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Using an inferior decoy alternative to nudge COVID-19 vaccination

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Optimizing vaccine uptake is a public health challenge that requires the implementation of effective strategies. The asymmetric dominance (or decoy) effect describes the increasing likelihood of selecting an option when a clearly inferior alternative is offered. Therefore, we aimed to test the impact of offering decoy alternatives—less convenient vaccination appointments—on vaccination intentions. Participants aged 18–33 years, residing in England, and initially not intending to get vaccinated, completed three online experiments. Participants were randomly assigned to either a control or an experimental condition in each experiment. The asymmetrically dominated options were: an appointment in two weeks at a distant location (experiment 1); a later time at the participant's local GP, pharmacy, or community centre (experiment 2); and a later time at a distant location (experiment 3). The primary outcome was vaccination intention, while secondary outcomes included an active interest in reading additional information about the vaccination procedure, perceived difficulty and cognitive effort. Initial analysis revealed no evidence of an asymmetric dominance effect. However, further subgroup analysis, supported by formative research, indicated that ensuring decoy alternatives are clearly perceived as inferior could enhance the effectiveness of this approach for certain individuals.

Keywords Decision making, Nudge, Decoy effect, Asymmetric dominance effect, Vaccination hesitancy, COVID-19, Behavioural public policy

COVID-19 remains an ongoing health issue, with concerns over seasonal variation in infection rates and the continued evolution of variants. As of March 2023, there have been 187,022 deaths in England with COVID-19 listed on the death certificate[1], while the World Health Organization has recorded approximately 6.9 million COVID-19-related deaths globally[2]. To optimize vaccine uptake, it is essential for health officials and policymakers to understand the factors contributing to vaccine hesitancy. Factors associated with the intention to receive a COVID-19 vaccine vary across studies[3]. The most significant factors that influence intention include perceived benefits and stronger subjective norms[4], perceived susceptibility to disease (not perceiving oneself as vulnerable to the disease), anticipating feelings of regret (i.e. the impact of missing a vaccination opportunity)[5], more positive beliefs and attitudes toward COVID-19 vaccination, and greater perceived knowledge about vaccination[4,6]. Additional factors associated with COVID-19 vaccination intention include prior influenza vaccination[4,7], trust[4], and sociodemographic characteristics, including sex, age, ethnic background, educational attainment and socioeconomic deprivation[6,8,9].

There are already several recommendations[10] to support vaccine roll-outs, which are targeted at groups that are at high risk of COVID-19 morbidity and mortality[11]. However, less is known about how to increase the share of people in lower-risk groups (e.g., younger people working outside the health sector or the service industry) accepting the vaccine[12]. Most interventions aimed at addressing vaccine hesitancy have concentrated on modifying knowledge, attitudes, and behaviours related to vaccine information and safety[13]. While some studies have demonstrated statistically significant improvements in vaccination intentions and uptake[13,14], a literature review conducted in 2017 found that many interventions designed to alter individuals' perceptions and emotions regarding vaccination have had a limited impact[15].

In healthcare settings, methods such as vaccination[16–21] and *nudging* techniques, which create optimal defaults and increase the convenience of desired options, have proven to be successful. A field trial showed that text message nudges encouraged people to receive the vaccination against COVID-19 [22]. Findings from a recent

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systematic review examining how interventions based on nudge theory influence intentions and behaviours related to COVID-19 vaccine uptake suggest that low-cost, short-duration interventions may effectively reduce vaccine hesitancy[23]. Nudge techniques predictably alter people's behaviour without forbidding any options by acting on their cognitive biases. The desired option should be the one "most likely to help and least likely to inflict harm"[24–26]. Nudges can best be explained using psychological dual-process models of decision-making: System 2 is precise and controlled, conscious and reflective but cognitively costly and therefore involves only a minority of every decision, whereas, System 1 is often dominant, often based on automatic, largely unconscious, 'heuristics' (cognitive shortcuts) that are highly economical and usually effective but can also lead to predictable errors (known as 'biases'). This theory has led to different and complementary approaches to behaviour change interventions and policymaking: the traditional, rational approach based on regulation, incentives and information and nudging strategies that change aspects of the choice environment that alter behaviour in a predictable way by triggering automatic heuristics and biases.

One potential nudge technique that has been found to be successful at increasing intentions among previous nonintenders is the use of an asymmetrically dominated choice (decoy). The *asymmetric dominance effect*, also known as the *decoy effect* or *attraction effect*, is a cognitive bias violating rational choice theory[27,28]. According to the multialternative decision field theory, because humans judge attractiveness relatively (not absolutely), the asymmetrically dominated alternative, compared with the superior target al.ternative, produces an adverse emotion for itself and a boosting effect for the target option, making it more attractive[29]. Different decoy positions result in different sizes of effects[30].

The literature on consumer choice has demonstrated that the addition of an inferior choice (decoy) can increase interest in a target product or action, including the intention to undergo preventive health behaviours such as cancer screening[31,32].

A study conducted in Israel revealed that an intervention that splits the option to receive the flu shot into an early (recommended) shot and a late shot has the potential to significantly increase influenza vaccination uptake rates[33]. The late option is inferior to the early option and is likely to generate comparisons that highlight the advantages of the more attractive flu shot. Thus, these individuals can lead those who intend to receive the vaccine early in the winter season. In summary, a decoy is an irrelevant (or nonpreferred) option (e.g., inconvenient vaccination location) that, when added to a binary choice, alters individuals' preferences between the other two options, strengthening the preference for one of them (the target of the decoy, e.g., convenient vaccination location) with respect to the alternative (the competitor, e.g., no vaccination)[29].

The UK vaccination programme set up a wide variety of locations for individuals to receive their vaccinations, ranging from large regional hubs to more localised sites, such as smaller community centres, GP surgeries, and pharmacies. There has been pressure coverage about individuals being offered the vaccine in centres as far as 100 miles from their residences[34]. However, vaccine invitees did not have to accept the opportunity to receive the vaccine at a regional centre if they chose to wait for the vaccine to become available at a local site.

We hypothesized that adding a less convenient vaccination appointment to the choice set of a hypothetical vaccine invitation scenario would increase individuals' intention to receive the COVID-19 vaccination, choosing the default vaccination appointment (target option). In line with previous studies on the asymmetrical dominance effect in medical decision-making, we tested alternative options that are worse in terms of the location and duration of the vaccination appointment, as they are relatively similar in terms of their underlying metric and have proven to be effective[31,33]. In multiattribute decision-making scenarios, decisionmakers often face options that are high in one attribute but low in another, necessitating a trade-off to reach a final decision[35]. For instance, in the context of vaccination decisions, individuals must evaluate the trade-off between "health" (the perceived benefit of vaccination) and "effort" (proxied by distance and/or time required to get vaccinated). In this case, the option of "nonvaccination" is perceived as high in effortlessness (easy and no effort required) but low in health benefits (no additional health protection). Conversely, "vaccination" is considered high in health benefits (protection from disease) but low in effort (requiring travel and waiting time). Thus, the concept of asymmetrical dominance is crucial in understanding these decisions. This nuanced understanding of decision-making highlights the complex and multifaceted nature of choices involving health and effort and underscores the importance of considering how different attributes interact and influence overall preferences.

Results

Intention-to-treat analysis

Experiment 1 – decoy alternative at a distant location

The inferior option regarding distance location (10–30 miles away) did not influence the likelihood of the target appointment being chosen (intervention: 30.2% vs. control: 35.7%; $x^2 = 0.95$, $p = 0.329$, df = 1; adjusted odds ratio (aOR) 0.74, 95% confidence interval (CI) 0.42–1.27 (Supplementary Table S1)). Similarly, there were no effects on active interest (39.6% vs. 42.1%; $x^2 = 0.19$, $p = 0.662$, df = 1; aOR 0.91, 95% CI 0.56–1.50 (Supplementary Table S2)), or cognitive effort ($x^2 = 2.54$, $p = 0.638$, df = 4; aOR 0.91, 95% CI 0.63–1.49 (Supplementary Table S3)), or perceived decision difficulty ($x^2 = 5.86$, $p = 0.210$, df4; aOR 1.10, 95% CI 0.87–1.72 (Supplementary Table S4)). Kruskal-Wallis (K-W) tests did not reveal any differences in confidence in vaccination or public authorities across the two conditions, with median values of 9 out of 18 (SD = 4.91, $\chi^2 = 0.034$, $p = 0.853$, df = 1 (Supplementary Table S5; Figure S1)), complacency (median = 8, SD = 4.89, $\chi^2 = 2.232$, $p = 0.135$, df = 1 (Supplementary Table S6; Figure S1)) or perceived constraints (median = 11, SD = 5.16, $\chi^2 = 0.003$, $p = 0.957$, df = 1 (Supplementary Table S7; Figure S1)).

Experiment 2 – decoy alternative at a later time point

Expanding the choice set with a later appointment option (1–3 weeks later) did not influence the likelihood of the target being chosen either (39.7% vs. 43.4%; $x^2 = 0.38$, $p = 0.538$, df = 1; aOR 0.97, 95% CI 0.56–1.67 (Supplementary Table S1)). Furthermore, there was no effect on active interest (46.3% vs. 41.1%; $x^2 = 0.73$, $p = 0.392$, df = 1; aOR 1.36, 95% CI 0.80–2.32 (Supplementary Table S2)), or cognitive effort ($x^2 = 5.95$, $p = 0.203$, df = 4; aOR 1.41, 95% CI 0.90–2.20 (Supplementary Table S3)), or perceived decision difficulty ($x^2 = 2.69$, $p = 0.610$, df = 4; aOR 1.21, 95% CI 0.76–1.91 (Supplementary Table S4)) or attitudes toward vaccination (confidence: median = 8, SD = 5.14, $\chi^2 = 0.826$, $p = 0.326$, df = 1 (Supplementary Table S5; Figure S2), complacency: median = 9, SD = 5.24, $\chi^2 = 0.298$, $p = 0.585$, df = 1 (Supplementary Table S6; Figure S2), perceived constraints: median = 12, SD = 5.26, $\chi^2 = 1.676$, $p = 0.196$, df = 1(Supplementary Table S7; Figure S2)).

Experiment 3 – decoy alternative further away at a later time point

In contrast, the addition of an alternative appointment, which was inferior in both attributes, decreased the likelihood of selecting the target option (33.8% vs. 44.2%; $x^2 = 4.50$, $p = 0.034$, df = 1; aOR 0.63, 95% CI 0.40–0.97, $p < 0.05$ (Supplementary Table S1)). The same effect was also revealed for active interest (31.3% vs. 41.2%; $x^2 = 4.20$, $p = 0.040$, df = 1; aOR 0.56, 95% CI = 0.37–0.90, $p < 0.05$ (Supplementary Table S2)). However, the inclusion of the additional appointment did not affect perceived cognitive effort ($x^2 = 2.81$, $p = 0.591$, df = 4; aOR 0.90, 95% CI = 0.63–1.28 (Supplementary Table S3)), or perceived decision difficulty ($x^2 = 2.86$, $p = 0.582$, df = 4; aOR 0.70, 95% CI = 0.48–1.02 (Supplementary Table S4)). Attitudes toward vaccination were not influenced by the inclusion of the decoy appointment (confidence: median = 8, SD = 4.45; $\chi^2 = 3.643$, $p = 0.056$; df = 1 (Supplementary Table S5; Figure S3), complacency: median = 7, SD = 4.18; $\chi^2 = 0.270$, $p = 0.603$; df = 1 (Supplementary Table S6; Figure S3), or perceived constraints: median = 11, SD = 4.69; $\chi^2 = 3.182$, $p = 0.075$; df = 1 (Supplementary Table S7; Figure S3)).

Integrative analysis

The results aligned with the findings of the third experiment, demonstrating a statistically significant decrease in the likelihood of selecting the target option when the decoy alternative was added (aOR 0.72, 95% CI 0.55–0.95, $p < 0.05$ (Supplementary Table S8)). The random intercept variance for the grouping variable "experiment" was estimated at 0.0055 (SD = 0.074), indicating minimal variability in the likelihood of selecting the target option across experiments. The Intraclass Correlation Coefficient (ICC) was 0.002, suggesting that only 0.2% of the total variance in the likelihood of selecting the target option is attributable to differences between experiments. However, the inclusion of the decoy alternative did not affect active interest (aOR 0.86, 95% CI = 0.66–1.12 (Supplementary Table S9)), perceived cognitive effort (aOR 0.99, 95% CI = 0.79–1.25 (Supplementary Table S10)), or perceived decision difficulty (aOR 0.95, 95% CI = 0.75–1.20 (Supplementary Table S11)).

Subgroup analysis

The decoy effect rests on people actually perceiving the decoy to be inferior. However, our data revealed that this is not the case for some participants. The individuals who selected the later times or/ and further locations as more attractive might have done so for various reasons, such as genuine preference (e.g., for later times because of personal circumstances), indifference (e.g., further locations are not seen as different for individuals who commute a lot), and inattention (and hence random decisions). Therefore, this subgroup analysis excluded people who did not recognize the decoy as inferior. Thus, we set screening criteria to determine whether the alternative appointments were indeed perceived as inferior and acted as a decoy.

First, we excluded from the analyses the participants ($n = 71$, 15%) who selected the inferior appointment of the question "What would you prefer?" (Supplementary Figure S4) (the participants who chose the decoy in the intervention condition were originally classified as not wanting to get vaccinated). The results revealed no significant effects on vaccination intention across all three experiments. Additionally, there were no observed effects on active interest, cognitive effort, or perceived decision difficulty in the first and second experiments. However, the third experiment demonstrated a negative effect on both active interest and perceived decision difficulty (Supplementary Tables S12 & S13).

We also excluded from the analyses the participants ($n = 212$, 24.2%) who did not select the target appointment of the question "Which of the two appointments is more convenient for you?" (Supplementary Figure S5). The response options were "appointment 1; appointment 2; both are equally convenient". One appointment represented the target appointment, whereas the other appointment represented the inferior appointment.

Experiment 1 – decoy alternative at a distant location

The results of 198 participants revealed that the inferior option regarding distant location (10–30 miles away) did not influence the likelihood of the target appointment being chosen (intervention: 37.9% vs. control: 35.7%; $x^2 = 0.09$, $p = 0.768$, df = 1; aOR 1.167, 95% confidence interval (CI) 0.567–2.401 (Supplementary Table S14)). Similarly, there were no effects on active interest (34.5% vs. 42.1%; $x^2 = 1.00$, $p = 0.316$, df = 1; aOR 0.769, 95% confidence interval (CI 0.395–1.496 (Supplementary Table S15)), cognitive effort ($x^2 = 4.11$, $p = 0.391$, df = 4; aOR 0.935, 95% confidence interval (CI 0.527–1.666 (Supplementary Table S16)) or perceived decision difficulty ($x^2 = 5.17$, $p = 0.270$, df = 4; aOR 1.087, 95% confidence interval (CI 0.593–1.993 (Supplementary Table S17)).

Experiment 2 – decoy alternative at a later time point

The final sample included 172 participants. Expanding the choice set with a later appointment option (1–3 weeks later) positively influenced the likelihood of the target being chosen (72.2% vs. 43.1%; $x^2 = 9.47$, $p = 0.002$, df = 1; aOR 4.709, 95% confidence interval (CI) 1.721–12.885 $p < 0.01$ (Supplementary Table S14)). There was no effect on active interest (52.8% vs. 41.2%; $x^2 = 1.56$, $p = 0.212$, df = 1; aOR 1.798, 95% confidence interval (CI) 0.760–4.254 (Supplementary Table S15), cognitive effort ($x^2 = 8.83$, $p = 0.066$, df = 4; aOR 1.646, 95% confidence interval (CI) 0.790–3.429 (Supplementary Table S16), or perceived decision difficulty ($x^2 = 3.15$, $p = 0.533$, df = 4; aOR 1.353, 95% confidence interval (CI) 0.662–2.762 (Supplementary Table S17)).

Experiment 3 – A decoy alternative at a distant location at a later time

The final sample included 299 participants. The inferior option of the later time and distant location increased the likelihood of the target appointment being chosen (56% vs. 44.2%; $x^2 = 3.70$, $p = 0.054$, df = 1; aOR 1.923, 95% confidence interval (CI) 1.113–3.321 $p < 0.05$ (Supplementary Table S14)). The inclusion of inconvenient appointments did not affect active interest (30% vs. 41.2%; $x^2 = 3.57$, $p = 0.059$, df = 1; aOR 0.624, 95% confidence interval (CI 0.365–1.069 (Supplementary Table S15), cognitive effort ($x^2 = 6.24$, $p = 0.182$, df = 4; aOR 0.748, 95% confidence interval (CI 0.481–1.164 (Supplementary Table S16), or perceived decision difficulty ($x^2 = 2.39$, $p = 0.665$, df = 4; aOR 0.714, 95% confidence interval (CI 0.450–1.134 (Supplementary Table S17)).

Integrative analysis

The results aligned with the findings of the second and third experiment, demonstrating a statistically significant increase in the likelihood of selecting the target option when the decoy alternative was added (aOR 1.79, 95% CI 1.24–2.59, $p < 0.005$ (Supplementary Table S18)). The random intercept variance for the grouping variable "experiment" was estimated at 0.058 (SD = 0.242), indicating limited variability in the likelihood of selecting the target option across experiments. The Intraclass Correlation Coefficient (ICC) was 0.017, suggesting that only 1.7% of the total variance in the likelihood of selecting the target option is attributable to differences between experiments. However, the inclusion of the decoy alternative did not affect active interest (aOR 0.81, 95% CI = 0.57–1.15 (Supplementary Table S19)), perceived cognitive effort (aOR 0.92, 95% CI = 0.68–1.24 (Supplementary Table S20)), or perceived decision difficulty (aOR 0.97, 95% CI = 0.70–1.32 (Supplementary Table S21)).

Discussion

In three online experiments, we tested the asymmetric dominance (decoy) effect as a nudge technique during COVID-19 vaccination. We presented individuals (aged 18–33 years) with the choice between two appointments, with one being inferior in terms of distance or/and waiting time (decoy option). The initial analysis revealed that none of the three experiments provided evidence supporting this hypothesis. This result suggested that alternative appointments were not perceived as inferior.

Therefore, we conducted additional analyses after excluding the participants who preferred to get vaccinated at the inferior appointment and did not select the target appointment as the most convenient choice. The findings from two experiments suggest that decoys increase individuals' preference for COVID-19 vaccination. Furthermore, an integrative analysis, combining all datasets into a single dataset to maximize analytical power, reinforced this conclusion by demonstrating a consistent increase in individuals' preference for COVID-19 vaccination when decoys were present. The presence of an inferior vaccination appointment at a later time point or a distant location influences the attractiveness of the target appointment. This finding is in accordance with the existing literature. Previous research has identified both travel and waiting time as potential barriers to attending appointments[36–38]. A recent study in which a decoy was tested by waiting and travel times in cancer screening indicated an increase in screening intentions[31]. Similarly, a study using a dominant option for receiving a seasonal influenza vaccine later in the season, which also provided information and recommendations, revealed positive effects on vaccination intentions, with the vast majority of those who were willing to receive vaccination intended to receive early vaccination[33]. The difference in active interest was not statistically significant between the control and experimental groups in the three experiments.

Although the differences in cognitive effort and decision difficulty between the control and experimental groups were not significant, the majority of participants in the experiments reported that they expended little cognitive effort and did not perceive the decision as difficult, indicating that adding an alternative appointment to the choice set did not cause choice overload[39].

The design and analysis plan for our experimental study were rigorously pre-registered on the Open Science Framework before any data collection began. Pre-registration is particularly important in vaccination studies due to their significant implications for public health and individual well-being. By pre-registering, we enhance transparency, minimize potential biases, and uphold the integrity of the research process. This approach not only strengthens the credibility of our findings but also fosters an open and accountable research practice.

This study has several limitations. First, the assumption that the alternative appointments were inferior was not tested beforehand. Although previous studies have designed inferior alternatives to act as decoys, in our study, the dimensions regarding distance and time were taken from the literature rather than defined by iterative processes[31,32]. Second, the study used hypothetical scenarios and nonrepresentative online study samples. Third, similar to previous studies, all the decision options were made explicit in the experiments, including not being vaccinated[31,32]. While one could argue that this is not realistic, studies have confirmed the decoy effect when the undesired option (not engaging in the behaviour) is hidden[40]. An additional limitation is the response or acquiescence bias regarding the nonintenders, who might have deliberately mislabelled themselves to stay in the survey[41]. Moreover, the participant pool did not include people older than 33 years. Younger adults are less likely to receive a COVID-19 shot and less likely to follow standard health recommendations from providers[42]. Thus, this age group might require new approaches, such as the one suggested in this study, to increase its uptake rates. Although our findings are based on data from a specific region and age range, they offer valuable insights that may be applicable to similar contexts. Nonetheless, this limitation should be acknowledged, and future research should investigate other geographic areas and more diverse populations to assess the generalizability of these results. Furthermore, the study was powered at 80%, which is standard practice in research design. However, this power may have been insufficient to detect smaller effects. Due to resource constraints, such as limited participant availability, we were only able to recruit approximately two-thirds of the originally planned sample size (about 1,000 participants instead of 1,500). Although the absence of significant findings from the manipulation is not unexpected, this limitation should be considered when interpreting the null findings. Finally, this study examined intentions rather than actual vaccination uptake. As anticipated in the existing literature[43–45], the effects on actual behaviour were smaller than those reported through self-reported intentions. This highlights a key limitation, suggesting that detecting significant effects in actual behavioural outcomes may require larger sample sizes. Self-reported measures can often inflate perceived effects, as individuals tend to overestimate their intentions or likelihood of engaging in specific behaviours. Nevertheless, research has shown that influencing intentions is strongly associated with a higher likelihood of actually receiving the vaccine[3,7,46].

The findings from our experiments indicate that providing additional alternative vaccination appointments—either later or at more distant locations—may be an effective strategy to increase the prevalence of Covid-19 vaccinations among certain adults in England who do not currently intend to be vaccinated. This is contingent upon ensuring, through formative research, that the decoy alternative is perceived as inferior by the general population. Understanding asymmetrical dominance is essential for grasping the complex, multifaceted nature of vaccination decisions, as it highlights how different attributes interact with and influence overall preferences. Although the initial results did not support the hypothesis that presenting an inferior (decoy) option would increase the preference for the target vaccination appointment, further subgroup analysis indicated that offering additional alternative vaccination appointments later or at more distant locations is likely to be an effective way to increase the uptake of COVID-19 vaccination appointments among some adults in England who do not currently intend to be vaccinated if we can ensure that the decoy alternative is perceived as inferior. Importantly, introducing a decoy option did not result in choice overload, underscoring the viability of this nudge technique. These findings contribute to a broader understanding of how behavioural economics can inform public health strategies, highlighting the potential of simple yet powerful nudges to improve health outcomes.

Method

Preregistration

The design and analysis plan for the experimental study were preregistered on the Open Science Framework (OSF; https://osf.io/5n3zd) before any data were collected. The questionnaire (see online supplemental file_questionnaire), analysis scripts and an abridged dataset containing all primary study variables can also be found on OSF.

Sample size calculation

The sample sizes for the three experiments were based on estimates from previous studies[31–33]. The experiments were sufficiently powered to detect differences of at least 10% in participants choosing the target option between conditions, with a power of 80% and an alpha value of 0.05[47].

Sample and procedure

The three independent online experiments were conducted in accordance with institutional ethics policy. This research was approved by HSSREC (number 117/20–21) at the University of Warwick, and all methods were performed in accordance with the relevant guidelines and regulations. The online survey data were collected by the survey vendor Dynata. The study participants who completed the survey received a small financial incentive from the survey vendor, which was defined by the length of the questionnaire (approximately 15 min). The study participants provided informed consent for their data to be used and published as part of this research project. A total of 948 individuals aged 18 to 33 years, residing in England and not yet eligible for vaccination at the time of the study, participated in the online experiments.

In experiment 1, data from 279 individuals were collected from May 22 to June 6, 2021. In experiment 2, data from 272 individuals were collected from May 28 until June 6, 2021. Experiment 3 was conducted between June 4 and July 7, 2021, and included a sample of 397 participants (Fig. 1).

Table 1 shows that the majority of the participants were between 26 and 33 years old for experiments 1 and 2 and between 18 and 25 years old for the third experiment. Female White-British individuals had at least A-levels, were not in paid employment, owned a car, lived in an urban area, and initially neither agreed nor disagreed to get vaccinated.

In all three experiments, participants were asked to indicate how much they agreed with the statement "*When it's available to me, I will have a coronavirus vaccine*" with the response options 'strongly disagree', 'disagree', 'neither agree nor disagree', 'agree' and 'strongly agree', taken from the National Institutes of Health (NIHR) Policy Research Unit Behavioural Sciences questionnaire on vaccination intentions[4]. Those who agreed or strongly agreed with the statement were redirected to the study briefing and final survey page, where they were thanked for their participation. Those who strongly disagreed, disagreed or neither agreed nor disagreed with the statement were individually randomized, with equal probability, to one of two conditions[31,32]. The reasons for conducting the study with individuals who initially expressed little or no interest in receiving vaccination were to minimize the ceiling and social desirability effects often associated with self-reported intention measures and to simulate a targeted intervention aimed at nonattenders who are in greatest need of effective behavioural interventions[31,32,48].

Experimental design

Eligible participants were individually randomized, with equal probability, to one of the two experimental vignettes with different versions of the COVID-19 vaccination invitation letter in each experiment. Participants

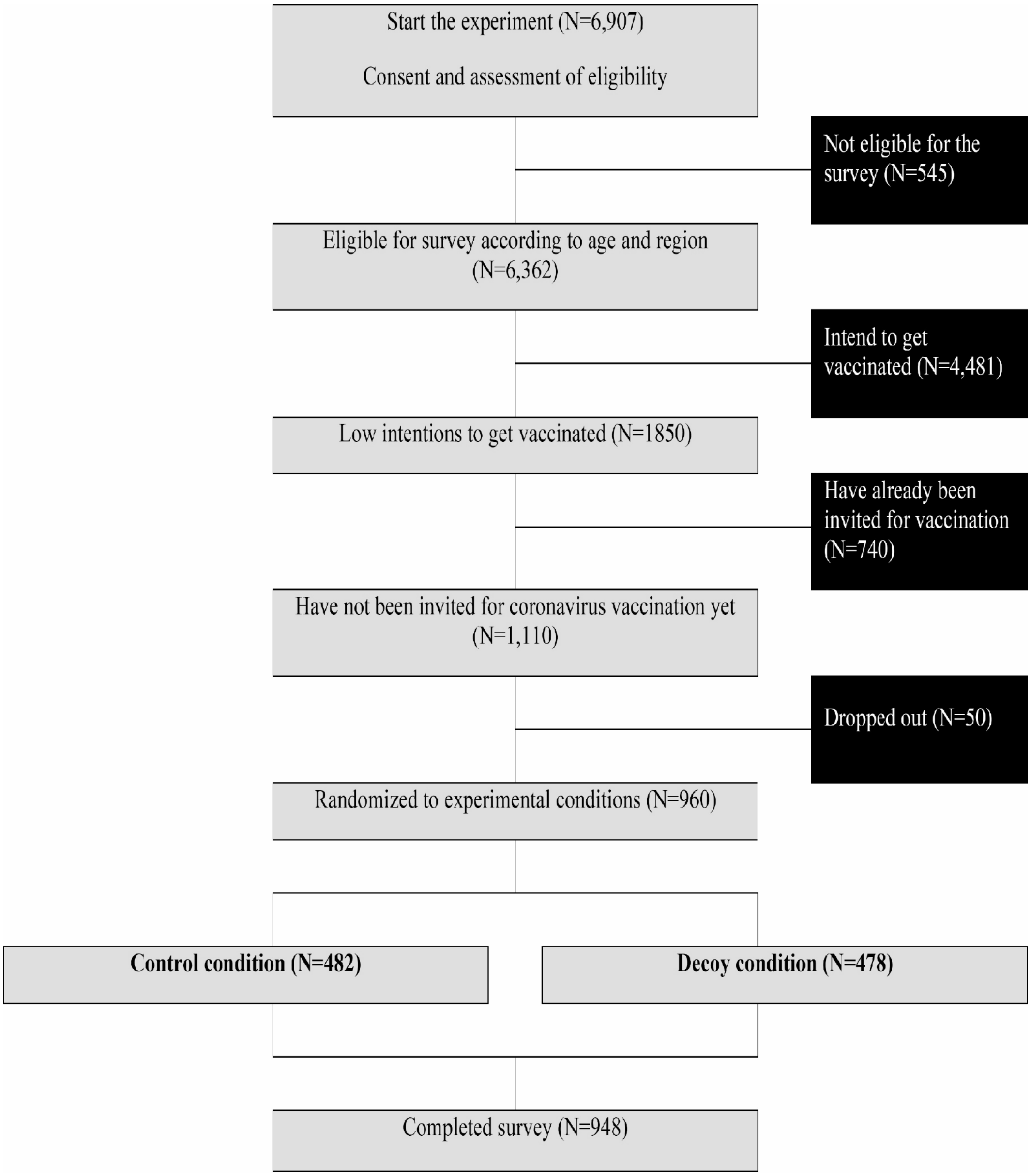

Fig. 1. Flow through all the experiments.

were instructed to imagine that they had received an invitation letter directly from the NHS. This approach aimed to enhance the credibility and authenticity of the message while fostering a sense of trust, which is the key for crafting convincing vaccination messages[49]. The control invitation letter was the same for all three experiments and included an appointment after two weeks at the participant's local GP practice, local pharmacy or local community centre (target appointment). The decoy condition in experiment 1 offered a less convenient alternative appointment at a distant location (same time at a vaccination centre 10–30 miles away); that in experiment 2 offered a less convenient alternative appointment at a later time point (after 3–5 weeks at the participant's local GP practice, local pharmacy or local community centre); experiment 3 offered an alternative less convenient appointment at a distant location and later time (after 3–5 weeks at a vaccination centre 10–30 miles away) (see Table 2).

Outcome measures

All three experiments had the same outcome variables.

Vaccination intention. The primary outcome variable was the intention to get vaccinated by stating what they prefer, with answer options being "to get vaccinated at the offered appointment(s)" or "to not get vaccinated". To prevent order effects, the order of the appointment(s) and the 'no vaccination' option were counterbalanced. Vaccination intention is essential as it directly reflects participants' willingness to engage with vaccination.

Active interest. The secondary outcome consisted of a behavioural measure in the form of active interest in reading more about the COVID-19 vaccine[31,32]. The participants were asked whether they would like to 'read' or

	Experiment 1 (N=279)				Experiment 2 (N=272)				Experiment 3 (N=397)			
	Control (N=140)		Decoy (N=139)		Control (N=136)		Decoy (N=136)		Control (N=199)		Decoy (N=198)	
	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)	N	(%)
Initial intentions												
Strongly disagree	47	(33.6%)	54	(38.8%)	49	(36.0%)	49	(36.0%)	63	(31.7%)	62	(31.3%)
Disagree	32	(22.8%)	20	(14.4%)	27	(19.9%)	26	(19.1%)	41	(20.6%)	40	(20.2%)
Neither agree/dis.	61	(43.6%)	65	(46.8%)	60	(44.1%)	61	(44.9%)	95	(47.7%)	96	(48.5%)
Age												
18-21 years old	17	(12.1%)	18	(12.9%)	27	(19.8%)	35	(25.7%)	67	(33.7%)	57	(28.8%)
22-25 years old	26	(18.6%)	28	(20.1%)	33	(24.3%)	32	(23.5%)	66	(33.2%)	60	(30.3%)
26-29 years old	44	(31.4%)	46	(33.1%)	42	(30.9%)	39	(28.7%)	46	(23.1%)	52	(26.3%)
30-33 years old	53	(37.9%)	47	(33.8%)	34	(25.0%)	30	(22.0%)	20	(10.0%)	29	(14.6%)
Gender												
Male	55	(39.3%)	55	(39.6%)	62	(45.6%)	59	(43.4%)	82	(41.2%)	90	(45.5%)
Female	85	(60.7%)	83	(59.7%)	74	(54.4%)	74	(54.4%)	117	(58.8%)	106	(53.5%)
Non-binary	0	(0.0%)	1	(0.7%)	0	(0.0%)	3	(2.2%)	0	(0.0%)	2	(1.0%)
Ethnicity												
White	106	(75.7%)	102	(73.4%)	101	(74.3%)	91	(66.9%)	143	(71.9%)	127	(64.1%)
Black	7	(5.0%)	13	(9.4%)	10	(7.3%)	11	(8.1%)	17	(8.5%)	16	(8.1%)
Asian	17	(12.1%)	18	(12.9%)	14	(10.3%)	16	(11.8%)	22	(11.1%)	29	(14.7%)
Mixed and other	10	(7.1%)	6	(4.3%)	11	(8.1%)	18	(13.2%)	17	(8.5%)	26	(13.1%)
A-levels												
No	55	(39.3%)	50	(36.0%)	44	(32.4%)	45	(33.1%)	66	(33.2%)	67	(33.8%)
Yes	85	(60.7%)	89	(64.0%)	92	(67.6%)	91	(66.9%)	133	(66.8%)	131	(66.2%)
Paid employment												
No	82	(58.6%)	83	(59.7%)	72	(52.9%)	77	(56.6%)	130	(65.3%)	122	(61.6%)
Yes	58	(41.4%)	56	(40.3%)	64	(47.1%)	59	(43.4%)	69	(34.7%)	76	(38.4%)
Living condition												
Alone	46	(32.9%)	50	(36.0%)	43	(31.6%)	34	(25.0%)	69	(34.7%)	71	(35.9%)
With someone	94	(67.1%)	89	(64.0%)	93	(68.4%)	102	(75.0%)	130	(65.3%)	127	(64.1%)
Car ownership												
No	55	(39.3%)	59	(42.4%)	48	(35.3%)	59	(43.4%)	89	(44.7%)	93	(47.0%)
Yes	85	(60.7%)	80	(57.6%)	88	(64.7%)	77	(56.6%)	110	(55.3%)	105	(53.0%)
Living area												
Urban	113	(80.7%)	110	(79.1%)	111	(81.6%)	113	(83.1%)	154	(77.4%)	154	(77.8%)
Rural	27	(19.3%)	29	(20.9%)	25	(18.4%)	23	(16.9%)	45	(22.6%)	44	(22.2%)
Confidence (0-12)	8.38	(3.30)	8.26	(3.25)	8.46	(3.52)	8.85	(3.32)	7.81	(2.87)	8.41	(2.95)
Complacency (0-12)	8.05	(3.30)	8.61	(3.03)	8.66	(3.47)	8.54	(3.37)	7.87	(2.68)	8.00	(2.76)
Constraints (0-12)	10.26	(3.32)	10.30	(3.37)	10.68	(3.60)	10.20	(3.30)	10.30	(3.12)	10.98	(2.93)

Table 1. Descriptive statistics.

Appointment	Attribute 1: Time	Attribute 2: Location	Objective
Experiment 1			
Target	In 2 weeks' time (random day and time)	In the participant's local GP, local pharmacy or local community centre	-
Decoy	In 2 weeks' time (random day and time)	In a vaccination centre 10–30 miles away	Test distance as an inferior option
Experiment 2			
Target	In 2 weeks' time (random day and time)	In the participant's local GP, local pharmacy or local community centre	-
Decoy	In 3–5 weeks' time (random day and time)	In the participant's local GP, local pharmacy or local community centre	Test later timing as an inferior option
Experiment 3			
Target	In 2 weeks' time (random day and time)	In the participant's local GP, local pharmacy or local community centre	-
Decoy	In 3–5 weeks' time (random day and time)	In a vaccination centre 10–30 miles away	Test both later timing and distance as an inferior option

Table 2. Vaccination appointments offered to study participants.

'skip' information about the vaccination procedure before continuing with the survey. Those who skipped it were sent to the end of the questionnaire with the sociodemographic question, whereas those who wanted to read the information were presented with additional information about the vaccination from the official NHS website. The comprehensiveness of the information was measured with four multiple-choice questions. Active interest assesses participants' willingness to seek additional information about the COVID-19 vaccine. Understanding whether participants show active interest in learning more can reveal their level of engagement and openness to vaccination.

Perceived difficulty and cognitive effort. To explore the impact of the experimental manipulation on perceived difficulty, we included the question '*How difficult was it for you to answer whether you would get vaccinated at appointment 1 or appointment 2?*' Additionally, we asked '*How much effort did you put into deciding whether you would get vaccinated or not?*' Both items were adapted and simplified from a 12-item subjective measurement of mental load and mental effort[50], featuring 5-point, fully labelled Likert scale response options. Perceived difficulty and cognitive effort provide valuable insights into how participants process the decision-making task. We can understand potential barriers or hesitations they may experience regarding vaccination.

Perceived attractiveness and similarity of the offered vaccination appointments. We also checked whether study participants in the intervention condition perceived the decoy as worse than the target, which is necessary to produce the expected effect[51]. Specifically, individuals were asked to state which appointment they perceived as more convenient ("appointment 1", "appointment 2" or "both are equally convenient") and how similar they perceived the two appointments. The latter question used a five-point fully labelled Likert scale ("not much", "little", "somewhat", "much" and "a great deal"). Perceived attractiveness and similarity of appointments are crucial for determining whether participants perceive the decoy option as inferior. By assessing perceived convenience and similarity between the appointments, we ensure that the experimental manipulation is functioning as intended.

Attitudes toward vaccination. Nine additional questions from the 5 C measure of the psychological antecedents of vaccination were used[52]. The questions featured 7-point fully labelled Likert scales [0;6] and were combined into three constructs on confidence in vaccination and public authorities, complacency and perceived constraints with scores between 0 and 18 each. The first construct measures participants' trust in vaccines and the institutions that promote them, such as healthcare authorities and government bodies. Thus, we can identify how perceptions of vaccine safety, efficacy, and the credibility of public authorities' impact individuals' decisions regarding vaccination. Complacency pertains to individuals' perceptions regarding the necessity of vaccination. It encompasses the belief that they may not be at significant risk of contracting the disease or that the potential consequences of the disease are not severe enough to justify vaccination. Identifying perceived constraints—such as access to vaccination sites, time limitations, and economic factors—enables us to understand the practical challenges individuals face when considering vaccination.

Together, these measures offer a comprehensive perspective on vaccine uptake by integrating both intentions and psychological constructs.

Patient and public involvement

The NIHR Policy Research Unit in Behavioural Science has its own dedicated PPI strategy group of seven patient and public representatives who were involved in developing the proposal for the project.

Statistical analysis

A chi-square test was used to determine if there were differences between the control group and the experimental group in terms of their likelihood of choosing the target appointment and reading additional information, as well as in their perceived decision difficulty and decision effort. We also used multivariable logistic regression adjusting for baseline intentions and sociodemographic variables to investigate the effect of adding alternative vaccination appointments on the likelihood of choosing the target and active interest. Additionally, ordered logistic regressions were employed for perceived decision difficulty and decision effort. Kruskal-Wallis tests were employed to analyse differences in vaccination attitudes across experimental conditions. To maximize the analytical power of our data, we performed an integrative analysis by combining all datasets into a single dataset and including the grouping variable "experiment" as a random factor. This approach accounts for variability across the experiments while leveraging the full dataset. We employed multilevel mixed-effects logistic regression to examine the effect of offering alternative vaccination appointments on the likelihood of selecting the target option and the active interest. For the outcomes of perceived decision difficulty and decision effort, we used multilevel mixed-effects ordered logistic regression. To further evaluate the robustness of the model, we assessed the random-effect variance and calculated the intraclass correlation coefficient (ICC). The ICC quantifies the proportion of variance attributable to the grouping variable, providing insights into the consistency of effects across experiments. The statistical analysis was conducted with Stata/SE V.17.0 (StataCorp LP).

Data availability

The data presented in this study are available upon reasonable request from the corresponding author.

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Author contributions
All authors conceptualized the study. Data curation was performed by A.G. and S.S. A.G., S.S., and I.V. carried out the formal analysis. The investigation was conducted by all authors. The methodology was developed by all authors. Supervision was provided by F.F.S. and I.V. In addition, A.G. and S.S. wrote the original draft of the manuscript and prepared figures and tables. All authors contributed to the review and editing of the manuscript.

Declarations

Competing interests
The authors declare no competing interests.

Ethics approval and consent to participate
This research was approved by HSSREC (number 117/20–21) at the University of Warwick, and all methods were performed in accordance with the relevant guidelines and regulations. The study participants provided informed consent for their data to be used and published as part of this research project.

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