Supplementary information

Contents:

Supplementary Notes

1. **Changes to eligibility criteria after publication of protocol but prior to study commencement:**
   Before study commencement, the minimum number of registered patients was increased from 500 to 1000 (this excluded two additional practices), and an additional criterion was added for the proportion of adults aged between 25 and 64 within the practice population to be between 10 and 85% (this excluded eight additional practices which appeared to be either care homes or services specifically for homeless people).

2. **Factors affecting timing of interventions:**
   For wave 1: the first Monday of the intervention period was a bank holiday when most practices would be closed, therefore faxes and emails were sent on the Tuesday; the complete set of fax numbers was not used initially and 112 faxes were sent two days later; and confusion during communication with the printing and mailing company led to the letters arriving a day or two late in the first wave. During wave 2, due to exceptional circumstances, staff absence caused a delay in sending faxes and emails by one day.

3. **Changes to data analysis after commencement of trial:**
   - *Data processing*: corrected brackets (curly:square) which assigned column suffixes incorrectly. See note 4 for changes made to Google Analytics extraction procedure.
   - *Primary engagement outcome*: no changes to data analysis.
   - *Secondary engagement outcomes*: Analysis of page views per page changed to change from baseline and using a regression model.
   - *Primary prescribing outcome*: no changes to data analysis.
   - *Secondary prescribing outcomes*: Estimation of impact on number of impact on number of items prescribed used simple arithmetic rather than the regression model.

4. **a) Prescribing data**
   Aggregation:

Aggregated measure values for the six-month baseline and follow-up periods were calculated for each practice, by summing items/ADQs prescribed (and averaging STAR-PU) then calculating proportions.

Exclusions:

Practices in the intervention group will be included in analysis whether or not they opt out of the intervention. Prescribing datasets are highly complete, but missing data (i.e. no prescribing) may occur in the case of practices closing before the start of the follow-up period. Such practices will be excluded from analysis, as this should not be influenced by our intervention; and during the course of closure they are likely to have substantially reduced prescribing levels and limited capacity to interact with the intervention.

b) Google Analytics data

Aggregation:

We extracted data on “Unique Pageviews” (separate browsing sessions) for practice dashboards. Aggregated unique pageviews for each baseline and follow-up period were calculated by summing across all practices in each group. For analysis of the number of pageviews per page, the 99th percentile value across all groups was set as a ceiling, i.e. the top 1% of values were made equal to this value to minimise the effect of extreme outliers.

Change made to extraction procedure:

There were some unexpected data extraction restrictions from Google Analytics: full links accessed by participants were not shown as expected and we had to use “segments”, which caused analysis periods to be limited to maximum 93-day periods. This did not affect the primary outcome.

Users:

Distinct users are defined in Google Analytics by storing a cookie on the browser when a site is first visited. This means that if someone uses a different device or browser they would be classed as a new user.

Minimisation of contamination:

Google Analytics activity tracking was blocked for research group members via browser tools.

Factors affecting page views:

Comparison of page views after each wave may have been affected by the monthly alerts, which were sent on June 19th (after wave 2) and August 6th (after wave 3). During the 15-week baseline period, alerts were sent on April 23rd and Feb 22nd. However, these issues should affect control and intervention practices to a similar extent.

5. **Letters returned unopened**

Seven letters were returned unopened (two were simply incorrectly stuffed). We had anticipated this may occur where practices were undergoing closure or other major changes. However this does not seem to be the case for those which were returned. Two letters were returned after wave 2, before which the previous letter is assumed to have been successfully delivered.

6. **Feedback question**
   An initial error in the code allowed the question to appear a second time following the wave 2 links, overwriting any previous response, potentially reducing the number of “yes” responses slightly.

Supplementary Figures and Tables

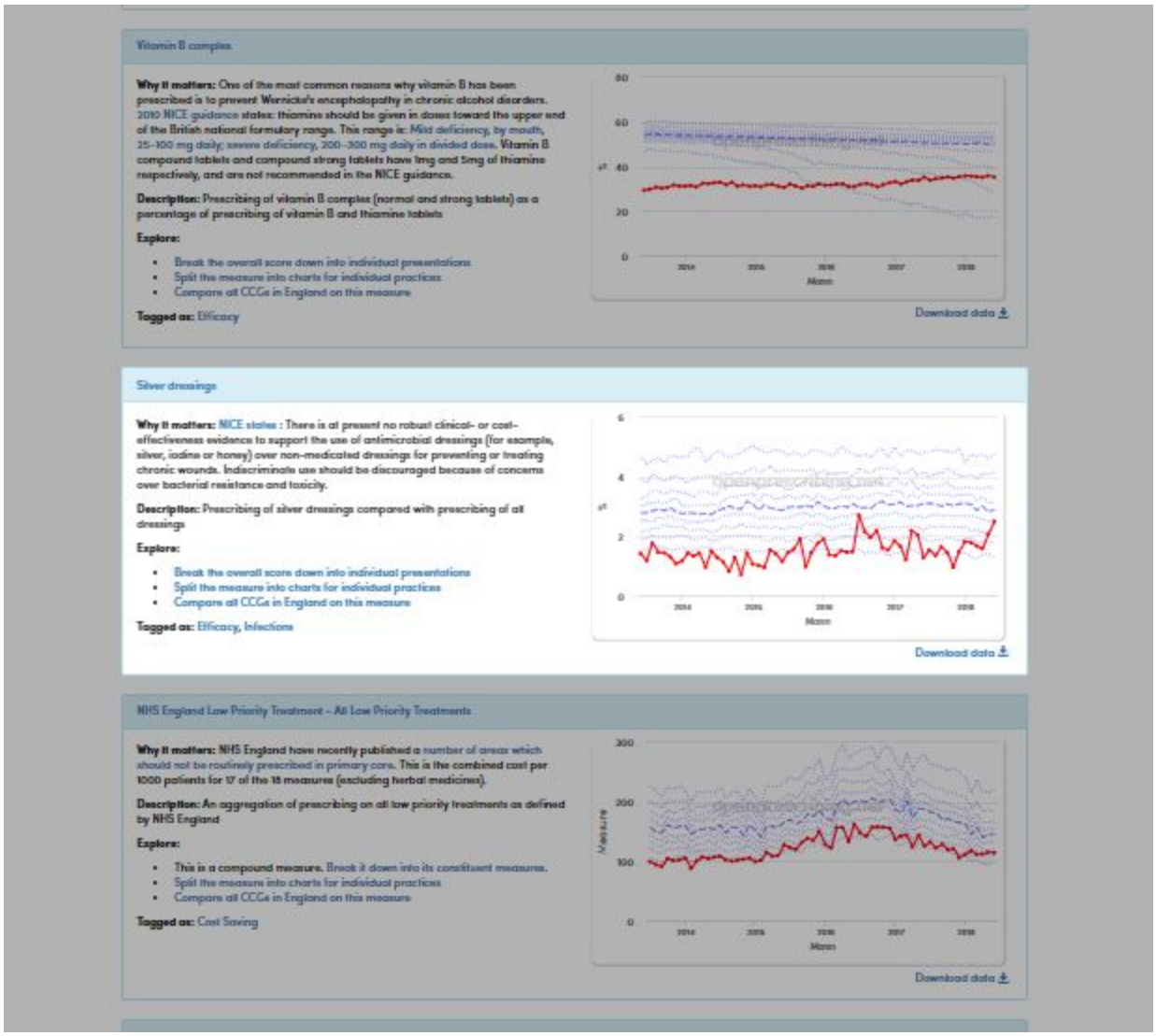


Figure S1. *Sample image similar to that which participants would see upon following a link supplied in an intervention (waves 1 and 2), a dashboard with a single measure highlighted. In wave 3, since different measures were mentioned in each group, no measure was highlighted on the dashboard.*

Table S1. Details of interventions sent.

Intervention wave	Intervention group	
	Behavioural impact	**Plain Feedback**
1	tailored broad-spectrum antibiotic feedback	tailored broad-spectrum antibiotic feedback (x3)
2	antibiotic feedback "reminder", with a link to prior evidence of feedback prompting change in antibiotic prescribing and an invitation to contact us	
3	a tailored chart of potential cost savings* and more information about other data available at OpenPrescribing.net	

** the 'standard' cost-saving measure from OpenPrescribing giving the greatest savings potential for each practice was selected. If no measure came over both threshold values of £250 in total and £50 per thousand patients registered at the practice, we instead used the NHS England low-value treatments measure (https://openprescribing.net/measure/lpzomnibus).*

Table S2. Outcomes as pre-specified in protocol. *Group A refers to the Behavioural impact group and Group B refers to the plain feedback group. "Inclusion check" column has been added to indicate that the specified outcomes have been included as planned.*

Objectives	**Outcome Measures**	**Timepoint(s) of evaluation of this outcome measure (if applicable)**	**Inclusion check**
Primary Objective P1. Our overall objective is to determine whether receipt of data feedback highlighting potential for improvement in antibiotic prescribing prompts practices to improve performance in	ENGAGEMENT: Difference in the proportion of practices having their dashboard viewed during the 15 week intervention period, between intervention and control groups.	ENGAGEMENT: Follow-up period: 5 weeks following each wave, including day of sending (total 15 weeks).	Included

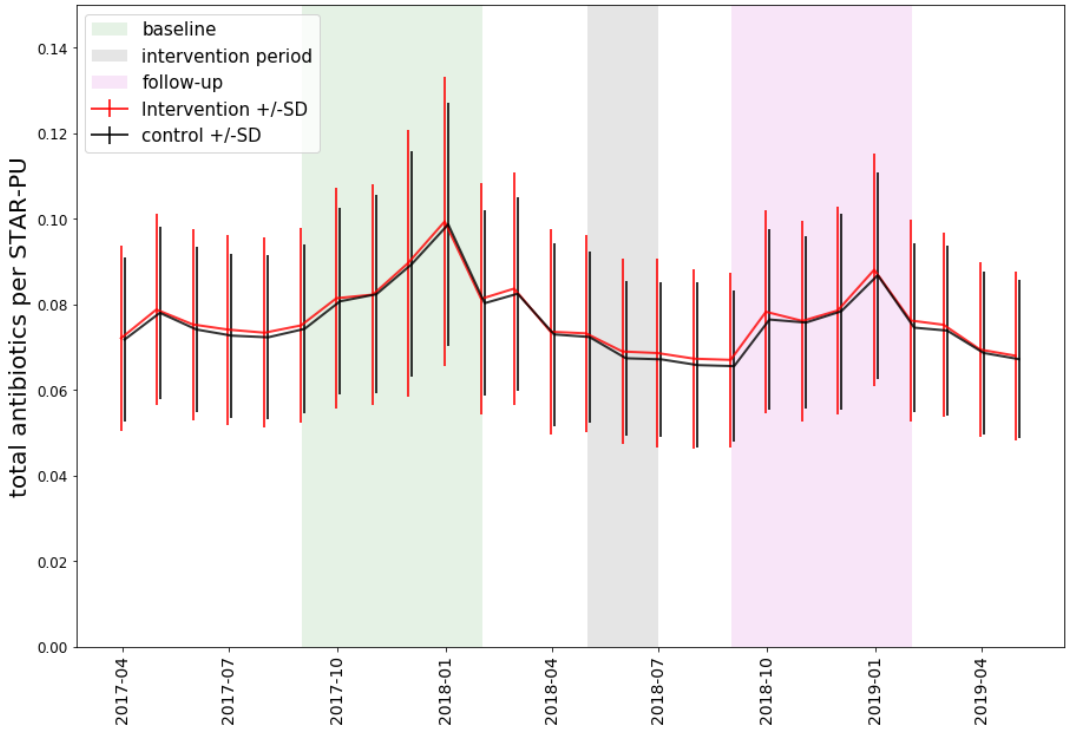
prescribing and engagement with data.	PRESCRIBING: Difference in the proportion of antibiotics prescribed which were broad-spectrum, during the follow-up period, between intervention and control groups.	Baseline period: 15 weeks prior to first intervention. PRESCRIBING: Follow-up period: corresponding six month period, one year on from baseline period. Baseline period: latest available six months of data at start of study.	Included
Our secondary objectives are to identify: S1. Whether behavioural change techniques affect the level of engagement; S2. Which method of communication is most effective (email, letter, fax); S3. Whether the intervention can lead to a wider impact on prescribing behaviours.	ENGAGEMENT: ● Difference in the proportion of practices having their dashboard viewed during the 15 week intervention period, and in the proportion of broad-spectrum antibiotics prescribed, between groups A and B (Objective S1). ● Difference in the mean dashboard views per practice during the 15 week intervention period, for intervention versus control groups, and for group A versus B (Objective P1, S1). ● Number of practices accessing at least one link provided in the intervention, as a proportion of all practices contacted, for group A versus B (Objective S1). ● Number of links accessed at least once as a proportion of all links delivered by each method of contact (email, fax, letter) (Objective S2).	See above.	Included Included Included Included

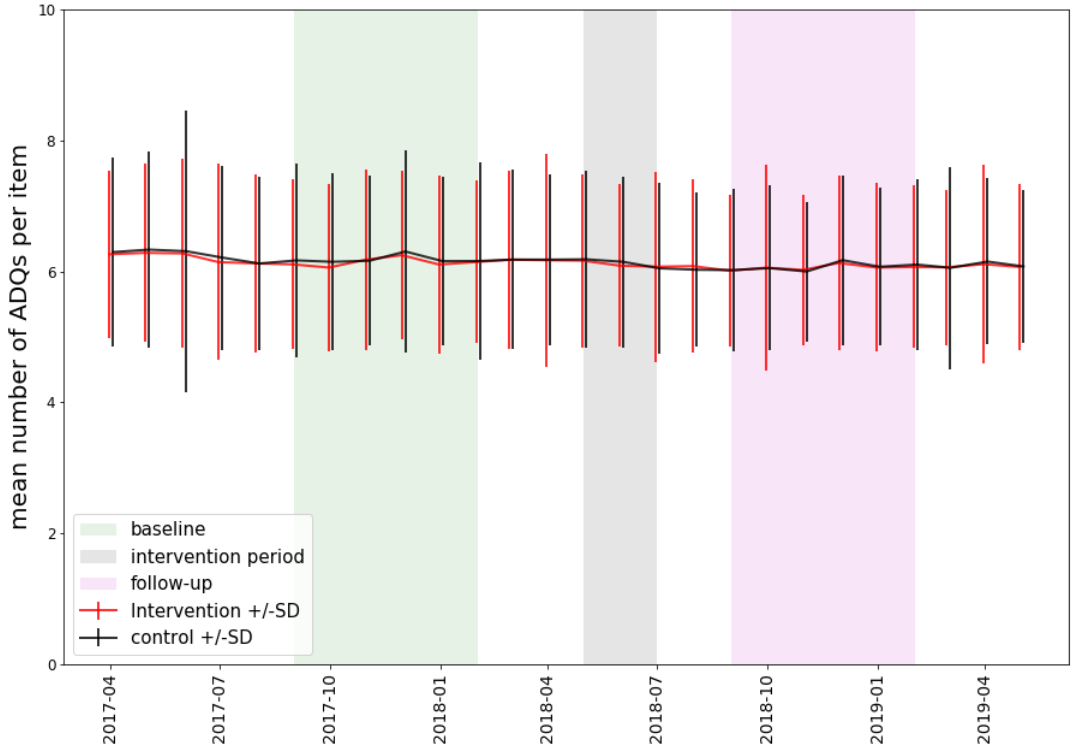
	● Proportion of emails opened overall; and total number of links accessed from emails as a proportion of those opened, during the follow-up period, for intervention A versus B (Objective S2).		Included
	● Exploratory descriptive analysis of browsing sessions arising from each link accessed: number of browsing sessions, number of different IP addresses, and number of pages viewed per session (to explore sharing of links among professionals) (Objectives S1-3, contamination).		Included except pages viewed per session (difficult to calculate from available data).
	PRESCRIBING:		
	● From the primary outcome measure we will estimate the overall effect of the intervention on the number of broad-spectrum antibiotics prescribed during the follow-up period. This will be calculated as the total difference between the observed number of broad-spectrum antibiotics per practice and the expected number had they been in the control group, using the regression model.		Included (but simple calculation rather than using regression model). Also included for group A vs B.
	● To assess wider impact on prescribing behaviours (Objective S3), we will also calculate the difference in other national antibiotic prescribing measures (a-c below) during the follow-up period, between intervention and control groups. These will be analysed using		Included Also included for group A vs B.

	multivariable linear regression as per the primary outcome, except where otherwise stated. 1. Rate of total antibiotic prescribing per adjusted population unit, Antibiotic STAR-PU (Specific Therapeutic group Age-sex Related Prescribing Unit) (EBM-DataLab 2017b). As this is a rate we will use a poisson regression model for analysis. 2. Mean number of daily doses per prescription for uncomplicated urinary tract infections (UTIs), measured as the mean number of average daily quantities (ADQs) per item, of trimethoprim 200mg tablets, nitrofurantoin 50mg tablets/capsules, nitrofurantoin 100mg M/R capsules and pivmecillinam 200mg tablets (EBM-DataLab 2017c). 3. Mean number of trimethoprim items prescribed as a percentage of all nitrofurantoin and trimethoprim items, per practice (EBM-DataLab 2017a). ● Each of the primary and secondary outcomes will also be compared between intervention groups A and B (Objective S1).		See notes above.

Other Analyses

Analysis	Inclusion check
Sub-group analyses: The primary and secondary **prescribing** outcome measures will also be compared ● between the sub-groups interacting with the link supplied, versus those not interacting; ● and for the sub-group which excludes those opting-out of the intervention.	Primary outcome only (no difference found). Primary outcome only (opt-out group very small)
Qualitative measures: The responses to the feedback question asked upon following the link in any of the interventions will be analysed against prior and post usage of the site. Any other feedback supplied by participants will also be collected (anonymously) and key themes compiled.	Included
Detection of contamination: Contamination is most likely to occur between practices belonging to the same CCGs, as practices are subject to management of prescribing by CCG Medicines Optimisation teams. However, this will be controlled for by block-randomising practices by CCG. Contamination beyond CCG boundaries may also occur through wider organisations or personal communications. However, provision of tailored advice should minimise the possibility for contamination among peer groups. By tracking links and web page access, rarely for an RCT we will be able to measure the extent of contamination by some routes: - Link sharing (links and pages accessed by multiple IP addresses) - Number of non-intervention practices having their OpenPrescribing.net pages viewed during sessions arising from links being clicked. This could either arise from participants observing other practices' behaviour after their own, or sharing the links with others who then look for their own practice.	Included Included


baseline
intervention period
follow-up
Intervention +/-SD
control +/-SD
total antibiotics per STAR-PU
0.00
0.02
0.04
0.06
0.08
0.10
0.12
0.14
2017-04
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04


mean number of ADQs per item
0
2
4
6
8
10
baseline
intervention period
follow-up
Intervention +/-SD
control +/-SD
2017-04
2017-07
2017-10
2018-01
2018-04
2018-07
2018-10
2019-01
2019-04

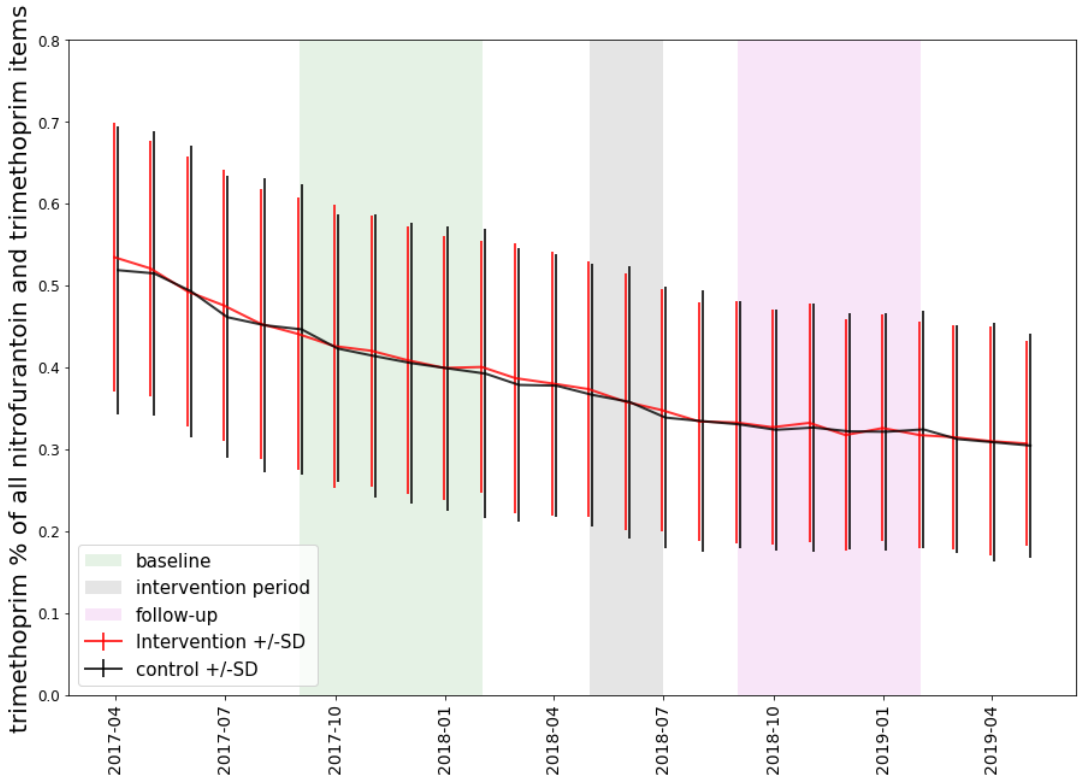


Figure S2. *Performance on other antibiotic prescribing measures, April 2017- May 2019, for practices included in the intervention (red) and control (black) groups: (a) Total antibiotics per STAR-PU, (b) Mean number of average daily quantities (ADQs) per item for antibiotics used in UTIs, and (c) percentage of items which were trimethoprim out of all nitrofurantoin and trimethoprim items. The baseline, intervention, and follow-up periods are shaded. SD=standard deviation.*

Table S3. Interventions delivered by each route, and links accessed as a result. *Figures shown in brackets represent results of distinct practice counts, ie. excluding where links are accessed by the same practice more than once. 'Emails Opened' figures are approximate, as this cannot be detected accurately. Seven letters were returned unopened (see Supplementary note 5). BI=behavioural impact feedback group.*

wave	group	Letters			Faxes			Emails					Any source
		Delivered	Links accessed		Delivered	Links accessed		Delivered	Opened		Links accessed		Links accessed
1	BI	356	12	3.4%	342	11	3.2%	351	94	26.8%	35	10.0%	54
	plain	343	14	4.1%	322	8	2.5%	329	61	18.5%	29	8.8%	47
	total	699	26	3.7%	664	19	2.9%	680	155	22.8%	64	9.4%	101
2	BI	353	8	2.3%	330	7	2.1%	339	86	25.4%	17	5.0%	30
	plain	343	5	1.5%	312	7	2.2%	314	61	19.4%	22	7.0%	34
	total	696	13	1.9%	642	14	2.2%	653	147	22.5%	39	6.0%	64
3	BI	349	7	2.0%	327	4	1.2%	329	57	17.3%	20	6.1%	30
	plain	342	2	0.6%	309	4	1.3%	309	47	15.2%	15	4.9%	20
	total	691	9	1.3%	636	8	1.3%	638	104	16.3%	35	5.5%	50
all	BI	1058	27	2.6%	999	22	2.2%	1019	237	23.3%	72	7.1%	114 (93)
	plain	1028	21	2.0%	943	19	2.0%	952	169	17.8%	66	6.9%	101 (85)
	all	**2086**	**48 (45)**	**2.3%**	**1942**	**41 (38)**	**2.1%**	**1971**	**406**	**20.6%**	**138 (109)**	**7.0%**	**215 (178)**

Table S4. Regression analysis results for number of page views per page.

Practice Views per Page						
R-squared: 0.073	**coef**	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
Intercept	1.0033	0.105	9.578	<0.001	0.798	1.209
data["Unique Pageviews_before"]	0.2983	0.03	10.059	<0.001	0.24	0.356
intervention	0.3888	0.134	2.903	**0.004**	0.126	0.652
Practice Views per Page - behavioural impact vs plain feedback						
R-squared: 0.050	**coef**	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**
Intercept	1.3271	0.166	7.983	<0.001	1.001	1.654
data["Unique Pageviews_before"]	0.3119	0.052	6.017	<0.001	0.21	0.414
intervention	0.0897	0.213	0.421	**0.674**	-0.328	0.508

Table S5. McNemar paired sample test statistics for number of links accessed from each method (email vs fax, email vs post, and fax vs post). *Numbers shown are counts of practices not accessing (0) vs accessing (1) a link from each source. The sensitivity analysis indicated that there was no major impact of availability of each method of contact for each practice.*

	email			**email**			**fax**	
fax	**0**	**1**	**post**	**0**	**1**	**post**	**0**	**1**
0	622	62	**0**	617	60	**0**	661	16
1	17	2	**1**	22	4	**1**	23	3
McNemar paired sample test statistics								
	17	p=3.59E-07		22	p=3.23E-05		16	p=0.34
Sensitivity analysis: filtered to practices only accessing links via all 3 methods								
	email			**email**			**fax**	
fax	**0**	**1**	**post**	**0**	**1**	**post**	**0**	**1**
0	602	61	**0**	598	59	**0**	641	16
1	17	2	**1**	21	4	**1**	22	3
McNemar paired sample test statistics								
	17	p=5.67E-07		21	p=2.53E-05		16	p=0.42

Table S6. Practice responses to the survey question *"Did the information we sent give you new information about your prescribing?" which was asked the first time any link was used for each practice. No response indicates that no link was accessed for a practice, but may include some practices who ceased attempting to interact with the site once faced with the question.*

Group	Total practices	Any response	no	yes
behavioural impact	356	90 (25.3%)	28	62 (68.9%)
plain	347	82 (23.6%)	23	59 (72.0%)
total	703	172 (24.5%)	51	121 (70.3%)

Table S7. Practice responses to the survey question *("Did the message we sent give you new information about your prescribing?") and number of practices having their dashboard views according to their answer "yes"/"no".*

Answer	**Total practices**	**Practice dashboards viewed**			
		Baseline period		**Follow-up period**	
yes	121	72	59.5%	97	80.2%

no	51	36	70.6%	44	86.3%

Table S8. Regression analysis results for prescribing outcomes.

Primary outcome		**coef**	**std err**	**t**	**P>|t|**	**[0.025**	**0.975]**	R-squared: 0.140
	Intercept	0.0348	0.006	6.182	<0.001	0.024	0.046	
	data["Baseline Measure"]	0.6384	0.043	14.871	<0.001	0.554	0.723	
	intervention	-0.0031	0.002	-1.625	0.104	-0.007	0.001	
Primary outcome (plain vs BI)		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.251
	Intercept	0.0233	0.006	3.907	<0.001	0.012	0.035	
	data2["Baseline Measure"]	0.6882	0.046	15.116	<0.001	0.599	0.778	
	Plain feedback	0.0041	0.002	1.998	0.046	7.23E-05	0.008	
Other antibiotic prescribing measures								
Total volume per STAR-PU		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.780
	Intercept	0.0571	0.006	9.169	<0.001	0.045	0.069	
	data["Baseline Measure"]	0.7945	0.011	69.477	<0.001	0.772	0.817	
	intervention	0.0035	0.003	1.071	0.284	-0.003	0.01	
UTI duration (ADQ per quantity)		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.498
	Intercept	1.8851	0.116	16.255	<0.001	1.658	2.113	
	data["Baseline Measure"]	0.6784	0.018	36.893	<0.001	0.642	0.714	
	intervention	0.0003	0.037	0.007	0.994	-0.072	0.072	
UTI preferred antibiotics (Nitrofurantoin vs trimethoprim)		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.493
	Intercept	0.0715	0.008	9.252	<0.001	0.056	0.087	

	data["Baseline Measure"]	0.6101	0.017	36.521	<0.001	0.577	0.643	
	intervention	0.0005	0.005	0.097	0.922	-0.009	0.01	
Other antibiotic prescribing measures - behavioural impact vs plain feedback								
Total volume per STAR-PU		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.796
	Intercept	0.0593	0.008	7.025	<0.001	0.043	0.076	
	data["Baseline Measure"]	0.7887	0.015	51.54	<0.001	0.759	0.819	
	plain feedback	0.0087	0.005	1.802	0.072	-0.001	0.018	
UTI duration (ADQ per quantity)		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.487
	Intercept	1.751	0.171	10.236	<0.001	1.415	2.087	
	data["Baseline Measure"]	0.6936	0.027	25.546	<0.001	0.64	0.747	
	plain feedback	0.0839	0.054	1.542	0.124	-0.023	0.191	
UTI preferred antibiotics (Nitrofurantoin vs trimethoprim)		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.441
	Intercept	0.085	0.012	7.375	0	0.062	0.108	
	data["Baseline Measure"]	0.584	0.025	23.29	0	0.535	0.633	
	plain feedback	-0.0044	0.007	-0.622	0.534	-0.018	0.009	
Other measures								
Cost saving measures		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.292
	Intercept	0.0858	0.008	10.631	<0.001	0.07	0.102	
	data["baseline measure"]	0.3589	0.019	18.542	<0.001	0.321	0.397	
	intervention	-0.0088	0.01	-0.893	0.372	-0.028	0.011	
Subgroup analyses								

Effect of list size (deciles)		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.141
	Intercept	0.031	0.006	4.979	<0.001	0.019	0.043	
	data["Baseline Measure"]	0.6491	0.044	14.871	<0.001	0.563	0.735	
	list_size_decile	4.98E-05	3.38E-05	1.474	0.141	-1.65E-05	0	
	intervention	-0.0032	0.002	-1.672	0.095	-0.007	0.001	
Subgroup interacting with a link vs not interacting		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.246
	Intercept	0.0257	0.006	4.335	<0.001	0.014	0.037	
	data["Baseline Measure"]	0.6866	0.046	15.036	<0.001	0.597	0.776	
	interaction	-0.0006	0.002	-0.247	0.805	-0.005	0.004	
Subgroup opting out		coef	std err	t	P>|t|	[0.025	0.975]	R-squared: 0.246
	Intercept	0.0255	0.006	4.341	<0.001	0.014	0.037	
	data["Baseline Measure"]	0.6868	0.046	15.04	<0.001	0.597	0.776	
	opt_out	-0.0012	0.009	-0.132	0.895	-0.019	0.017	