while changing the default prescription is a passive strategy.

## RESULTS

The database search yielded 1436 articles (figure 1); 36 duplicates and additional 1352 articles that did not fulfil the inclusion criteria were excluded. Of the 48 articles included for full-text review, 28 were excluded because they were not relevant to COVID-19, resulting in 20 articles included in the analysis.

### Summary of the included studies

Table 1 summarises the characteristics of the included studies. Online supplemental table S1 gives a more detailed view of the different interventions.

Four different focus areas relevant to COVID-19 were identified: ventilation, hand hygiene, vaccination and antibiotics (online supplemental table S1 for a more detailed view, and S2 table <https://doi.org/10.5281/zenodo.5545926> for full view). Four studies related to ventilation of intubated patients,<sup>18–21</sup> five targeted hand hygiene measures,<sup>22–26</sup> six focused on increasing vaccination rates<sup>27–32</sup> and five focused on encouraging judicious antibiotic prescription.<sup>33–37</sup>

Out of the 20 studies included for analysis, seven employed more than one medium of intervention, and

13 employed only one. While seven studies delivered the intervention via electronic health records (EHRs) or electronic prescription ordering systems, nine used communication technologies such as email, text messages or traditional letters. Six studies altered the physical environment by using posters, lights or aromatisation, two made modifications to the ventilation machines and two introduced electronic dashboards. Seventeen of the 20 articles had a statistically significant positive result (online supplemental table S1). Of the three that failed, two<sup>24 29</sup> delivered the nudge through email and one through letter.<sup>30</sup>

Overall, 28 different nudging strategies were identified, including accountable justifications, active choices, alerts and reminders, default settings, environmental cueing, feedback, peer comparison, goal setting, information transparency, suggested alternatives and education (online supplemental table S1). There was no standard nomenclature across articles, and many of the articles did not discuss the underlying behavioural theories that gave rise to the nudging intervention.

The authors characterised each of the identified nudging strategies as active, passive, synchronous or asynchronous (figure 2). Seven studies used a combination of several intervention strategies. While this increases the possibility of an effective intervention, it also makes it difficult to determine exactly which strategies make an intervention successful.

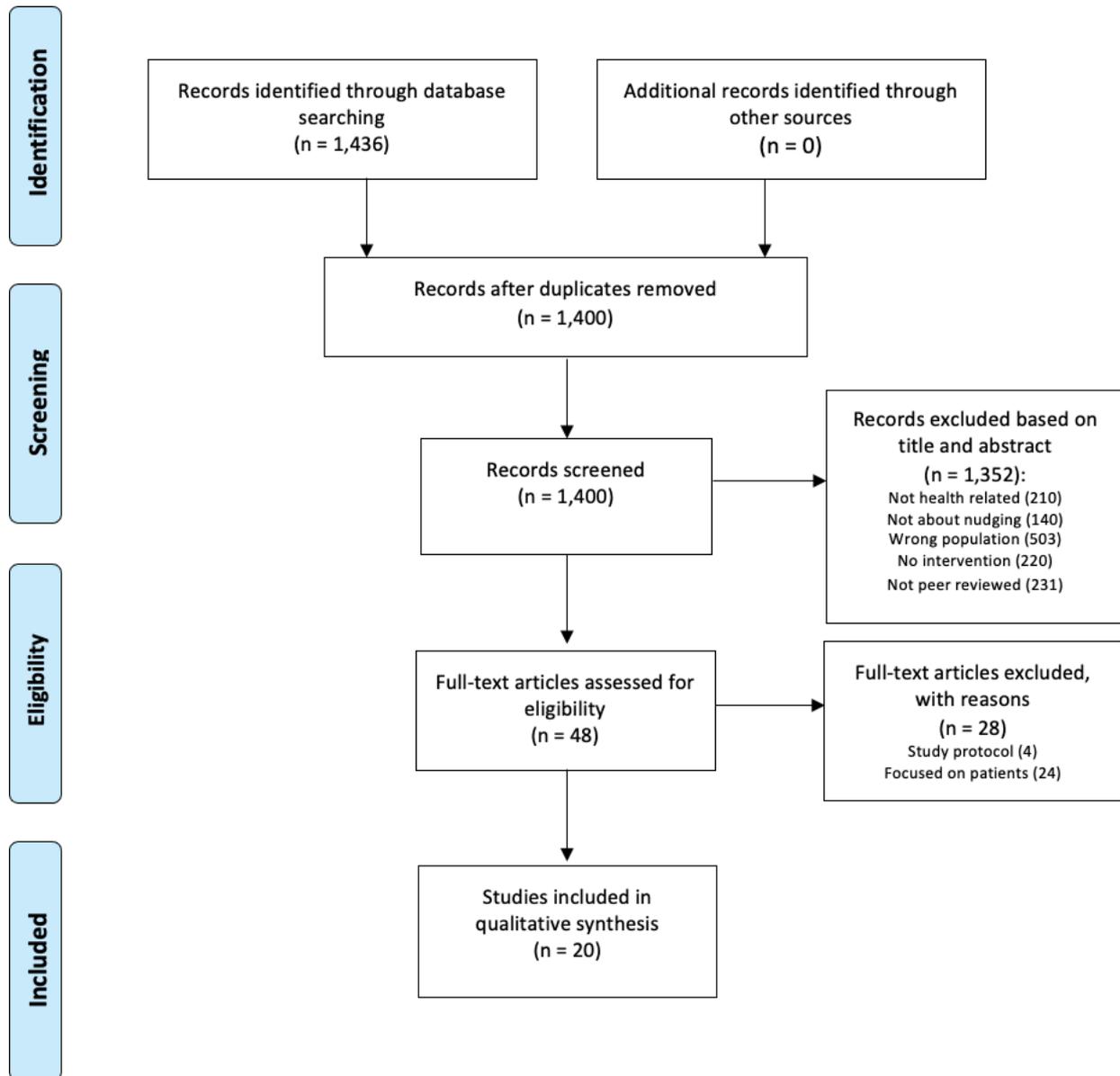
### Description of the nudging content and strategies

#### Improving care for mechanically ventilated patients

All four nudging interventions had significant positive results. Two studies<sup>19 20</sup> achieved a significant improvement by changing the default ventilator settings to comply with evidence. O'Reilly-Shah *et al*<sup>20</sup> complemented their intervention with personal emails to clinicians, summarising compliance metrics compared with department goals. These passive and asynchronous strategies do not require any action on the part of the clinician and can be performed anytime.

Anderson *et al*<sup>21</sup> reduced the duration of mechanical ventilation (MV) and intensive care unit (ICU) length of stay by implementing an electronic dashboard and alert system to promote sedation minimisation and ventilator liberation. The intervention consisted of: (1) a web-based dashboard with real-time data on spontaneous breathing trial readiness, sedation depth, sedative infusions, and nudges to wean sedation and ventilator support; and (2) text-message alerts once patients met the criteria for spontaneous breathing and spontaneous awakening trials. A real-time dashboard was also implemented to visualise which patients were receiving appropriate low tidal volume (TVe).<sup>19</sup> These active strategies prompt clinicians to make conscious decisions at a critical moment.

Another intervention beneficial to MV patients is the use of chlorhexidine mouthwash, which reduces the rate of ventilator-associated pneumonia (VAP) in critically ill patients. An intervention was designed with chlorhexidine mouthwash as a default prescription to the electronic



**Figure 1** Flow diagram of publication selection process.

prescribing template, leading to a significant increase in its prescription.<sup>18</sup> Although ordering a prescription is a conscious decision, including default orders is a passive strategy that reduces the cognitive burden. No active action is required unless the clinician has a strong reason to remove the default order.

#### Improving hand hygiene in the hospital or clinic

Four of the five studies showed a significant positive result. Posters with carefully crafted messages and hand washing pictures effectively increased the use of hand sanitisers.<sup>22</sup> One of the messages appealed to social norms—‘Half of all healthcare workers performed well in hand hygiene. Which category do you belong?’—and the other to loss aversion—a ‘40% increase in hand hygiene, and a 40% decrease in healthcare-associated infections’. Pictures of eyes were placed above a hand gel dispenser to introduce a perception of being watched<sup>23</sup> and ‘fresh

citrus’ fragrances were dispersed into the environment to achieve a significant positive effect on hand hygiene.<sup>23 25</sup> Both the visual and olfactory cues described above were passive and asynchronous.

Iversen *et al*<sup>26</sup> used smart sensors and light displays placed on alcohol gel dispensers as a more active strategy. The light display switched between random lights (cue) and green smileys after hand hygiene (reward) to reinforce the desired behaviour. The target action of using the alcohol gel dispenser produced a synchronous reward, creating a positive association. The authors complemented their environmental nudge with performance feedback, highlighting hand hygiene compliance in different rooms as well as before and after patient contact, individually and compared with colleagues.

Despite not achieving a significant positive result, Kwok *et al*<sup>24</sup> showed that social cohesion—colleagues reminding

**Table 1** Characteristics of the articles included in the review

Reference	Nudging objective and target	Implementation details	Findings
Bourdeaux <i>et al</i> <sup>18</sup>	Increase prescription of a mouthwash and reduce the prescription of an intravenous fluid among ICU HCPs.	Chlorhexidine mouthwash was added as a default prescription to the prescribing template and hydroxyethyl starch was removed from the prescribing template.	Patients prescribed chlorhexidine increased while patients prescribed hydroxyethyl starch decreased.
Bourdeaux <i>et al</i> <sup>19</sup>	Increase compliance from ICU HCPs with TVe ventilation.	Default ventilator settings were adjusted to comply with low TVe targets and a large dashboard was deployed displaying TVe with alerts when TVe was excessive.	In the dashboard intervention, TVe fell more quickly and by a greater amount.
O'Reilly-Shah <i>et al</i> <sup>20</sup>	Improve compliance from hospital HCPs with LPV strategies.	Dashboard with compliance metrics were emailed to providers. Additionally, default setting on anaesthesia machines for TVe was decreased.	Dashboards and modification of default ventilator settings improved provider compliance with LPV strategies.
Anderson <i>et al</i> <sup>21</sup>	To promote sedation minimisation and ventilator liberation among ICU HCPs.	A web-based dashboard with real-time data and text-message alerts once patients met criteria for a spontaneous breathing trial and spontaneous awakening trial.	Patients were more likely to be extubated and more likely to be discharged from the ICU at any point.
Caris <i>et al</i> <sup>22</sup>	Increase the use of alcohol-based hand rub among ICU physicians and nurses.	Hand hygiene posters were displayed to assess their effect on the use of alcohol-based hand rub, measured with electronic dispensers.	Posters displayed next to dispensers increased use of hand rub.
King <i>et al</i> <sup>23</sup>	Influence HHC among ICU HCPs	A clean, citrus smell was released in the air and pictures of male or female eyes were placed above a hand gel dispenser to introduce a perception of being watched.	HHC was improved with the clean, citrus smell and also when a picture of 'male eyes' was placed over the hand gel dispenser.
Kwok <i>et al</i> <sup>24</sup>	Improve HHC among hospital ward HCPs.	Nurse unit managers were provided with HHC rates via email and shared them with staff at morning handover meetings. In a second phase teams were asked to set HHC goals and colleagues were encouraged to prompt each other.	HHC was improved among those who described themselves as a socially cohesive team.
Birnbach <i>et al</i> <sup>25</sup>	Improve HHC among medical students and graduates.	Trainees were randomly assigned so that some encountered a fresh-smelling environment and others a standard setting.	The fresh scent group had a higher rate of HHC.
Iversen <i>et al</i> <sup>26</sup>	Improve HHC among surgical HCPs.	An automated monitoring system measured HHC and alcohol-based hand rubbing events. Sensors on dispensers and data-driven performance feedback highlighted HHC of HCPs individually and compared with colleagues.	Doctors and nurses increased HHC. Nurses who also received feedback increased HHC even more.
Kim <i>et al</i> <sup>27</sup>	Improve patient influenza vaccination rates.	Active choice was implemented in the EHR prompting medical assistants to ask patients about vaccination during check-in and template orders for clinicians to review.	Vaccination rates increased compared with pre-intervention period.
Patel <i>et al</i> <sup>28</sup>	Improve patient influenza vaccination rates.	EHR confirmed patient eligibility during clinic visit and prompted the physician and medical assistant to actively choose to 'accept' or 'cancel' a vaccination order.	Vaccination rates increased compared with the pre-intervention period.
Lehmann <i>et al</i> <sup>29</sup>	Improve HCP influenza vaccination rates.	HCPs were randomly assigned to either an opt-out condition to a pre-scheduled appointment for vaccination (could be changed or cancelled) or an opt-in condition where they had to schedule an appointment if they wanted to get vaccinated. Only opt-out participants were sent a reminder.	HCPs in the opt-out condition were more likely to have an appointment for influenza vaccination, which in turn increased the probability of getting vaccinated.

Continued

Table 1 Continued

Reference	Nudging objective and target	Implementation details	Findings
Schmidtke <i>et al</i> <sup>30</sup>	Improve HCP influenza vaccination rates.	HCPs received one of four reminder letters: a standard letter encouraging the staff to take up the vaccination, a second letter using peer comparisons, a third letter with an appeal to authority, a fourth letter included a combination.	Vaccination coverage in all groups was the same. No evidence was found that the uptake of the seasonal influenza vaccination was affected by reminders using social norms to motivate uptake.
Lorini <i>et al</i> <sup>31</sup>	Increase staff vaccination at nursing homes.	A personal letter, signed by a high-profile person, was sent to raise awareness on the professional responsibility of vaccination together with a delivering form, a questionnaire on vaccination intent and an information leaflet.	Both vaccination uptake and vaccination intent increased.
Changolkar <i>et al</i> <sup>32</sup>	Improve HCP influenza vaccination rates.	The EHR assessed patient eligibility for vaccination and prompted medical assistants to accept or cancel an order for the vaccine. If accepted, the order was templated for the HCP to review and sign during patient visit.	Influenza vaccination rates increased.
Meeker <i>et al</i> <sup>33</sup>	Encourage HCP to judicious use of antibiotics for ARIs.	Commitment letters with HCP photographs and signatures were displayed in examination rooms stating their commitment to avoid inappropriate antibiotic prescribing.	Commitment letter resulted in a reduction in inappropriate antibiotic prescribing.
Meeker <i>et al</i> <sup>34</sup>	Reduce HCP inappropriate antibiotic prescribing.	3 interventions implemented alone or in combination: (1) the EHR suggesting non-antibiotic treatments; (2) HCPs needed to justify prescribing antibiotics; (3) emails comparing HCPs antibiotic prescribing rates with 'top performers'.	Mean antibiotic prescribing rates decreased for all interventions.
Yadav <i>et al</i> <sup>35</sup>	Reduce HCP inappropriate antibiotic prescribing.	Comparing adapted intervention with provider and patient education, a champion, and departmental feedback to an enhanced intervention with peer comparison feedback and commitment to judicious antibiotic prescribing.	Antibiotic prescribing visits dropped. More intensive nudging methods were not more effective in high-performance settings.
Tannenbaum <i>et al</i> <sup>36</sup>	Improve HCP guideline concordance for ARIs.	HCPs randomly assigned to simulated EHR displays listing antibiotics individually or grouping them together.	A reduction in choosing aggressive treatment options when aggressive options were grouped compared with when listed individually.
Dos Santos <i>et al</i> <sup>37</sup>	Improve HCP dosing for antimicrobials.	A window was inserted in the EHR with measurements of patient's renal function instead of demanding actively clicking.	The approach increased appropriateness of dosing.

ARI, acute respiratory infection; EHR, electronic health record; HCPs, healthcare professionals; HHC, hand hygiene compliance; ICU, intensive care unit; LPV, lung-protective ventilation; Tve, tidal volume.

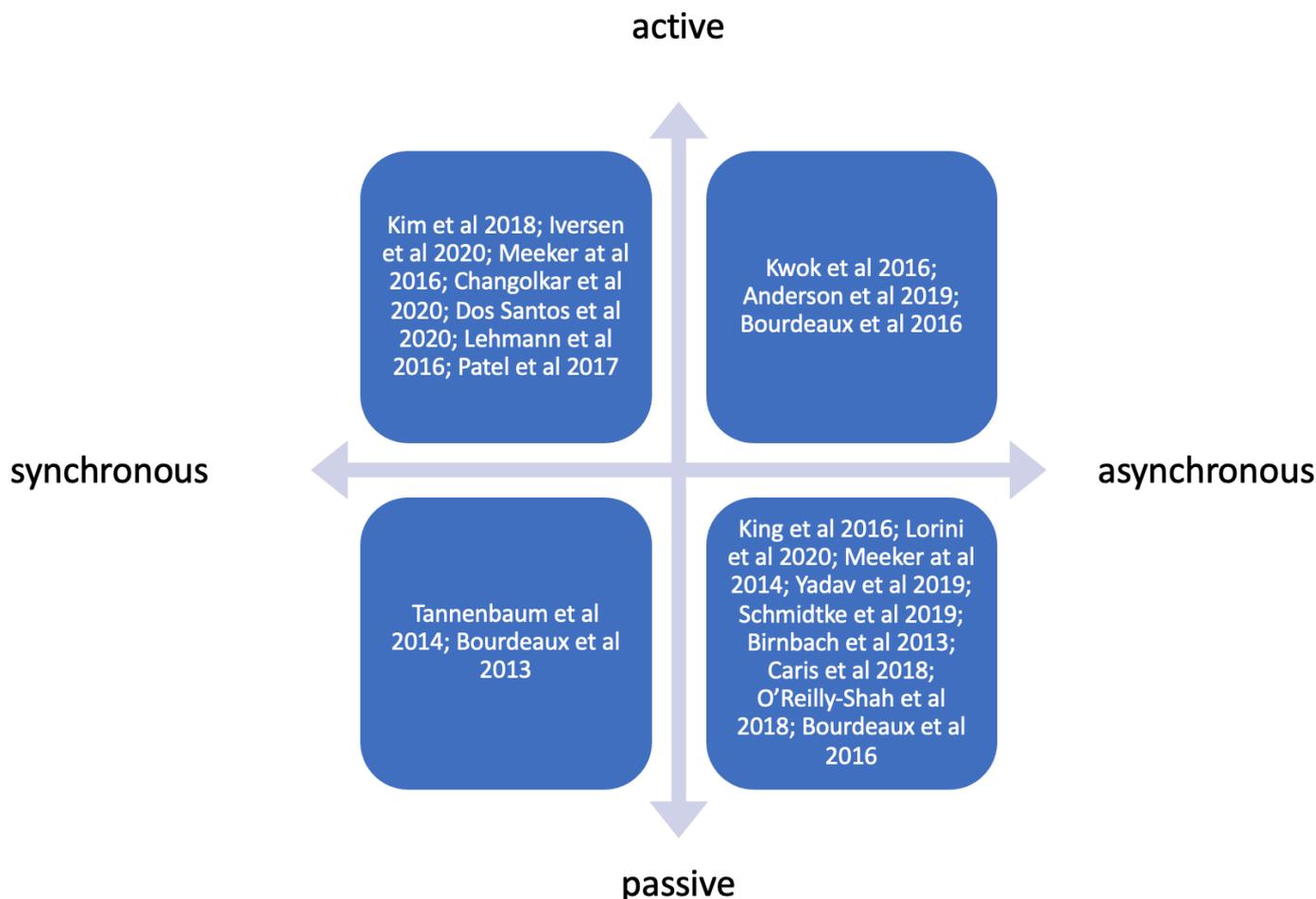
each other to wash their hands—could improve hand hygiene.

### Increasing vaccination rates for staff and patients

Four of the six studies had significant positive results. Three studies focused on increasing vaccination orders for patients, and three focused on that of the HCPs. All patient-oriented studies used active choice strategies, automatically prompting providers via EHRs to accept or decline vaccination orders to eligible patients.<sup>27 28 32</sup> These strategies impact HCPs with a higher workload more than those with a low workload.<sup>32</sup>

The HCP-focused interventions used letters and emails to HCPs, reminding them to get vaccinated. One study focused on creating messages based on social norms to encourage vaccination.<sup>30</sup> Another study compared strategies using pre-scheduled vaccination appointments (opt-out) versus reminders to schedule vaccination appointments (opt-in).<sup>29</sup> However, neither showed statistically significant differences.

Lorini *et al*<sup>31</sup> also sent personal letters to nursing home staff, signed by high-profile persons (the Chief Director of the Health Regional Agency and the Head of the Department of Health Sciences), to raise awareness not



**Figure 2** How included studies fit into a two-dimensional view of nudging.

only about their professional responsibility but also the personal working burden the staff would have to deal with in cases of colleagues getting sick. Unlike Schmidtke *et al*,<sup>30</sup> Lorini *et al*<sup>31</sup> found a significant effect in the intervention group regarding the intention to get the influenza vaccine, which increased from 2018 to 2019 and 2020.

#### Judicious antibiotic prescription

All five studies had a significant positive outcome. Poster-sized commitment letters were displayed in examination rooms, reminding clinicians of their pledge to judicious antibiotic prescription and informing patients of the importance of that choice.<sup>33 35</sup> They showed that simply eliciting the intent to perform an action increases the chances of performing it.<sup>3</sup> It is noteworthy that posters as visual cues are a passive and asynchronous strategy; but these were personalised, showing photos and names of clinicians who had pledged.

Two studies<sup>34 35</sup> sent private emails to HCPs with performance metrics, comparing individuals with their groups and top-performing peers. Peer comparison relies on social norms and is an effective nudging strategy.<sup>38</sup>

In one study,<sup>34</sup> clinicians were presented with suggestions for non-antibiotic treatment together with the message 'Antibiotics are not recommended for this

diagnosis. See the alternatives below'. If clinicians decided to continue with the antibiotic prescription, they were required to enter a free-text justification for their choice in the EHRs prescription ordering system. This is an active and synchronous strategy that not only requires immediate action but also forces the clinician to reason about their choice.

Tannenbaum *et al*<sup>36</sup> nudged appropriate prescription by rearranging the visual display of treatment options in the EHRs. HCPs showed a 11.5% reduction in choosing aggressive treatment options (eg, broad-spectrum antibiotics) when these were shown in groups compared with individual lists. This passive and subconscious effect may be explained by 'anchoring'—treatments are perceived as more aggressive when grouped with other aggressive treatments; or 'priming'—the perception of certain treatments is subconsciously affected by seeing other treatment options listed closely.

To increase the appropriateness of dosing based on renal function, Dos Santos *et al*<sup>37</sup> made a simple change in the EHRs layout to show the patients' latest estimated glomerular filtration rate on the main screen. Before the intervention, this information had to be accessed by actively clicking (four clicks) on the system—a task that required approximately 15–20 s. This simple change

increased the appropriateness of dosing from 33.9% to 41.4%. Both these studies<sup>36 37</sup> suggest that order sets should not be arbitrary.

## DISCUSSION

We identified and described how nudging techniques have been used to affect the behaviour of HCPs in ways that are relevant for handling the COVID-19 pandemic in a clinical setting. Four focus areas were found that could be implemented quite easily: mechanical ventilation, hand hygiene, vaccination and antibiotic prescription.

### Nudging care of ventilated patients

The COVID-19 pandemic has put severe strain on available ICU beds, with a large number of patients requiring invasive mechanical ventilation (MV) for COVID-19-associated pneumonia and acute respiratory distress syndrome (ARDS).<sup>39</sup> These patients account for a substantial portion of ICU admissions and hospital costs.<sup>40</sup> In addition to the risks intrinsic to MV, ventilator-associated pneumonia (VAP) has been reported as a complication in hospitalised patients with COVID-19.<sup>41–43</sup>

Our review indicates that default strategies may improve outcomes in MV patients. It has been shown that although low TVE ventilation benefits MV patients with ARDS,<sup>44</sup> there is poor compliance.<sup>45</sup> Additionally, the preventive use of chlorhexidine mouthwash can reduce (VAP). Default settings for ventilators coupled with alarms can improve compliance with low TVE ventilation. Furthermore, the default inclusion of chlorhexidine mouthwash on order sets for intubated patients significantly increases its preventive use, thus improving patient outcomes. Default strategies that reduce the cognitive burden on HCPs nudge them to better comply with clinical evidence.

### Nudging hand hygiene

The COVID-19 pandemic has resulted in worldwide hand hygiene awareness. Unfortunately, studies have shown that hand hygiene is often inadequately practised among HCPs,<sup>46–48</sup> despite studies showing that it may decrease the spread of transmissible disease by 24%–31%,<sup>49 50</sup> and is considered one of the most important measures to prevent hospital-acquired infections.<sup>51–53</sup>

Our review shows that priming strategies that alter the physical environment with images, messages and fragrances can improve hand hygiene compliance (HHC). These are easy and cost-effective interventions that can increase safety in the clinical setting and prevent the spread of COVID-19 in the short term. Visual and olfactory nudges can work as subconscious cues to action but can also easily be ignored. The long-term effects of such strategies were not discussed in the studies we reviewed; more complex strategies may be needed to affect hand washing behaviour in the long term.

### Nudging vaccination

Vaccination is a core component in mitigating the COVID-19 pandemic.<sup>54</sup> However, the efficacy of

vaccination programmes largely depends on population compliance and vaccine hesitancy or refusal around COVID-19 vaccines quickly became a growing concern in most countries. The fraction of the population that must be vaccinated against COVID-19 to achieve herd immunity has been estimated to be 60%–80%.<sup>55</sup> Although there is precedence for mandatory vaccination programmes around the world<sup>56</sup> and current discussions regarding COVID-19 vaccines,<sup>57</sup> it is likely that vaccination will remain an individual choice.

Despite numerous campaigns and initiatives, voluntary influenza vaccination rates in the USA have remained mostly unchanged for nearly a decade, with only 40% of the population being vaccinated each year.<sup>58</sup> Recent studies have shown that staff vaccination rates in nursing homes are generally low.<sup>59 60</sup> Since nursing homes and other long-term care facilities account for a disproportionate share of COVID-19 cases and fatalities worldwide, increasing vaccination rates among nursing home staff is especially important. Vaccines have been especially instrumental in reducing COVID-19 cases and related deaths among nursing home residents,<sup>61</sup> but at the same time vaccine hesitancy or refusal around COVID-19 vaccines is a growing concern worldwide and has become an issue in most countries.

Therefore, public awareness campaigns and nudging strategies may be key to achieving high vaccination rates.<sup>62</sup> This review identified two types of interventions: those targeting vaccination orders for patients and those targeting staff vaccination. While all the patient-focused interventions had a positive result, two out of three interventions directed at HCPs did not. It is noteworthy that these passive and asynchronous strategies could easily be ignored, whereas the patient-oriented strategies were active and synchronous, requiring immediate action, which could prove valuable during a mass vaccination campaign. That said, HCPs might now have a much different emotional and cognitive response to COVID-19 than influenza, and new intervention strategies should be investigated. The significant positive results found by Lorini *et al*<sup>31</sup> could for instance be due to the already large impact of COVID-19 affecting inclination towards vaccination among HCPs. Other studies have shown vaccine hesitancy among skilled nursing facility staff regarding the COVID-19 vaccine, either because of the development and testing or personal fears of getting sick.<sup>63</sup> An effective behaviour change strategy for COVID-19 vaccines uptake will therefore need to address multiple beliefs and behavioural determinants, by reducing barriers and leveraging enablers.<sup>64</sup> Text-based reminders have for instance been shown to be effective to get patients vaccinated, especially when designed to make them feel ownership of the vaccine dose,<sup>65 66</sup> and that the vaccine dose was reserved for them.<sup>65</sup> This has also been tested on actual uptake of COVID-19 vaccines.<sup>66</sup> This is something future nudging studies need to explore when it comes to HCPs.

### Nudging antibiotic prescriptions

Appropriate hospital antibiotic use is a key element in patient safety, and it has been shown that antibiotics are often unnecessary in the treatment of COVID-19.<sup>67</sup> Although bacterial co-pathogens are common in viral respiratory infections, the prevalence of bacterial infections in patients with COVID-19 is not well understood.<sup>68</sup> Hence, the prevention of inappropriate antibiotic use is important not only to reduce the risk of opportunistic infections and other adverse drug events, but also to deter the natural selection of antibiotic-resistant bacteria.<sup>69 70</sup>

Our review indicates that social interventions such as public pledges, public-facing commitment letters and peer comparisons can effectively reduce inappropriate antibiotic prescriptions. EHRs or electronic prescription systems are important tools for changing prescribing behaviour. Both passive and active strategies have shown promise for reducing inappropriate antibiotic prescriptions. Health providers should not only consider how medications are displayed, but also the steps required to complete an order as possible windows of opportunities to deliver nudging interventions via the EHR.

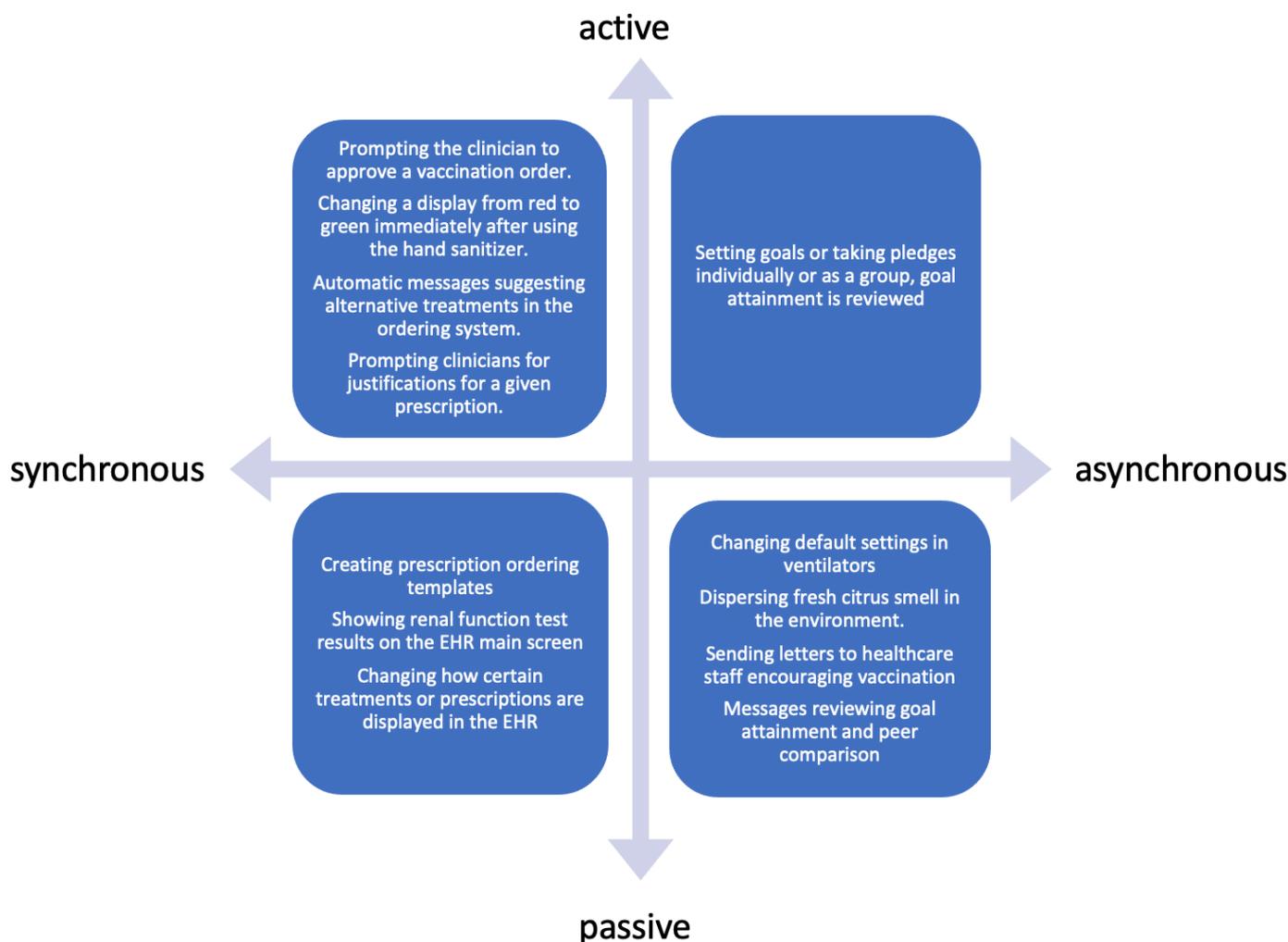
### Using the two-dimensional view of nudging

The active/passive and synchronous/asynchronous dimensions are practical in characterising how and when HCPs are exposed to the nudging intervention, without requiring deep knowledge of behavioural economics or behavioural psychology.

These two dimensions created four quadrants, each containing different nudging strategies (figure 3). While active strategies enable the clinician to consciously reflect on the target behaviour, passive strategies can reduce their cognitive burden by making a behaviour easier or automatic.

### CONCLUSION

Evidence suggests that different nudging techniques can be used in clinical settings as simple, cost-effective strategies to fight COVID-19, reduce complications for intubated patients, improve hand hygiene, increase vaccination rates and avoid unnecessary antibiotic prescriptions. These strategies could be important in the continued handling of the pandemic, which will not be over until the whole world reaches herd immunity from vaccination.



**Figure 3** Examples of how nudging strategies fit into a two-dimensional view of nudging. EHR, electronic health record.

As the COVID-19 pandemic continues, there is a need to gather the best available evidence-based treatment to avoid death and unnecessary suffering. The first wave led to better treatment options during the second and third wave.<sup>71</sup> Nudging techniques can be an easy and cost-effective way to optimise care and, ultimately, save lives.

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## Supplementary Tables

Table S1. Characteristics of the articles included in the review

Author/year/country	Focus area	Nudging objective	Population/setting	Implementation details	Nudging labels	Findings	Statistically significant positive results	Nudging Dimension	COVID-19
Bourdeaux <i>et al</i> 2013, UK[18]	Ventilation	Increase prescription of chlorhexidine mouthwash and reduce the prescription of hydroxyethyl starch (HES) to patients in the ICU.	ICU admitting doctors	Chlorhexidine mouthwash was added as a default prescription to the prescribing template and HES was removed from the prescribing template. Both interventions were available to prescribe manually throughout the study period.	Defaults/pre-orders	Patients prescribed chlorhexidine increased from 55% to 90.4%, while patients prescribed hydroxyethyl starch decreased from 54% to 3%.	Yes	Passive/Synchronous	Redesigning choices in the EHR can increase delivery of evidence-based interventions.
Bourdeaux <i>et al</i> 2016, UK[19]	Ventilation	Increase compliance with low tidal volume (T <sub>Ve</sub> ) ventilation in the ICU.	ICU clinical team	Default ventilator settings were adjusted to comply with low T <sub>Ve</sub> targets from the initiation of ventilation unless actively changed by a clinician. A large dashboard was deployed displaying T <sub>Ve</sub> s with alerts when T <sub>Ve</sub> s were excessive.	Defaults/pre-orders; Alerts/reminders	In the dashboard intervention, T <sub>Ve</sub> fell more quickly and by a greater amount.	Yes	Active/Asynchronous	Adjustment of default ventilator settings and a dashboard with alerts for excessive T <sub>Ve</sub> can influence clinical decision-making.
O'Reilly-Shah <i>et al</i> 2018, USA[20]	Ventilation	Improve compliance with lung-protective ventilation (LPV) strategies during general anaesthesia.	Hospital anaesthesiologists	Dashboard with compliance metrics were emailed to providers. Additionally, default setting on anaesthesia machines for tidal volume was decreased.	Defaults/pre-orders	Dashboards and modification of default ventilator settings improved provider compliance with LPV strategies.	Yes	Passive/Asynchronous	Audit and feedback tools in conjunction with default changes improve provider compliance.
Anderson <i>et al</i> 2019, USA[21]	Ventilation	To promote sedation minimization and	ICU respiratory therapists and nurses	An automated application consisting of 1) a web-based dashboard with real-	Alerts/reminders	After implementation, patients were 28% more likely to be	Yes	Active/Asynchronous	An EHR based dashboard and text-alert system can identify

		ventilator liberation.		time data on spontaneous breathing trial readiness, sedation depth, sedative infusions, and nudges to wean sedation and ventilatory support and 2) text-message alerts once patients met criteria for a spontaneous breathing trial and spontaneous awakening trial.		extubated and 31% more likely to be discharged from the ICU at any point.			opportunities to improve sedation minimization and ventilator liberation and reduce duration of mechanical ventilation and ICU stay.
Caris <i>et al</i> 2018, Netherlands[22]	Hand hygiene	Increase the use of alcohol-based hand rub.	ICU physicians and nurses	Hand hygiene posters were displayed on two hospital wards to assess their effect on the use of alcohol-based hand rub, measured with electronic dispensers. Poster 1: 'Half of all healthcare workers perform well in hand hygiene. Which category do you belong to?' Poster 2: '40% increase in hand hygiene, 40% decrease in healthcare-associated infections.	Environmental cueing/priming	Posters displayed next to dispensers increased their overall use on one ward and during doctor's rounds on both wards. Use of dispensers without nudges did not increase.	Yes	Passive/Asynchronous	Posters with hand hygiene slogans next to dispensers can provide an easy, inexpensive measure to increase use of alcohol based hand rub.
King <i>et al</i> 2016, USA[23]	Hand hygiene	Influence hand hygiene compliance (HHC).	ICU physicians, nurses, and ancillary staff	Interventions included either an olfactory prime (clean, citrus smell) that was introduced to the environment through a commercially available aroma dispenser or visual prime (male or female eyes) placed above a hand gel dispenser to introduce a perception of being watched.	Environmental cueing/priming	A significant improvement in HHC was observed with the clean, citrus smell (46.9% vs. 15.0%) and also when a picture of "male eyes" was placed over the hand gel dispenser (33.3% vs. 15.0%). No significant improvement was	Yes	Passive/Asynchronous	Visual and olfactory priming can influence HHC by increasing the use of alcohol-based hand rub.

						seen with a picture of female eyes.			
Kwok <i>et al</i> 2016, Australia[24]	Hand hygiene	Improve hand hygiene compliance (HHC).	Hospital ward clinicians	In a first phase nurse unit managers were provided with HHC rates via e-mail and shared them with staff at morning hand-over meetings. In a second phase teams were asked to set HHC goals and colleagues were encouraged to prompt each other to HHC.	Feedback; Goal setting	Intervention improved hand hygiene in the surgical ward who described themselves as socially cohesive team but not in the medical ward where distrust to compliance rates and reluctance to nudge each other were described.	No	Active/Asynchronous	Goal setting with continuous feedback based on automated measurements and encouragement from colleagues in a socially cohesive team can improve HHC.
Birnbach <i>et al</i> 2013, USA[25]	Hand hygiene	Improve hand hygiene compliance (HHC)	Medical school students and recent graduates during a patient safety course.	Trainees were randomly assigned to groups via random number generation in different orders of training sessions so that some encountered a fresh-smelling environment and others the standard setting. There were four separate sessions which occurred in a single room; two of which had the active scent manipulation and the other two of which did not.	Environmental cueing/priming	The standard environment group had a hand hygiene compliance rate of 51% whereas participants in the fresh scent group had a higher rate of 80%	Yes	Passive/Asynchronous	Hand hygiene behavior may be subconsciously influenced by cues in the environment. Fragrance appears to have a positive effect on HHC.
Iversen <i>et al</i> 2020, Denmark[26]	Hand hygiene	Improve hand hygiene compliance (HHC).	Surgical ward doctors and nurses.	An automated monitoring system was implemented in the ward measuring hand hygiene opportunities and alcohol-based hand rubbing events in patient and working rooms. Baseline HHC of HCPs were	Environmental cueing/priming; Feedback	Doctors significantly increased HHC in patient rooms (16% vs 42%) and working rooms (24% vs 78%). Nurses increased HHC significantly from baseline in	Yes	Active/Synchronous	HHC can be significantly improved with light-guided nudging and data driven performance feedback using an automated hand hygiene system.

				compared with light-guided nudging from sensors on dispensers and data-driven performance feedback highlighting HHC in different rooms as well as before and after patient contact, individually and compared with colleagues.		both patient rooms (27% vs 43%), and working rooms (39% vs 64%), Nurses who subsequently received individual performance feedback, further increased HHC.			
Kim <i>et al</i> 2018, USA[27]	Vaccination	Improve influenza vaccination rates.	Primary care practice medical assistants	An active choice intervention was implemented in the EHR prompting medical assistants to ask patients about influenza vaccination during check-in and template vaccination orders for clinicians to review during the visit.	Active choice	The intervention was associated with a 9.5% increase in vaccination rates (nearly a 20% relative increase compared with the preintervention period).	Yes	Active/Synchronous	Active choice through the EHR can improve vaccination rates.
Patel <i>et al</i> 2017, USA[28]	Vaccination	Increase influenza vaccination rates.	Primary care physicians	The EHR confirmed patient eligibility during the clinic visit and, upon accessing the patient chart, prompted the physician and their medical assistant to actively choose to “accept” or “cancel” an order for the influenza vaccine.	Active choice	Intervention practice using active choice had a significantly greater increase than the control (37.3% increase) compared to pre-intervention. More than 99.9% of orders placed during the study resulted in vaccination.	Yes	Active/Synchronous	Active choice through the EHR can improve vaccination rates.
Lehmann <i>et al</i> 2016, Netherlands[29]	Vaccination	Improve influenza vaccination rates of staff.	Tertiary care HCPs	HCPs were randomly assigned to one of two conditions. In the opt-out condition participants received an e-mail with a pre-scheduled appointment for influenza	Defaults/pre-orders	10 out of 61 HCPs in the opt-in group were vaccinated, against 12 of 61 in the opt-out group. In the opt-in condition, 12 of	No	Active/Synchronous	Changing default to opt-out may not be enough to promote influenza vaccination among HCPs but might be an easy and cost-effective

				vaccination (could be changed or cancelled). In the opt-in condition participants received an e-mail explaining that they had to schedule an appointment if they wanted to get vaccinated. Opt-out participants that had changed or did not cancel their appointment were sent a reminder.		61 HCPs had an appointment, compared with 24 of 61 in the opt-out condition. Of 36 HCPs with an appointment, 25 got vaccinated, while only 2 of the 86 without an appointment got vaccinated.			alternative to complex vaccination if combined with other nudging techniques.
Schmidtke <i>et al</i> 2019, UK[30]	Vaccination	Increase influenza vaccination of front-line staff.	Hospital front-line staff	Staff were randomly allocated to receive one of four letters: a standard letter encouraging the staff to take up the vaccination (no norms), a second letter highlighted a type of social norm based on peer comparisons, a third letter highlighted a type of social norm based on an appeal to authority, a fourth letter included a combination of the social norms.	Alerts/reminders	Vaccination coverage in all groups was 43%. No evidence was found that the uptake of the seasonal influenza vaccination was affected by reminders using social norms to motivate uptake.	No	Passive/Asynchronous	Using only letters based on social norms seems not to be a viable way to increase vaccination rates among HCPs
Lorini <i>et al</i> 2020, Italy[31]	Vaccination	Increase staff vaccination at nursing homes.	Nursing home workers	A paper letter was personally addressed to every NH worker, signed by the Chief Director of the Health Regional Agency and the Head of the Department of Health Sciences. Its goal was to raise awareness on the professional responsibility towards fragile people in case of non-vaccination, but	Education; Social norms	Influenza vaccination uptake in the 2018–2019 season was similar in the two groups (23.6% vs. 22.2% respectively, in the nudge and comparison group), but significantly different in the 2019–2020	Yes	Passive/Asynchronous	A personal-addressed paper letter, signed by high-profile figures and aimed to raise awareness about the professional responsibility towards fragile people and colleagues, delivered with an information

				also on the personal working burden if colleagues contracted influenza. The letter ended with a manifestation of trust by the NH Chief Officer in its personnel, and a kind request to sign a delivering form and to compile a questionnaire on vaccination intent. A leaflet including useful information about how to get vaccinated was also provided.		season: 28% in the nudge vs. 20% in the comparison group. Also, the intention to get the vaccine in the 2020–2021 season was significantly different in the two groups: 37.9% in the nudge and 30.8% in the comparison group.			leaflet—could be useful in promoting influenza vaccination uptake.
Changolkar <i>et al</i> 2020, Australia[32]	Vaccination	Increase influenza vaccinations.	Primary care physicians and medical assistants	Prior to meeting with the physician, patients met with a medical assistant to check their vitals. At that time, the EHR assessed patient eligibility for influenza vaccination and prompted medical assistants to accept or cancel an order for the vaccine. If accepted, the order was templated for the physician to review and sign during patient visit.	Active choice	Influenza vaccination rates for the lower clinical workload group at intervention practices increased from 47.1% to 51.5%. For the higher workload group, vaccination rates increased from 42.0% to 51.4%.	Yes (among high workload group, but not low)	Passive/Synchronous	An active choice intervention in the EHR to prompt medical assistants to template influenza vaccination orders for physicians can increase influenza vaccination.
Meeker <i>et al</i> 2014, USA[33]	Antibiotics	Encourage judicious use of antibiotics for acute respiratory infections (ARIs).	Community clinicians	Poster-sized commitment letters were displayed in examination rooms. These letters, featuring clinician photographs and signatures, stated their commitment to avoid inappropriate antibiotic prescribing for ARIs. It was written	Environmental cueing/priming	Controlling for baseline prescribing the posted commitment letter resulted in a 19.7 absolute percentage reduction in inappropriate antibiotic	Yes	Passive/Asynchronous	Displaying poster-sized commitment letters in examination rooms can decrease inappropriate antibiotic prescribing for ARIs.

				at an eighth grade reading level and displayed in English and Spanish.		prescribing rate relative to control.			
Meeker <i>et al</i> 2016, USA[34]	Antibiotics	Reduce inappropriate antibiotic prescribing.	Primary care clinicians	3 behavioural interventions, implemented alone or in combination: (1) suggested alternatives presented in the EHR suggesting non antibiotic treatments; (2) accountable justification prompting clinicians to enter free-text justifications for prescribing antibiotics into patients' EHR; (3) peer comparison sent emails to clinicians that compared their antibiotic prescribing rates with those of "top performers".	Peer-comparison; Accountable justification; Suggested alternatives	Mean antibiotic prescribing rates decreased by 11% for control practices, 16% for suggested alternatives, 18% for accountable justification, and 16% for peer comparison. There were no statistically significant interactions (neither synergy nor interference) between interventions.	Yes (interventions 2 and 3)	Active/Synchronous	Socially motivated interventions like accountable justification and peer comparison can reduce inappropriate antibiotic prescribing.
Yadav <i>et al</i> 2019, USA[35]	Antibiotics	Reduce inappropriate antibiotic prescribing.	Emergency clinicians	Compared an adapted intervention including provider and patient education, a physician champion, and departmental feedback with an enhanced intervention also including peer comparison feed-back and locally tailored public-facing demonstration of commitment to judicious antibiotic prescribing. Peer comparison was distinct from traditional audit-and-feedback interventions, in that individuals were	Peer-comparison; Environmental cueing/priming	Antibiotic prescribing for acute respiratory infection visits dropped from 6.2% to 2.4%. After adjusting for health-system and provider-level effects, inappropriate prescribing dropped from 2.2% to 1.5%. More intensive behavioural nudging methods were not more effective in high-performance settings.	Yes	Passive/Asynchronous	Implementation of antibiotic stewardship for ARI is feasible and effective to remind prescriber to appropriately prescribe antibiotics.

				compared to top-performing peers.					
Tannenbaum <i>et al</i> 2014, USA[36]	Antibiotics	Improve guideline concordance for acute respiratory infection treatment.	Primary care physicians	Providers were randomly assigned to one of two menu partitions in simulated EHR displays. In the antibiotic-inappropriate panel, the treatment menu either listed over-the-counter (OTC) medications individually, while grouping prescriptions together or displayed the reverse partition. In the antibiotic-appropriate panel, the treatment menu either listed narrow-spectrum antibiotics individually while grouping broad-spectrum antibiotics or displayed the reverse partition.	Defaults/pre-orders	There was an 11.5 per-centage point reduction in choosing aggressive treatment options (e.g., broad-spectrum antibiotics) when aggressive options were grouped compared to when those same options were listed individually.	Yes	Passive/ Synchronous	Using order sets in the EHR can help reduce inappropriate antibiotic prescribing.
Dos Santos <i>et al</i> 2020, Brazil[37]	Antibiotics	Improve dosing for antimicrobials.	Physicians at a large public university hospital	A window was inserted in the computerized physician order entry (CPOE) in the EHR with measurements of patient's renal function. Before the intervention this information had to be accessed by actively clicking (4 clicks) on the system, a task that required ~15–20 seconds.	Information transparency	The approach increased appropriateness of dosing from 33.9% to 41.4%	Yes	Active/ Synchronous	A simple change in the EHR layout for prescribing physicians can boost strategies for appropriate antibiotic use.