The Effect of Expert Feedback on Antibiotic Prescribing in Pediatrics: Experimental Evidence

Kerstin Eilermann
Department of Business Administration and Health Care Management, University of Cologne

Katrin Halstenberg
University of Cologne, Medical Faculty and University Hospital, Department of Pediatrics, Cologne

Ludwig Kuntz
Department of Business Administration and Health Care Management, University of Cologne

Kyriakos Martakis
University of Cologne, Medical Faculty and University Hospital, Department of Pediatrics, Cologne

Bernhard Roth
University of Cologne, Medical Faculty and University Hospital, Department of Pediatrics, Cologne

Daniel Wiesen
Department of Business Administration and Health Care Management, University of Cologne

UNIVERSITY OF OSLO
HEALTH ECONOMICS RESEARCH NETWORK

Working paper 2020: 1

Health Economics Research Network at the University of Oslo
ISSN 1501-9071 (print version.), ISSN 1890-1735 (online), ISBN 978-82-7756-267-4

The Effect of Expert Feedback on Antibiotic Prescribing in Pediatrics: Experimental Evidence

Running head: Feedback Experiment in Pediatrics

Authors:

Kerstin Eilermann, MSc
Cologne Graduate School in Management, Economics, and Social Sciences (CGS) and Department of Business Administration and Health Care Management, University of Cologne, Germany. Email: eilermann@wiso.uni-koeln.de

Katrin Halstenberg, MD
University of Cologne, Medical Faculty and University Hospital, Department of Pediatrics, Cologne, Germany. Email: katrin.halstenberg-scherer@uk-koeln.de

Ludwig Kuntz, PhD
Department of Business Administration and Health Care Management, University of Cologne, Germany, and Operations Management Group, Judge Business School, University of Cambridge, UK. Email: kuntz@wiso.uni-koeln.de

Kyriakos Martakis, MD, MSc
University of Cologne, Medical Faculty and University Hospital, Department of Pediatrics, Cologne, Germany, Maastricht University, Department of International Health, Care and Public Health Research Institute, School CAPHRI, Maastricht, the Netherlands, and Department of Pediatric Neurology, University Children's Hospital (UKGM) and Medical Faculty, Justus Liebig University of Giessen, Germany. Email: kyriakos.martakis@uk-koeln.de

Bernhard Roth, MD
University of Cologne, Medical Faculty and University Hospital, Department of Pediatrics, Cologne, Germany. Email: Bernd.Roth@uk-koeln.de

Daniel Wiesen, PhD (corresponding author)
Department of Business Administration and Health Care Management, University of Cologne, Albertus-Magnus-Platz, 50923 Cologne, Germany, and Institute of Health and Society, Department of Health Management and Health Economics, University of Oslo, Oslo, Norway. Telephone: +49 221 470 89171. Email: wiesen@wiso.uni-koeln.de

Departments and institutions: University of Cologne, Department of Business Administration and Health Care Management Cologne, Germany, and University of Cologne, Medical Faculty and University Hospital, Department of Pediatrics, Cologne, Germany.

Presentations: This work was presented at the 17th Biennial European Conference of the Society for Medical Decision Making in Leiden, the Netherlands, in 2018, at the 6th Behavioral Experiments in Health Workshop in Oslo, Norway, in 2018, at the annual conference of the German Association for Health Economics in Berlin, Germany, in 2016, and in seminars at the University of Cologne, Germany, and the University of Wuppertal, Germany.

Financial support: Financial support for this study was provided by a grant from the Excellence Initiative of the German federal and state governments. The funding agreement ensured the authors' independence in designing the study, interpreting the data, writing, and publishing the report.

Abstract

Background. Inappropriate prescribing of antibiotics, which is common in pediatric care, is a key driver of antimicrobial resistance. To mitigate the development of resistance, antibiotic stewardship programs often suggest the inclusion of feedback targeted at individual providers. Empirically, however, it is not well understood how feedback affects individual physicians' antibiotic prescribing decisions. Also, the question of how physicians' characteristics, such as clinical experience, relate to antibiotic prescribing decisions and to responses to feedback is largely unexplored.

Objective. To analyze the causal effect of descriptive expert feedback (and individual characteristics) on physicians' antibiotic prescribing decisions in pediatrics.

Design. We employed a randomized, controlled framed field experiment, in which German pediatricians (n=73) decided on the length of first-line antibiotic treatment for routine pediatric cases. In the intervention group (n=39), pediatricians received descriptive feedback in form of an expert benchmark, which allowed them to compare their own prescribing decisions with expert recommendations. The recommendations were elicited in a survey of pediatric-department directors (n=20), who stated the length of antibiotic therapies they would choose for the routine cases. Pediatricians' characteristics were elicited in a comprehensive questionnaire.

Results. Providing pediatricians with expert feedback significantly reduced the length of antibiotic therapies by ten percent on average. Also, the deviation of pediatricians' decisions from experts' recommendations significantly decreased. Antibiotic therapy decisions were significantly related to pediatricians' clinical experience, risk attitudes, and personality traits. The effect of feedback was significantly associated with physicians' experience.

Conclusion. Our results indicate that descriptive expert feedback can be an effective means to guide pediatricians, especially those who are inexperienced, towards more appropriate antibiotic prescribing. Therefore, it seems to be suitable for inclusion in antibiotic stewardship programs.

Keywords: Framed field experiment, descriptive feedback, expert benchmark, length of antibiotic therapy, clinical experience.

1 Introduction

Inappropriate use of antibiotics is widespread and contributes to rapidly increasing antimicrobial resistance (AMR),[1,2] which has become a serious global public health problem.[3,4] Besides the choice of the antibiotic agent, the dosage, and the correct initiation, the length of therapy is relevant for an appropriate antibiotic treatment.[5,6] Excessive use of antibiotics and unnecessarily long treatment courses have a significant impact on the development of AMR.[1,7] In pediatrics, inappropriate antibiotic prescribing is a particular concern due to antibiotic-related adverse outcomes, such as organ toxicity.[8-10] The need for effective measures to support physicians practicing in pediatric and neonatal settings is therefore an urgent issue.[11] Antibiotic stewardship programs pick up on this and often suggest the inclusion of feedback mechanisms targeted at antibiotic prescribing practices of individual providers.[1,12,13]

Empirically, however, it is not well understood how feedback causally affects *individual* physicians' antibiotic prescribing and whether their characteristics, such as clinical experience, relate to their responses to feedback. Some studies using cross-sectional data report that feedback can be effective in achieving more appropriate antibiotic prescribing.[14-16] Nevertheless, cross-sectional data may suffer from multiple confounding effects (e.g., lack of control, self-selection, or simultaneous policy interventions and institutional changes) making causal inferences difficult.[17,18] Further, evidence from randomized controlled experiments on the effectiveness of feedback in medical practice is rather mixed.[19] Systematic evidence relating to antibiotic prescribing is scarce.[13] A recent randomized controlled trial (RCT) in the UK reported that providing social norm feedback affects general practitioners' antibiotic prescribing behavior.[20] Similarly, an RCT in the US found that peer comparison among primary care practitioners decreases overall antibiotic prescribing rates at the practice level.[21] However, the causal effect of feedback on antibiotic prescribing at the level of *individual* physicians remains barely understood.

The main objective of our study was to analyze the causal effect of expert feedback, a descriptive norm, on antibiotics prescribing in pediatrics. We considered physicians' individual prescribing decisions in a randomized, controlled, framed field experiment with 73 pediatricians.[a] In our experiment, which followed a mixed factorial design, pediatricians decided on the length of antibiotic therapies for hypothetical routine cases of pediatric

[a] According to Harrison and List's widely-used taxonomy of behavioral experiments, which ranges from laboratory experiments to natural field experiments, a framed field experiment is a structured experiment with subjects making decisions in their natural environment with the familiar context of the task, stakes, or information set.[22-24]

infectious diseases. In the intervention group, we first announced that feedback would be given and then provided expert feedback. Pediatricians received an aggregate expert recommendation (expert benchmark) on the appropriate length of therapies to which they could compare their own (aggregated) decisions. The control group did not receive any feedback. The expert recommendations were elicited in a survey of directors of pediatric departments in Germany (n=20).

Our study relates to recent social-norm feedback interventions in health care.[20,21] In our feedback mechanism, we employed an expert benchmark as a descriptive norm to guide pediatricians toward appropriate antibiotic prescribing. Our aim was to avoid potential adverse effects of comparisons with peers, such as an unintended change in the behavior of those performing better than the peers' average (the so-called "boomerang-effect").[25-27] The psychological literature on social norms provides evidence that descriptive normative information is an effective tool for changing behavior and for reducing undesired conduct.[28,29] We thus hypothesized that giving pediatricians expert feedback, which conveys a descriptive norm for antibiotic prescribing, would affect decisions on the length of antibiotic therapies and increase the appropriateness of prescribing.

We focused on the *length* of antibiotic therapy as it is critical for outcomes in children and for the development of antibiotic resistance.[5,6] Despite its importance, the length of antibiotic therapy has been neglected in studies on feedback interventions aimed at improving antibiotic prescribing. Existing studies rather focus on the choice of antibiotic agents or whether antibiotic therapies are initiated or not.[16,20,21] We thus complement this literature by providing evidence on the causal effect of feedback on the length of antibiotic therapies.

Further, we investigated whether and how pediatricians' individual characteristics, including gender, clinical experience, risk attitudes, and personality traits, relate to antibiotic therapy decisions. We thus contribute to a recent stream of literature linking physicians' characteristics to medical treatment decisions. Current evidence suggests that medical service provision is related to physicians' risk attitudes[30-35] and experience.[36,37] Further, the gender of physicians is associated with treatment[36] and prescribing decisions[38] and with patient outcomes.[39,40] Personality traits are also important to explain decisions and behavior in various contexts.[41,42] A few recent studies aim to link personality traits to the behavior of health care providers.[43,44] While these characteristics seem to be relevant in explaining the behavior of physicians, their association with antibiotic prescribing decisions remains largely inconclusive.[45,46] With respect to antibiotic prescribing, only the role of experience has been studied to a somewhat larger extent. Evidence from primary care settings suggests a positive

association between physicians' years of experience and their willingness to prescribe antibiotics.[47,48,49]

To contribute to a better understanding of how provider characteristics affect antibiotic prescribing, we related pediatricians' decisions on the length of antibiotic therapies to their gender, clinical experience, risk attitudes, and personality traits. In a comprehensive post-experimental questionnaire, we elicited the pediatricians' demographics, personality traits (using the Big-Five inventory[50,51]) as well as social and risk preferences.[52-54] We linked information on the pediatricians' characteristics to their decisions made in the experiment and controlled for the potential impact of characteristics in our regression analyses.

We further analyzed how responses to expert feedback are related to clinical experience. Drawing on the theory of knowledge[55,56] and theories of learning and routines,[57-59] which imply that humans develop knowledge, specific capabilities, and routines mainly through repetition and experiential hands-on learning, we hypothesized that physicians with more experience would be less prone to adapt their decisions after receiving expert feedback, but would rather tend to follow their own routines (built, for example, through hands-on experience with patients). We assumed that less experienced physicians would rely more on external input and hence be more likely to adapt their decisions.

In sum, our study addressed the main research question of how expert feedback causally affects individual pediatricians' decisions on (i) the length of antibiotic therapies and (ii) the appropriateness of antibiotic therapy decisions. We also investigated (iii) how pediatricians' individual characteristics relate to antibiotic prescribing decisions and (iv) how pediatricians' clinical experience relates to responses to expert feedback.

2 Methods

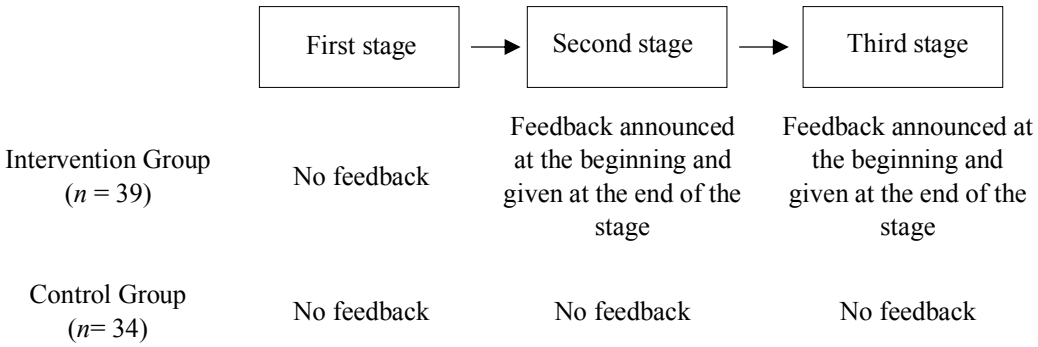
2.1 The Experiment: Design

Our framed field experiment comprised three stages. In each stage, pediatricians decided on the length of first-line antibiotic therapies for 40 routine pediatric cases, which were shown on the subjects' computer screens in randomized order. For each case, the pediatricians decided on the length of antibiotic therapy by entering an integer between 0 and 28 in an open field below the respective case description. In total, each pediatrician made 120 decisions in the three stages of the experiment. For completing the task, participants received a lump-sum payment of €50.

Pediatricians were randomly allocated to either an intervention or a control group. In the intervention group, we introduced feedback in form of an expert benchmark at the within-

subject level (see Figure 1). In the first stage, no feedback was provided. In the second stage, we announced that feedback would be provided at the end of the stage. After the second stage, feedback was shown (graphically as bar charts and numerically) such that subjects could compare their average length of antibiotic therapies for the 40 cases with the expert benchmark; for a sample screen, see Figure A.1 in Appendix A.1. The third stage was analogous to the second stage. This design allowed us to disentangle the effect of announcing feedback (comparing decisions from the first and second stages) and the effect of providing feedback (comparing decisions from the second and third stages). In the control group, feedback was neither announced nor provided in any stage. For the instructions of the experiment, see Appendix A.2.

Figure 1: Stages of the experiment



Notes. In each stage of the experiment, subjects decided on the length of antibiotic therapy for 40 routine cases, which were shown in randomized order. The first stage was the same in the intervention and control groups. At the beginning of the second stage, the intervention group was told that feedback would be given. After the second stage, feedback was shown such that subjects could compare the average of their chosen length of antibiotic therapies with the expert benchmark. The third stage was analogous to the second stage. In the control group, the decision situations in the second and third stages were identical to those in the first stage, and no feedback was announced or given.

2.2 Medical Cases and Expert Benchmark

The 40 cases covered a broad range of typical infectious diseases in pediatrics, namely (i) neonatal infections, (ii) infections of the central nervous system, (iii) bone and joint infections, (iv) upper respiratory tract infections, (v) lower respiratory tract infections, and (vi) urinary tract infections; Appendix A.3.1 provides the case descriptions. The case scenarios had been developed by the clinicians in the research team (three pediatricians with different sub-specializations) based on their clinical experience, clinical case reports, and textbooks. Afterwards, the cases were validated by five pediatricians of the Department of Pediatrics at the University Hospital Cologne, who did not participate in the experiment. The aim was to ensure (i) clarity and comprehensibility of the cases, (ii) their relevance in clinical practice, (iii)

their plausibility, and (iv) correctness and completeness of the given information; for more details, see Appendix A.3.2.

For all cases, the study participants decided on the length of first-line antibiotic therapy, which could be between zero and 28 days. Besides the length of therapy, the class of antibiotics as well as the dosage play a role for treatment outcomes.[60] We asked the pediatricians to consider the standard antibiotic agent and the standard dosage for each case when deciding on the length of therapies. We designed the cases such that a standard antibiotic agent and a standard dosage were available for all cases for which antibiotic treatment was indicated; see Appendix A.3.2 for details. We did not specify the agent to be used, as we intended to leave the decision on whether any antibiotics should be prescribed to the discretion of the pediatrician. With the option to choose zero days of antibiotic therapy, the task includes the decision on whether to initiate antibiotic therapy or not.

By using an expert benchmark as a norm for antibiotic prescribing, we contribute to the literature on the use of benchmarks in health care.[61] The expert benchmark is a descriptive norm because it provides information on the decisions of others for purposes of comparison.[28,29] We chose experts to define a normative benchmark that reflects personal expertise, national medical guidelines, and local standards in pediatric departments. To form the benchmark, we surveyed directors of German pediatric departments (referred to as 'experts') on their recommended length of antibiotic therapies for the 40 cases we used in the experiment. In total, 50 randomly chosen directors were contacted by formal letter, in which we asked them about their willingness to participate in a survey; 20 directors participated in our online survey between September and October 2014. As the expert benchmark, we chose the length of therapy averaged over all cases and experts, which was 6.42 days (SD 4.94, 95% CI 4.26 to 8.59).

To qualify the experts' decisions and to assess their suitability for a normative benchmark, we compared them with published recommendations on the length of antibiotic therapies. In particular, we considered recommendations published by the German Society for Pediatric Infectious Diseases for comparison[62]. While we observed some variation, the experts' decisions imply a high compliance with the recommendations; see Appendix A.4 for details. Besides the fact that the experts' recommendations were close to guidelines, we chose the aggregated expert benchmark as a means of feedback: (i) to maintain the pediatricians' discretion in choosing the cases for which, if at all, they would change their initially chosen length of therapy; (ii) to mimic a simple feedback mechanism which could potentially be implemented in a real clinical setting, as providing feedback on a case-by-case basis seems

prohibitively challenging; and (iii) to provide pediatricians in the experiment with a simple *directional* reference which could guide their own decisions.

Providing pediatricians with an expert benchmark which allows comparing one's own decisions with an expert recommendation is distinct from feedback applying peer comparisons (e.g., relative performance compared to peers). The latter may have unintended effects such as the previously mentioned "boomerang effect";[25,26] see Linder[27] on the importance of the design of feedback mechanisms and Meeker et al.,[21] who used a similar approach by allowing for comparisons with top performers instead of average-performing peers in their feedback intervention.

We employed a benchmark based on the opinion of experts instead of guideline recommendations, because physicians' negative attitudes toward medical guidelines have been identified as one of the main reasons for low guideline compliance in clinical practice.[63] Major concerns include the flexibility and applicability of guidelines in general and, in particular, antibiotic treatment recommendations for real cases.[63,64] Qualitative research has shown that other clinicians' opinions are the main source of knowledge about antibiotic prescribing in clinical practice. The opinions of other medical professionals have a greater impact on antibiotic prescribing decisions and are perceived as more effective in modifying prescribing patterns than guideline recommendations.[65] Based on these findings, we assumed expert-based feedback, reflecting the opinions of German pediatric-department directors, to have a potentially greater effect than guideline-based feedback.

2.3 Sample and Procedure

The computerized experiment was conducted with mobile tablet computers of the Cologne Laboratory for Economic Research (CLER). The experiment was programmed in z-Tree.[66] Experimental sessions took place at the Department of Pediatrics at the University Hospital Cologne (October and December 2014), the Children's Hospital of the City of Cologne (June 2015), and during the annual conference for pediatricians (Päd-Ass 2015) in Cologne (March 2015). Experiments were conducted in hospital seminar rooms, which we equipped with tablet computers and cubicles to ensure anonymous decision-making; for an illustration, see Figure A.2 in Appendix A.5.

Sample size calculations showed that at least 32 subjects in each experimental group were necessary to detect a difference of 0.5 days between the two groups, considering changes from Stage 2 to Stage 3 in both groups (between-subject comparison), using a two-tailed Mann-

Whitney-U test, and assuming a power of 80% and a 5% significance level. Pre-study sample size calculations were conducted using G*Power;[67] for more details, see Appendix A.6.

Overall, 73 pediatricians participated in our experiment; directors of pediatric departments were excluded. Pediatricians were recruited via e-mail and posters, which provided general information about the experiment and the scheduled sessions. Pediatricians were allowed to register only for one of the sessions publicized through an online poll. In total, eight sessions were conducted. In sessions at the Department of Pediatrics at the University Hospital Cologne and the Päd-Ass conference 2015, 22 and 6 subjects participated in the intervention and 14 and 20 in the control group, respectively. At the Children's Hospital of the City of Cologne, 11 subjects participated in the intervention group.

Using a simple coin toss, it was randomly determined whether intervention (feedback) or control treatment would be employed in a particular session. Pediatricians, uninformed about the content of the experiment prior to participation, were therefore allocated randomly to one of the two experimental groups. The baseline characteristics of the participants were well balanced between the two groups; see Table 1.

Table 1: Baseline characteristics of the study population

		Intervention group (n=39)	Control group (n=34)
Sex	Male	11 (28%)	6 (18%)
	Female	28 (72%)	28 (82%)
Share of consultants		15 (39%)	12 (35%)
Experience (Years worked in hospital)		5.37 (4.66)	5.05 (5.98)

Notes. Data are n (%) and mean (sd) for experience (years worked in hospital).

We employed a double-blind procedure. The person who conducted the experiment and managed the data was not involved in the recruiting of subjects. For each session, an external research assistant, employed by the Department of Personnel Economics of the University of Cologne, facilitated subject recruitment, registration, and remuneration. Upon their arrival, pediatricians drew a number that indicated their cubicle and computer. Decisions on the computer screens were made anonymously; the experimenter was only able to link the randomly assigned computer number to the respective subject's data. Payment was handed out in sealed envelopes.

The experimental sessions lasted for about one hour. Before the experiment started, written informed consent was obtained from all subjects and they received written instructions describing the general structure, the decision situation, and the task of the experiment. Prior to each stage of the experiment, subjects received stage-specific instructions. They were given sufficient time to read the instructions and any upcoming questions were answered in private at the cubicles. After completing the experiment and before receiving their payment, subjects were asked to answer some questions on their demographics and practical experience. Further, we elicited subjects' personality traits using the short 10-item Big Five questionnaire,[50,51] and their economic preferences, including risk attitudes, using validated survey questions;[52-54] for the full questionnaire, see Appendix A.7. One month after the study had been concluded, debriefings with participating pediatricians and heads of pediatric clinics took place.[68]

2.4 Statistical Analyses

To determine the effect of expert feedback on the length of antibiotic therapies and on the appropriateness of the length of therapies, we employed non-parametric statistical analyses. At the within-subject level, we compared the length of therapies and the absolute deviation from the expert recommendations between the three stages in both experimental groups. We assessed the impact of merely announcing feedback (differences between the first and second stages) and of actually providing feedback (differences between the second and third stages), using two-sided Fisher-Pitman permutation tests for paired replicates. For between-subject comparisons, we used two-sided Fisher-Pitman permutation tests for independent samples. We also employed Mann-Whitney-U and Wilcoxon signed-rank tests for between-subject and within-subject comparisons, respectively.

To account for heterogeneity in the experimental data, we ran a series of multilevel mixed-effects panel regression models. For details on the model specification, see Appendix B.

To analyze the association between pediatricians' individual characteristics and their antibiotic therapy decisions, we employed multilevel mixed-effects models. For this analysis, we only considered the decisions from the first stage of the experiment when the instructions were the same for subjects in the control and in the intervention group. The statistics software STATA 14.1 was used for all analyses.

2.5 Role of the Funding Source

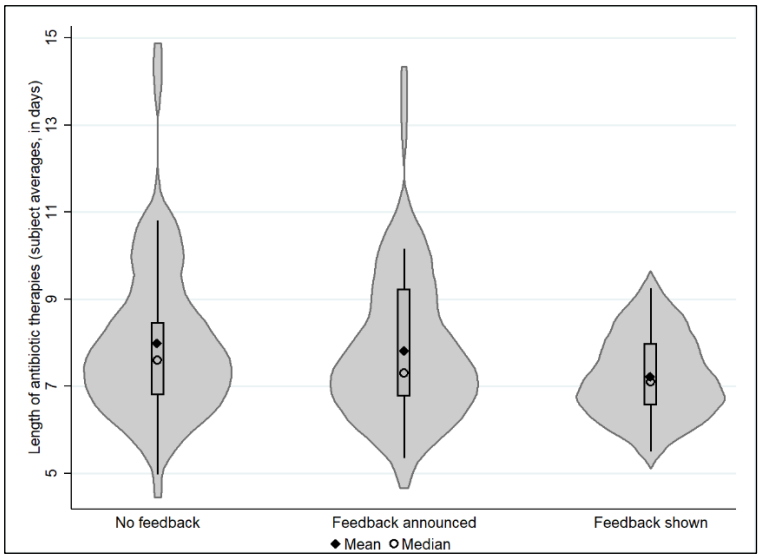
The funding source had no role in the study design or implementation.

3 Results

3.1 The Effect of Feedback on Antibiotic Prescribing

First, we analyzed the effect of feedback on pediatricians' decisions at a within-subject level in both groups. In the intervention group, the average length of antibiotic therapy was 7.98 days (95% CI 7.42 to 8.53, n=1,560) in the first stage. After the announcement of feedback (in the second stage), the average number of days fell slightly to 7.83 (95% CI 7.31 to 8.35, n=1,560), which was not statistically significant (p=0.153, Fisher-Pitman permutation test for paired replicates). In the third stage, when pediatricians had compared their average length of antibiotic therapies (from the second stage) with the expert benchmark, the mean length of antibiotic therapies fell to 7.23 days (95% CI 6.93 to 7.53, n=1,560). Providing pediatricians with the expert benchmark significantly reduced the length of antibiotic therapies (p=0.000, Fisher-Pitman permutation test for paired replicates). For an illustration of how the decisions in the intervention group changed between the stages, see Figure 2. Changes between the stages in the control group were not significant (both p-values ≥ 0.180, Fisher-Pitman permutation tests for paired replicates).

Figure 2: The effect of feedback on the length of antibiotic therapies



Notes. This figure plots individual pediatricians' antibiotic therapy decisions (averaged over the 40 cases) for the three stages of the experiment in the intervention group. In each stage, 39 subjects decided on the length of antibiotic therapies for 40 routine medical cases, presented in random order on the subjects' computer screens. No feedback was given in the first stage; feedback was announced at the beginning of the second and third stages and shown after the second and third stages.

We then compared the pediatricians' decisions in both experimental groups. Panel A of Table 2 shows differences in the length of antibiotic therapies between the second and first stages and between the third and second stages for pediatricians in both groups. In the intervention group, the pediatricians' mean change in the number of days of antibiotic treatment after announcement of feedback was -0.15 days (SD 0.63, 95% CI -0.34 to 0.06). The mean change in the number of days was -0.06 (SD 0.25, 95% CI -0.28 to 0.16) for pediatricians in the control group; this change did not differ significantly from the change in the intervention group (p=0.577, Fisher-Pitman permutation test for independent samples). After feedback had been provided to pediatricians in the intervention group, the number of days of antibiotic treatment changed, on average, by -0.60 (SD 0.97, 95% CI -0.91 to -0.29). For pediatricians in the control group, the average change in the number of days in Stage 3 was -0.06 (SD 0.25, 95% CI -0.15 to 0.03). The change in the intervention group was significantly larger than in the control group (p=0.000, Fisher-Pitman permutation test for independent samples).

Table 2: Differences in days of antibiotic therapy and absolute deviations from the expert recommendations

	Experimental group		
	Feedback (Intervention, n=39)	No Feedback (Control, n=34)	p-value
A. Average changes in days of therapy			
d_2 - d_1	-0.15 (0.63)	-0.06 (0.63)	0.577
d_3 - d_2	-0.60 (0.97)	-0.06 (0.25)	0.000
B. Average changes in absolute deviation from the expert recommendations			
Δ_2 - Δ_1	-0.15 (0.56)	-0.09 (0.45)	0.587
Δ_3 - Δ_2	-0.33 (0.73)	0.00 (0.27)	0.004

Notes. This table shows average changes in days of antibiotic therapy and in absolute deviation from the expert recommendations for subjects in both experimental groups. Standard deviations are in parentheses. Note that d_t denotes days and Δ_t the average absolute deviation per subject from the expert recommendation B for cases i = 1, 2, . . . , 40 and subjects j = 1, 2, . . . , J with $J \in \{34, 39\}$ in stage $t \in \{1, 2, 3\}$ of the experiment. More formally, $\Delta_t = \frac{1}{J}\frac{1}{40}\sum_{j=1}^{J}\sum_{i=1}^{40}|d_{ijt} - B_i|$ with $B_i = \frac{1}{20}\sum_{k=1}^{20} d_{ik}$ for experts k= 1, 2, . . ., 20. p-values for differences between the groups are shown for two-sided Fisher-Pitman permutation tests for independent samples. Wilcoxon-Mann-Whitney-U tests yielded very similar p-values.

A study sample of 73, with 39 subjects in the intervention group and 34 subjects in the control group, gave the experiment a statistical power of 82% to detect an average effect of feedback in size of a reduction by 0.54 days (difference in changes from Stage 2 to Stage 3 between both groups) assuming a two-tailed Mann-Whitney-U test at 5% significance level with an SD of 0.97 in the intervention group and an SD of 0.25 in the control group. A power analysis of the effect we defined as relevant a-priori (a difference of 0.5 days between the

groups) yielded an achieved power of 85% for a two-tailed Mann-Whitney-U test with a 5% significance level. For more details on the power analyses, see Appendix A.6.

To assess the effect of feedback on the appropriateness of therapy decisions, we analyzed the pediatricians' absolute deviation from the experts' recommended length of therapies; see Panel B of Table 2. In Stage 1, the pediatricians' absolute deviation from the experts' recommendations was not significantly different between the intervention and the control groups (p=0.301, Fisher-Pitman permutation test for independent samples). In the intervention group, the difference between the pediatricians and the expert recommendations was weakly significantly affected by the announcement of feedback (p=0.085, Fisher-Pitman permutation test for paired replicates). After providing feedback, the deviation from the experts significantly decreased in the intervention group (p=0.001, Fisher-Pitman permutation test for paired replicates). In the control group, we observed no significant differences between the stages (both p-values $\geq$ 0.278, Fisher-Pitman test for paired replicates). Announcing feedback did not lead to more appropriate therapy decisions, as changes in deviation from Stage 1 to Stage 2 were not significantly different in the intervention and the control group (p=0.587, Fisher-Pitman permutation test for independent samples). From Stage 2 to Stage 3, the reduction in deviation was significantly greater in the intervention group than in the control group (p=0.004, Fisher-Pitman permutation test for independent samples). Wilcoxon signed-rank tests and Wilcoxon-Mann-Whitney-U tests yielded very similar results.

Further, we used multilevel mixed-effects panel regressions to investigate the effect of feedback on antibiotic therapy decisions. For regression results, see Table 3. The effect of providing feedback is indicated by the interaction term 'Third stage × Feedback'. The effect of announcing feedback is indicated by the interaction term 'Second stage × Feedback'. The dependent variables are 'days of antibiotic therapies' and 'deviation from the expert recommendations', measured as the absolute difference between the pediatricians' decisions and the experts' recommended length of therapies.

The estimates of the regression models support the results of our non-parametric analyses. The provision of feedback in the intervention group led to a highly significant reduction both in length of antibiotic therapies and absolute deviation from the recommendations, while the announcement had no statistically significant effect. These findings are robust when adding individual-specific controls, including gender, experience, personality traits, and economic preferences; for length of therapies, see Model (3); for absolute deviation from the expert recommendations, see Model (6) in Table 3. All models include session-, subject-, and case-specific random effects and account for potential within-group

correlation. We conducted several analyses to check the robustness of our main results, see Appendix C.

Table 3: Multilevel mixed-effects panel regression models on the effect of feedback on antibiotic therapy decisions

Dependent variable:	Length of antibiotic therapies (in days)			Absolute deviation from the expert recommendations (in days)		
Model:	(1)	(2)	(3)	(4)	(5)	(6)
	Fixed effects					
Feedback (= 1 if intervention)		0.937** (0.423)	0.875 (0.560)		0.312 (0.294)	0.250 (0.364)
Second stage (= 1 if second stage)	-0.107 (0.073)	-0.063 (0.107)	-0.063 (0.107)	-0.122** (0.060)	-0.086 (0.088)	-0.086 (0.088)
Third stage (= 1 if third stage)	-0.450*** (0.108)	-0.112 (0.150)	-0.112 (0.150)	-0.297*** (0.082)	-0.085 (0.115)	-0.085 (0.115)
Effect of announcement (Second stage x Feedback)		-0.082 (0.147)	-0.082 (0.147)		-0.068 (0.120)	-0.068 (0.120)
Effect of feedback (Third stage x Feedback)		-0.633*** (0.205)	-0.633*** (0.205)		-0.397** (0.158)	-0.397** (0.158)
Female (= 1 if female)			0.581 (0.439)			0.073 (0.218)
Experience (Years in hospital)			-0.077** (0.032)			-0.050*** (0.016)
Willingness to take risks			-0.213*** (0.081)			0.001 (0.040)
Extraversion			0.062 (0.141)			0.074 (0.070)
Agreeableness			-0.084 (0.203)			-0.051 (0.101)
Conscientiousness			-0.309 (0.209)			-0.278*** (0.104)
Neuroticism			-0.093 (0.134)			-0.025 (0.066)
Openness			0.150 (0.139)			-0.002 (0.069)
Further individual characteristics (Economic preferences)	No	No	Yes	No	No	Yes
Constant	7.527*** (0.211)	7.035*** (0.311)	7.660*** (1.648)	2.919*** (0.152)	2.752*** (0.215)	4.543*** (0.839)
	Random effects					
Session level						
Var(Constant)	0.000 (0.000)	0.017 (0.112)	0.289 (0.283)	0.010 (0.043)	0.000 (.)	0.101*** (0.089)
Subject level						
Var(Stage 2)	0.222*** (0.065)	0.226*** (0.066)	0.226*** (0.066)	0.150*** (0.043)	0.153*** (0.044)	0.153*** (0.044)
Var(Stage 3)	0.686* (0.143)	0.595** (0.128)	0.595** (0.128)	0.375*** (0.081)	0.342*** (0.076)	0.342*** (0.076)

Var(Constant)	2.567***	2.364***	1.583	1.405*	1.396*	1.094
	(0.556)	(0.521)	(0.494)	(0.265)	(0.263)	(0.242)
Cov(Stage 2, Stage 3)	0.241***	0.232***	0.232***	0.147***	0.143***	0.143***
	(0.078)	(0.075)	(0.075)	(0.048)	(0.047)	(0.047)
Cov(Stage 2, Constant)	-0.299**	-0.285**	-0.245*	-0.277***	-0.276***	-0.286***
	(0.141)	(0.137)	(0.137)	(0.085)	(0.086)	(0.084)
Cov(Stage 3, Constant)	-1.084***	-0.944***	-0.740***	-0.679***	-0.653***	-0.586***
	(0.242)	(0.219)	(0.215)	(0.136)	(0.131)	(0.124)
Case level						
Var(Constant)	24.108***	24.108***	24.108***	4.732***	4.732***	4.732***
	(0.785)	(0.669)	(0.669)	(0.145)	(0.145)	(0.145)
Var(Residual)	3.322***	3.322***	3.322***	2.192***	2.192***	2.192***
	(0.062)	(0.062)	(0.062)	(0.041)	(0.041)	(0.041)
Number of observations	8,760	8,760	8,760	8,760	8,760	8,760
Number of subjects	73	73	73	73	73	73
Number of sessions	8	8	8	8	8	8

Notes. This table shows parameter estimates from multilevel mixed-effects REML regressions. The interaction 'Third stage × Feedback' indicates the effect of showing feedback to subjects. In Models (1) to (3), the dependent variable is 'length of antibiotic therapies (in days)'. In Models (4) to (6), the dependent variable is 'absolute deviation from the expert recommendations', measured in absolute values of the difference between the pediatricians' choices and the experts' recommended therapy length (in days). For each case, the subjects' choices were compared to the experts' aggregate opinion for the respective case. Standard errors are shown in parentheses. 'Economic preferences' comprise validated measures for trust, reciprocity, and altruism, as well as time and risk preferences.[52-54] All models include session-, subject-, and case-specific random effects. In Model (5), the variance component at the session level is close to zero. Therefore, this model was estimated without grouping on the session level. *** p<0.01, ** p<0.05, * p<0.1.

3.2 Pediatricians' Characteristics and Antibiotic Prescribing

To analyze how pediatricians' characteristics relate to their antibiotic therapy decisions, we considered decisions made in the first stage of the experiment and merged data from the control and the intervention groups. The average length of antibiotic therapy for the 40 cases chosen in the first stage was of 7.53 days (95% CI 7.32 to 7.73, n=2,920).

Table 4 shows estimation results from multilevel mixed-effects regression models. The pediatricians' experience was highly significantly associated with the length of antibiotic therapies. The longer pediatricians had practiced in a hospital, the shorter was the length of therapies and the smaller was the absolute deviation from the expert recommendations. Further, the length of therapies significantly declined with the pediatricians' increasing willingness to take risks,[52-54] while the deviation from the expert recommendations was not significantly related to pediatricians' risk attitudes. Concerning personality traits,[50,51] we found that more conscientious pediatricians chose shorter therapies and, by doing so, deviated less from the experts. Other personality traits were not significantly associated with the pediatricians' decisions. In the regressions, we controlled for pediatricians' economic preferences, which comprised validated measures for trust, reciprocity, and altruism, and time preferences.[52-54]

Table 4: Regressions on the association of antibiotic therapy decisions with pediatricians' characteristics

Dependent variable:	Length of antibiotic therapies (in days)		Absolute deviation from the expert recommendations (in days)	
Model	(1)		(2)	
	Fixed effects			
Female (= 1 if female)	0.856	(0.528)	0.394	(0.399)
Experience (Years in hospital)	-0.110***	(0.039)	-0.076***	(0.030)
Willingness to take risks	-0.291***	(0.098)	-0.102	(0.074)
Extraversion	0.082	(0.169)	0.152	(0.128)
Agreeableness	0.154	(0.246)	-0.035	(0.185)
Conscientiousness	-0.581**	(0.252)	-0.538***	(0.190)
Neuroticism	0.159	(0.161)	0.136	(0.122)
Openness	0.205	(0.167)	0.165	(0.126)
Constant	8.912***	(2.001)	4.358***	(1.497)
	Random effects			
Session level				
Var(Constant)	0.846	(0.583)	0.265	(0.217)
Subject level				
Var(Constant)	1.255	(0.408)	0.952	(0.235)
Case level				
Var(Constant)	25.651	(77.382)	6.750	(54.123)
Var(Residual)	3.342	(77.380)	0.998	(54.123)
Number of observations	2,920		2,920	
Number of subjects	73		73	
Number of sessions	8		8	

Notes. This table shows parameter estimates from multilevel mixed-effects REML regressions, considering the first stage of the experiment. The dependent variables are 'length of antibiotic therapies' and 'absolute deviation from the expert recommendations', both measured in days. Standard errors are shown in parentheses. 'Willingness to take risks' was measured on a Likert scale ranging from 0 (fully risk-averse) to 10 (fully risk-seeking).[52-54] Besides the Big Five personality traits,[50,51] which are displayed in the table, we controlled for 'economic preferences', which comprise validated measures for trust, reciprocity, and altruism, as well as risk and time preferences,[52-54] in both models. Both models include session-, subject-, and case-specific random effects. *** p<0.01, ** p<0.05, * p<0.1.

3.3 The Association Between Feedback and Pediatricians' Experience

Results from our regressions showed a consistent association between pediatricians' antibiotic prescribing decisions and experience: More experienced physicians chose shorter therapies and deviated less from the experts' recommendations. Using multilevel mixed-effects panel regression models, we tested whether the effect of feedback was specific to pediatricians' experience; see Table 5 for regression results. The positive coefficient of the interaction between the effect of feedback and experience suggests that pediatricians with less experience responded more strongly to feedback. More specifically, the less experienced the pediatricians were, the larger the effect of feedback was on the length of therapies and the appropriateness

of antibiotic therapies. The effect of feedback decreased in the pediatricians' experience, suggesting that feedback does *not* mitigate the positive impact of experience on antibiotic prescribing decisions.

Table 5: Multilevel mixed-effects panel regression models on the association between individual characteristics and responses to feedback

Dependent variable:	Length of antibiotic therapies (in days)		Absolute deviation from the expert recommendations (in days)	
Model:	(1)		(2)	
Feedback (= 1 if intervention)	0.801	(0.567)	0.205	(0.376)
Second stage (= 1 if second stage)	-0.063	(0.107)	-0.086	(0.088)
Third stage (= 1 if third stage)	-0.112	(0.148)	-0.085	(0.114)
Effect of announcement (Second stage x Feedback)	-0.082	(0.147)	-0.068	(0.120)
Effect of feedback (Third stage x Feedback)	-0.879***	(0.222)	-0.548***	(0.168)
Experience (Years in hospital)	-0.109***	(0.034)	-0.074***	(0.019)
Experience x Effect of feedback	0.049***	(0.018)	0.030**	(0.013)
Female (= 1 if female)	0.499	(0.422)	0.022	(0.213)
Willingness to take risks	-0.208***	(0.078)	0.003	(0.039)
Constant	7.558***	(1.590)	4.566***	(0.825)
Random effects				
Session level				
Var(Constant)	0.307	(0.278)	0.120***	(0.098)
Subject level				
Var(Stage 2)	0.226***	(0.066)	0.153***	(0.044)
Var(Stage 3)	0.583**	(0.126)	0.332***	(0.074)
Var(Constant)	1.577	(0.482)	1.068	(0.234)
Cov(Stage 2, Stage 3)	0.233***	(0.075)	0.144***	(0.047)
Cov(Stage 2, Constant)	-0.239*	(0.136)	-0.283***	(0.083)
Cov(Stage 3, Constant)	-0.778***	(0.214)	-0.577***	(0.121)
Case level				
Var(Constant)	24.108***	(0.669)	4.732***	(0.145)
Var(Residual)	3.322***	(0.062)	2.192***	(0.041)
Number of observations	8,760		8,760	
Number of subjects	73		73	
Number of sessions	8		8	

Notes. This table shows parameter estimates from multilevel mixed-effects REML regressions. The interaction 'Third stage × Feedback' indicates the effect of showing feedback to subjects. The interaction 'Experience x Effect of feedback' indicates the association between the subjects' experience (number of years worked in hospital) and the effect of feedback. Standard errors are shown in parentheses. In all models, we controlled for the Big Five personality traits[50,51] and for 'economic preferences', which comprise validated measures for trust, reciprocity, and altruism, as well as time and risk preferences.[52-54] Both models include session-, subject-, and case-specific random effects. *** p<0.01, ** p<0.05, * p<0.1.

4 Discussion

We introduced a framed field experiment with pediatricians to analyze the causal effect of expert feedback on antibiotic prescribing in a tertiary pediatric care setting. Pediatricians decided on the length of antibiotic treatment for a series of routine pediatric cases. We found that providing pediatricians with simple directional expert feedback significantly reduced the length of antibiotic therapies by, on average, ten percent. The absolute deviation of the pediatricians' decisions from length of therapies recommended by experts decreased significantly. The experimental data thus suggest that the expert benchmark 'nudged' pediatricians towards a more *appropriate* use of antibiotics.[69]

The combination of experimental and survey data allowed us to relate pediatricians' decisions on the length of antibiotics therapies and their responses to feedback to their individual characteristics. We found that pediatricians who were more experienced and more conscientious chose shorter therapies and deviated significantly less from appropriate therapy durations. Previous studies in primary care settings, suggesting that more experienced physicians prescribe antibiotics more often,[47-49] neither considered the length, nor did they assess the appropriateness of antibiotic therapies. While subjects in our experiment responded to feedback in a heterogeneous way, the main effect of feedback was robust towards the pediatricians' characteristics. When considering the interaction between the effect of feedback and experience, we found that feedback was most effective for physicians with little experience. These findings suggest that descriptive expert feedback can nudge pediatricians towards more appropriate antibiotic prescribing and compensates to some extent for a lack of experience.

The expert benchmark shown to pediatricians transmitted a descriptive normative message,[29] which was directed at pediatricians' self-image concerns.[70-72] Capitalizing on the human capacity to reflexive thinking,[73] this implies that expert feedback might have triggered pediatricians' self-directed concerns and may refer to the awareness of congruence between the expert benchmark and their own antibiotic therapy decisions. In contrast to self-image concerns, social-image concerns appear when people are observed by others and when their behavior is judged against a standard or a norm.[70-72] As the pediatricians took their decisions in anonymity and no information on identity or treatment patterns was shared among participants in the experiment, it seems more likely that changes in decisions were due to self-image concerns than due to social-image concerns. Related experimental studies investigating the effect of social norm feedback and peer comparison rather focus on physicians' social-image concerns. [20,21,74] We add to this recent stream of the literature by providing evidence on the effect of descriptive

expert feedback, which addresses physicians' self-image concerns in the absence of peer comparisons at an *individual* decision-maker level. Further, while prior research has mainly focused on whether and which antibiotics are prescribed,[16,20,21] we investigate the effect of a simple feedback mechanism on physicians' decisions regarding the *length* of antibiotic therapies.

Limitations and Future Research. We now discuss potential limitations of our study and avenues for future research. First, one might argue that the experimental design is somewhat simplistic to be reflective of a real clinical setting. It is true that we elicited hypothetical treatment decisions and that our experimental frame is parsimonious, used a set of hypothetical cases, and did not allow physicians to acquire additional information to assess the cases further. More specifically, one might argue that we were unable to consider pediatricians' responses to influencing factors, which are relevant in real-world clinical settings, but which might go beyond the constructed case descriptions (e.g., parental expectations[47] or risk and efficacy perceptions[75]). Second, different interpretations of the same case information may have affected individual physicians' judgements of the cases and their treatment decisions.[76,77] While we kept the information constant for all subjects, our study design and analyses did not focus on the process by which the therapy decisions were made (e.g., what heuristics had been used). Third, in real clinical practice, physicians may ask colleagues, search for information in guidelines, or order additional lab tests before making a treatment decision. The purpose of our experiment was to isolate the effect of feedback for a given, comparable, set of information for each case. Not giving them the option to acquire additional information ensured that all pediatricians based their decisions on exactly the same information, allowing us to draw causal inferences on the effect of feedback. We made a real *ceteris paribus* variation of feedback, controlled the decision environment, and avoided confounding factors that potentially affect pediatricians' decisions.

Another concern might relate to the aggregated nature of our feedback mechanism. We employed an aggregated benchmark instead of case-by-case recommendations. By doing so, our experimental design allowed us to examine whether a 'simple' feedback intervention raised awareness for appropriate use of antibiotics while maintaining the discretion for the pediatrician to decide on antibiotic prescribing for each medical case. After provision of feedback, we observed an overall change in the length of therapies towards what is more appropriate. One might argue that our aggregated results could conceal negative changes in therapy length for individual cases. Analyses on a case level, however, showed rather the opposite: For the vast majority of the cases, both the length of therapies and the absolute deviation from the expert recommendations decreased. Changes in the opposite direction for the remaining cases were

not statistically significant; see Appendix C for details. Our results hence suggest that comparison of own their prescribing decisions with an expert benchmark raises pediatricians' awareness for judicious use of antibiotics, but maintains their individual and case-specific discretion when deciding whether and for which cases to adjust their treatment decisions.

An appealing feature of our parsimonious design is that it lends itself to further research. For example, future research could consider whether our findings can be translated to real clinical practice and to medical areas beyond pediatrics. Our findings also call for further studies investigating how long-lasting an effect of descriptive expert feedback on physicians' antibiotic prescribing decisions is and how the effect can be maintained. Another interesting question would be whether and, if so, how antibiotic prescribing decisions are affected by decision-support tools which provide physicians with case-specific therapy recommendations and consider case-specific ranges of appropriate therapy durations. Relatedly, future studies could investigate the differential effect of expert and guideline-based feedback. Another potential avenue for future research would be to address social-image rather than self-image concerns.

Conclusion. Our experimental results suggest that descriptive expert feedback affects individual pediatricians' antibiotic prescribing decisions. Using a novel methodology and taking inter-individual differences into account, we have shown that expert feedback, which conveys a normative message on antibiotic prescribing, can be an effective means in guiding pediatricians towards a more appropriate use of antibiotics. Most importantly, our results suggest that it is especially useful if targeted at physicians with low levels of experience. Our findings are also of practical importance as they provide an argument for the inclusion of individual feedback addressing the physicians' self-image in antibiotic stewardship programs.

Acknowledgements

We thank the associate editor (Olga Kostopoulou) and three anonymous reviewers for their constructive comments and suggestions. For helpful feedback, we also thank Robert Böhm, Pablo Brañas, Matteo M. Galizzi, Rob Hamm, Glenn Harrison, Heike Hennig-Schmidt, Bernd Irlenbusch, Hendrik Juerges, Brian Monroe, Joe Newhouse, Andrea Rachow, Martin Roland, Don Ross, Gari Walkowitz, and seminar participants at the Universities of Cologne and Wuppertal, as well as participants at the German Association for Health Economics (dggö) conference in Berlin, Germany, in 2016, at the 17th Biennial European Conference of the Society for Medical Decision Making in Leiden, The Netherlands, in 2018, and at the 6th Behavioral Experiments in Health Workshop in Oslo, Norway, in 2018. We are grateful to

Professor Dr Jörg Dötsch, MD, and Professor Dr Michael Weiss, MD, for providing support and the facilities to conduct our experiment at the Department of Pediatrics at the University Hospital Cologne and the Children's Hospital of the City of Cologne, respectively. We thank Dr Angela Kribs, MD, and five consultants from the University Hospital Cologne for validating the medical cases. The support of Professor Dr Ronald G. Schmid, MD, and Monika Kraushaar from the *Berufsverband der Kinder-und Jugendärzte, BVKJ e.V.* is gratefully acknowledged. We also thank Emanuel Castillo for programming the online survey and experiment, Uta Richter from the Department of Personnel Economics at the University of Cologne for facilitating the registration and payment of subjects, and Lena Kuhne for helping us to conduct the experiments. Parts of this research have been conducted while Daniel Wiesen was employed at the Institute of Health and Society at the Department of Health Management and Health Economics, University of Oslo, and member of the IRECOHEX group, supported by the Research Council of Norway.

Financial support for this study was provided by a grant from the Excellence Initiative of the German federal and state governments. The funding agreement ensured the authors' independence in designing the study, interpreting the data, writing, and publishing the report.

References

1. Laxminarayan R, Duse A, Wattal C, Zaidi AK, Wertheim HF, Sumpradit N, et al. Antibiotic resistance – the need for global solutions. Lancet Infect Dis. 2013;13(12):1057–98.
2. Laxminarayan R, Amábile-Cuevas CF, Cars O, Evans T, Heymann DL, Hoffman S, et al. UN high-level meeting on antimicrobials – what do we need? Lancet. 2016;388(10041):218–20.
3. Levy SB, Marshall B. Antibacterial resistance worldwide: causes, challenges and responses. Nat Med. 2004;10:122–9.
4. Nathan C, Cars O. Antibiotic resistance – problems, progress, and prospects. N Engl J Med. 2014;371:1761–3.
5. Haider BA, Lassi ZS, Bhutta ZA. Short-course versus long-course antibiotic therapy for non-severe community-acquired pneumonia in children aged 2 months to 59 months. Cochrane Database Syst Rev. 2008;2, Art. No.: CD005976.
6. Lassi ZS, Imdad A, Bhutta ZA. Short-course versus long-course intravenous therapy with the same antibiotic for severe community-acquired pneumonia in children aged two months to 59 months. Cochrane Database Syst Rev. 2017;10, Art. No.: CD008032.
7. Spellberg B. The new antibiotic mantra – "shorter is better". JAMA Intern Med. 2016;176(9):1254–5.
8. Hersh AL, Shapiro DJ, Pavia AT, Shah SS. Antibiotic prescribing in ambulatory pediatrics in the United States. Pediatrics. 2011;128(6):1053–61.
9. Downes KJ, Hahn A, Wiles J, Courter JD, Vinks AA. Dose optimisation of antibiotics in children: application of pharmacokinetics/ pharmacodynamics in paediatrics. Int J Antimicrob Agents. 2014;43(3):223–30.
10. Schulman J, Dimand RJ, Lee HC, Duenas GV, Bennett MV, Gould JB. Neonatal intensive care unit antibiotic use. Pediatrics. 2015;135(5):826–33.
11. Hyun DY, Hersh AL, Namtu K, Palazzi DL, Maples HD, Newland JG, et al. Antimicrobial stewardship in pediatrics: how every pediatrician can be a steward. JAMA Pediatr. 2013;167(9):859–66.

12. Vodicka TA, Thompson M, Lucas P, Heneghan C, Blair PS, Buckley DI, et al. Reducing antibiotic prescribing for children with respiratory tract infections in primary care: a systematic review. Br J Gen Pract. 2013;63(612):e445–54.

13. Davey P, Marwick CA, Scott CL, Charani E, McNeil K, Brown E, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. Cochrane Database Syst Rev. 2017;2, Art. No.: CD003543.

14. Welschen I, Kuyvenhoven MM, Hoes AW, Verheij TJ. Effectiveness of a multiple intervention to reduce antibiotic prescribing for respiratory tract symptoms in primary care: randomised controlled trial. BMJ. 2004;329(7463):431–6.

15. Gjelstad S, Høye S, Straand J, Brekke M, Dalen I, Lindbæk M. Improving antibiotic prescribing in acute respiratory tract infections: cluster randomised trial from Norwegian general practice (prescription peer academic detailing (Rx-PAD) study). BMJ. 2013;347:f4403.

16. Gerber JS, Prasad PA, Fiks AG, Localio AR, Grundmeier RW, Bell LM, et al. Effect of an outpatient antimicrobial stewardship intervention on broad-spectrum antibiotic prescribing by primary care pediatricians: a randomized trial. JAMA. 2013;309(22):2345–52.

17. Falk A, Heckman JJ. Lab experiments are a major source of knowledge in the social sciences. Science. 2009;326(5952):535–8.

18. Herbst D, Mas A. Peer effects on worker output in the laboratory generalize to the field. Science. 2015;350(6260):545–9.

19. Ivers N, Jamtvedt G, Flottorp S, Young JM, Odgaard-Jensen J, French SD, et al. Audit and feedback: effects on professional practice and healthcare outcomes. Cochrane Database Syst Rev. 2012;6, Art. No.: CD000259.

20. Hallsworth M, Chadborn T, Sallis A, Sanders M, Berry D, Greaves F, et al. Provision of social norm feedback to high prescribers of antibiotics in general practice: a pragmatic national randomised controlled trial. Lancet. 2016;387(10029):1743–52.

21. Meeker D, Linder JA, Fox CR, Friedberg MW, Persell SD, Goldstein NJ, et al. Effect of behavioral interventions on inappropriate antibiotic prescribing among primary care practices: a randomized clinical trial. JAMA. 2016;315(6):562–70.

22. Harrison GW, List JA. Field experiments. J Econ Lit. 2004;42(4):1009–55.

23. Galizzi MM, Wiesen D. Behavioural experiments in health: an introduction. Health Econ. 2017;26(3):3–5.

24. Galizzi MM, Wiesen D. Behavioral experiments in health economics. In: Hamilton JH, Dixit A, Edwards S, Kenneth J, eds. Oxford research encyclopedia of economics and finance. Oxford (UK): Oxford University Press; 2018.

25. Clee M, Wicklund R. Consumer behavior and psychological reactance. J Consum Res. 1980;6(4):389–405.

26. Alcott H. Social norms and energy conservation. J Public Econ. 2011;95(9-10):1082–95.

27. Linder JA. Moving the mean with feedback: insights from behavioral science. NPJ Prim Care Respir Med. 2016;26:16018.

28. Cialdini R, Reno R, Kallgren C. A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. J Pers Soc Psychol. 1990;58(6):1015–26.

29. Schultz PW, Nolan JM, Ciladini RB, Goldstein NJ, Griskevicius V. The constructive, destructive, and reconstructive power of social norms. Psychol Sci. 2007;18(5):429–34.

30. Holtgrave DR, Lawler F, Spann SJ. Physicians' risk attitudes, laboratory usage, and referral decisions: the case of an academic family practice center. Med Decis Making. 1991;11(2):125–30.

31. Pearson SD, Goldman L, Orav EJ, Guadagnoli E, Garcia TB, Johnson PA, et al. Triage decisions for emergency department patients with chest pain. J Gen Intern Med. 1995;10(10):557–64.

32. Allison JJ, Kiefe CI, Cook EF, Gerrity MS, Orav EJ, Centor R. The association of physician attitudes about uncertainty and risk taking with resource use in a Medicare HMO. Med Decis Making. 1998;18(3):320–9.

33. Michel-Lepage A, Ventelou B, Nebout A, Verger P, Pulcini C. Cross-sectional survey: risk-averse French GPs use more rapid-antigen diagnostic tests in tonsillitis in children. BMJ Open. 2013;3(10):e003540.

34. Nebout A, Cavillon M, Ventelou B. Comparing GPs' risk attitudes for their own health and for their patients': a troubling discrepancy? BMC Health Serv Res. 2018;18:283.

35. Massin S, Ventelou B, Nebout A, Verger P, Pulcini C. Cross-sectional survey: risk-averse French general practitioners are more favorable towards influenza vaccination. Vaccine. 2015;33(5):610–4.

36. Franks P, Williams GC, Zwanziger J, Mooney C, Sorbero M. Why do physicians vary so widely in their referral rates? J Gen Intern Med. 2000;15(3):163–8.

37. Forrest CB, Nutting, PA, Von Schrader S, Rohde C, Starfield B. Primary care physician specialty referral decision making: patient, physician, and health care system determinants. Med Decis Making. 2006;26(1):76–85.

38. Rochon PA, Gruneir A, Bell CM, et al. Comparison of prescribing practices for older adults treated by female versus male physicians: a retrospective cohort study. PLoS One. 2011;13(10):e0205524.

39. Wallis CJ, Ravi B, Coburn N, Nam RK, Detsky AS, Satkunasivam R. Comparison of postoperative outcomes among patients treated by male and female surgeons: a population based matched cohort study. BMJ. 2017; 359:j4366.

40. Tsugawa Y, Jena AB, Figueroa JF, Orav EJ, Blumenthal DM, Jha AK. Comparison of hospital mortality and readmission rates for Medicare patients treated by male vs female physicians. JAMA Intern Med. 2017;177(2):206–13.

41. Borghans L, Druckworth AL, Heckman JJ, ter Weel B. The economics and psychology of personality traits. J Hum Resour. 2008;43(4):972–1059.

42. Almlund M, Duckworth AL, Heckman J, Kautz T. Personality psychology and economics. In: Hanushek EA, Machin S, Woessmann, L, eds. Handbook of the economics of education. Vol. 4. 1st ed. Amsterdam (Netherlands): North Holland;2011. p. 4–28.

43. Callen M, Gulzur S, Hasanain A, Khan Y, Rezaee A. Personalities and public sector performance: evidence from a health experiment in Pakistan. National Bureau of Economic Research. 2015;NBER Working Paper Series No. 21180.

44. Donato K, Miller G, Mohanan M, Truskinovsky Y, Vera-Hernández M. Personality traits and performance contracts: evidence from a field experiment among maternity care providers in India. Am Econ Rev. 2017;107(5):506–10.

45. Hulscher ME, Grol RP, van der Meer JW. Antibiotic prescribing in hospitals: a social and behavioural scientific approach. Lancet Infect Dis. 2010;10(3):167–75.

46. Rodrigues AT, Roque F, Falcão A, Figueiras A, Herdeiro MT. Understanding physician antibiotic prescribing behaviour: a systematic review of qualitative studies. Int J Antimicrob Agents. 2013;41(3):203–12.

47. Sirota M, Round T, Samaranayaka S, Kostopoulou O. Expectations for antibiotics increase their prescribing: causal evidence about localized impact. Health Psychol. 2017;36(4):402–9.

48. de Jong BM, van der Ent CK, van der Zalm MM, van Putte-Katier N, Verheij TJ, Kimpen JL, Uiterwaal CS. Respiratory symptoms in young infancy: child, parent and physician related determinants of drug prescription in primary care. Pharmacoepidemiol Drug Saf. 2009;18(7), 610–8.

49. Akkerman AE, Kuyvenhoven MM, Van der Wouden JC, Verheij TJ. Prescribing antibiotics for respiratory tract infections by GPs: management and prescriber characteristics. Br J Gen Pract. 2005;55(511):114–8.

50. Gosling SD, Rentfrow PJ, Swann Jr WB. A very brief measure of the Big Five personality domains. J Res Pers. 2003;37(6):504–28.

51. Rammstedt B, John OP. Measuring personality in one minute or less: a 10-item short version of the Big Five inventory in English and German. J Res Pers. 2007;41(1):203–12.

52. Falk A, Becker A, Dohmen T, Enke B, Huffman DB, Sunde U. Global evidence on economic preferences. Q J Econ. 2018;133(4):1645–92.

53. Falk A, Becker A, Dohmen T, Huffman DB, Sunde U. The preference survey module: a validated instrument for measuring risk, time, and social preferences. Institute for the Study of Labor (IZA). 2016; IZA Discussion Papers No.9674.

54. Dohmen T, Falk A, Huffman D, Sunde U, Schupp J, Wagner GG. Individual risk attitudes: measurement, determinants, and behavioral consequences. J Eur Econ Assoc. 2011;9(3):522–50.

55. Chomsky N. A Review of B.F. Skinner's verbal behavior. Language. 1959;35:26–58.

56. Popper KR. Objective knowledge: an evolutionary approach. Oxford: Oxford University Press; 1972.

57. Felin T, Foss NJ. The endogenous origins of experience, routines, and organizational capabilities: the poverty of stimulus. J Institut Econ. 2011;7(2):231–56.

58. Levinthal DA, March J. The myopia of learning. SMJ. 1993;14:95–112.

59. Nonaka L. A dynamic theory of organizational knowledge creation. Organ Sci. 1994;5(1):14–37.

60. Olofsson SK, Cars O. Optimizing drug exposure to minimize selection of antibiotic resistance. Clin Infect Dis. 2007;45(Supplement_2):129–36.

61. Kiefe CI, Allison JJ, Williams OD, Person SD, Weaver MT, Weissman NW. Improving quality improvement using achievable benchmarks for physician feedback: a randomized controlled trial. JAMA. 2001;285(22):2871–9.

62. Deutsche Gesellschaft für Pädiatrische Infektiologie (DGPI). DGPI-Handbuch Infektionen bei Kindern und Jugendlichen. 7th ed. Stuttgart(Germany): Thieme; 2018.

63. Cabana MD, Rand CS, Powe NR, Wu AW, Wilson MH, Abboud PAC, Rubin HR. Why don't physicians follow clinical practice guidelines? A framework for improvement. JAMA. 1999;282(15):1458–65.

64. Barlow G, Nathwani D, Myers E, et al. Identifying barriers to the rapid administration of appropriate antibiotics in community acquired pneumonia. J Antimicrob Chemother. 2008(2);61:442–51.

65. May L, Gudger G, Armstrong P, Brooks G, Hinds P, Bhat R, et al. Multisite exploration of clinical decision making for antibiotic use by emergency medicine providers using quantitative and qualitative methods. Infect Control Hosp Epidemiol. 2014;35(9):1114–25.

66. Fischbacher U. Z-tree: Zurich toolboox for readymade economic experiments – experimenter's manual. Exp Econ. 2007;10(2):171–8.

67. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39(2):175–91.

68. List JA. Why economists should conduct field experiments and 14 tips for pulling one off. J Econ Perspect. 2011;25(3):3–16.

69. Thaler R, Sunstein CR. Nudge: improving decisions about health, wealth, and happiness. New Haven: Yale University Press;2008.

70. Bénabou R, Tirole J. Incentives and prosocial behavior. Am Econ Rev. 2006;96(5):1652–78.

71. Bénabou R, Tirole J. Identity, morals, and taboos: beliefs as assets. Q J Econ. 2011;126(2):805–55.

72. Falk A. Facing yourself – a note on self-image. Center for Economic Studies and Ifo Institute (CESifo). 2017;CESifo Working Paper Series No.6428.

73. Leary MR, Tangney JP. The self as an organizing construct in the behavioral and social sciences. In: Leary MR, Tangney JP, eds. Handbook of self and identity. 2nd ed. New York (USA): The Guilford Press; 2012. p. 1–18.

74. Meeker D, Knight TK, Friedberg MW, Linder JA, Goldstein NJ, Fox CR, et al. Nudging guideline-concordant antibiotic prescribing: a randomized clinical trial. JAMA Intern Med. 2014;174(3):425–31.

75. Broniatowski DA, Klein EY, May L, Martinez EM, Ware C, Reyna VF. Patients' and clinicians' perceptions of antibiotic prescribing for upper respiratory infections in the acute care setting. Med Decis Making. 2018;38(5):547–61.

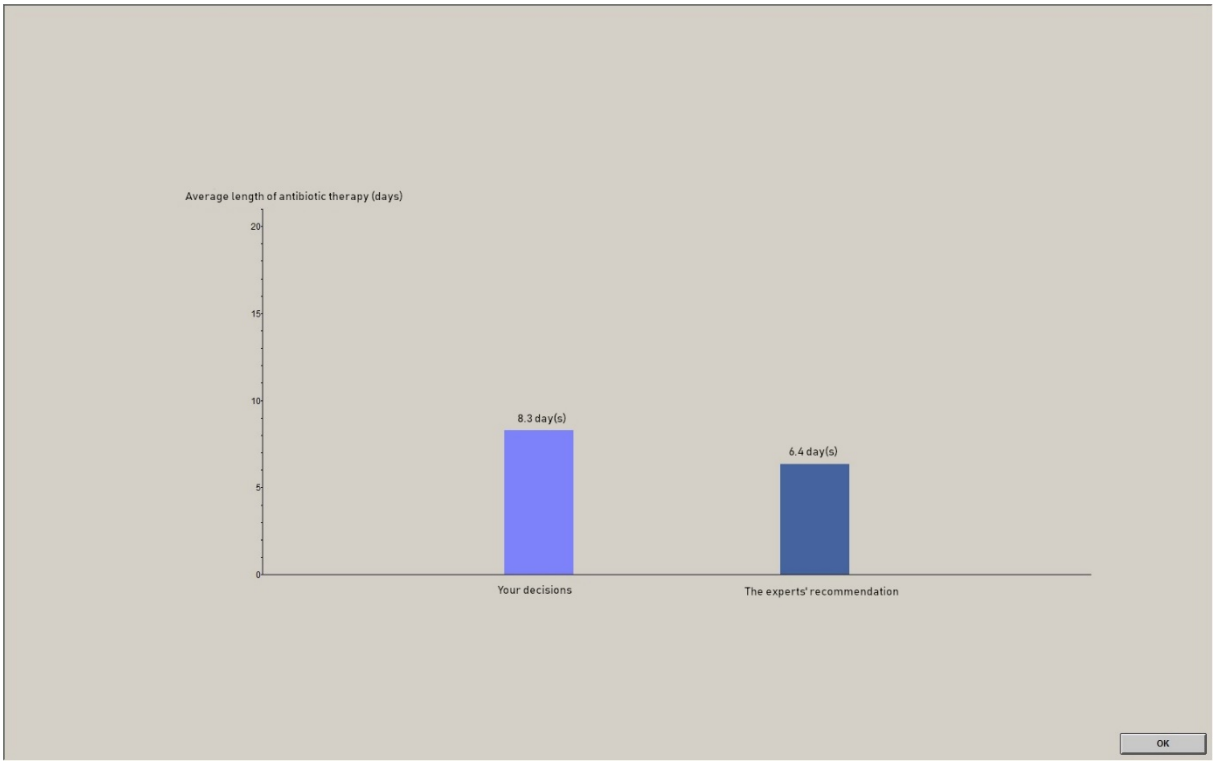
76. Kostopoulou O, Russo JE, Keenan G, Delaney BC, Douiri A. Information distortion in physicians' diagnostic judgments. Med Decis Making. 2012;32(6):831–9.

77. Nurek M, Kostopoulou O, Hagmayer Y. Predecisional information distortion in physicians' diagnostic judgments: strengthening a leading hypothesis or weakening its competitor? Judgm Decis Mak. 2014;9(6):572–85.

A. Additional Information on the Experiment

A.1 Sample Screen

Figure A.1 Sample screen



Notes. This figure shows a screenshot of the screen the subjects saw after each round of the experiment (translated from German to English). The left bar shows the average length of therapies the subject chose in the previous round (example), the right bar shows the aggregated expert recommendation. Both average numbers are displayed numerically above the respective bars. The y-axis displays the average length of antibiotic therapies (in days).

A.2 Instructions for the Experiment

[Note that in the squared brackets we present instructions from the second and third parts of the experiment.]

You are taking part in a decision experiment. Please read through the instructions carefully. It is important that you do not talk to other participants for the entire duration of the experiment. If you have any questions, please raise your hand. We will come to your cubicle and answer your questions in person.

In this experiment, all monetary amounts are denoted in 'Taler', at a rate of 1 Taler = €1. Your earnings will be paid in cash at the end of the experiment.

You will make your decisions anonymously in your cubicle. All data will be evaluated anonymously. You have drawn your own cubicle number in order to ensure anonymity.

The experiment will last for approximately 60 minutes and consists of three parts. You will receive detailed instructions prior to each stage of the experiment. Please note: Your decisions in each part of the experiment will not have any impact on any other part of the experiment.

At the end of the experiment, you will receive compensation for the experiment.

We also ask you please to answer a few questions at the end of the experiment.

First [Second, Third] part of the experiment

Decision situation

The first part of the experiment relates to a decision situation in the pediatric department of a hospital. You make your decision in the role of the on-duty pediatrician.

In the course of the first part of the experiment, you will be presented with a series of patients, each with different pathologies, symptoms, complaints, or results. If symptoms, complaints, or results are not provided, then they are not considered to be relevant for your decision-making.

In creating an initial treatment plan, you have the task of determining the duration of a course of antibiotics (in days). Here, you can set the length of the course at 0, 1, 2, . . ., 27, or 28 day(s). Note that the respective medicines will be administered according to the relevant guidelines. The initial treatment plan can be adjusted through a reevaluation.

Enter the length of the antibiotics course for each patient in the field 'For how many days do you prescribe antibiotic therapy?' on your computer screen. You can enter whole numbers

between zero and 28. Please confirm your decision by clicking 'OK', which will take you to the next screen.

[**After you have made your decision about the length of the antibiotic therapy for all patients, you will be informed about an expert opinion on the average length of antibiotic therapy for patients identical to those for whom you have made treatment decisions. The expert opinion is based on responses from 20 leading pediatricians drawn from a representative sample of children's hospitals in Germany**[*]]

Earnings

For carrying out the task in the first part of the experiment – determining the length of antibiotic therapy for a series of patients – you will receive a fixed payment of 50 Talers.

Important information:

- Make your decisions anonymously on your computer screen.

- In order that no decision or payout can be matched with a particular participant, an employee of the Department of Business Administration and Personnel Economics at the University of Cologne, who is not involved in conducting the experiment, will place in your cubicle an envelope that is marked only with the cubicle number and contains the total payout for your cubicle.

- Afterwards, please leave the room in which the experiment was conducted.

[*] This survey was conducted in August and September 2014 among head physicians in German children's hospitals. Out of a total of 50 randomly chosen German children's hospitals, 20 hospitals answered questions about the length of antibiotic therapy in full. The study is archived in the German Clinical Trials Register under the study number DRKS00006782

A.3 The Medical Cases

A.3.1 List of the Medical Cases

Table A.1: Medical cases (with categories of pediatric infectious diseases)

	Case description	Randomized order
Neonatal infections		
1	Newborn at 38 weeks of gestation at the age of four hours after a normal standardized pediatric examination. Spontaneous vaginal delivery, rupture of membranes at birth, maternal fever 38.5 C at birth, C-reactive protein (CRP) < 5 mg/dl (mother), Group B-Streptococcal (GBS) status is negative. The child's vital signs and clinical examination are normal.	4
2	Term newborn at the age of six hours after normal postnatal examination. Spontaneous vaginal delivery, rupture of membranes < 18 hours before the onset of labor, positive maternal GBS status two weeks before birth. No antenatal antibiotic treatment. The child's vital signs and clinical examination are normal.	39
3	Newborn at 40 weeks of gestation at the age of 12 hours after a normal postnatal physical examination. Spontaneous vaginal delivery, rupture of membranes > 18 hours before the onset of labor, positive GBS status two weeks before birth. Maternal antibiotic treatment three hours before birth. The child's vital signs and clinical examination are normal. In the blood test, maximal CRP (C-reactive protein) 18 mg/l and Il-6 (Interleukin 6) 10 ng/l.	20
4	Term newborn on the second day of life. Spontaneous vaginal delivery, rupture of membranes at birth, normal postnatal physical examination. In the clinical examination, the child was hypotonic with gray skin color, impaired microcirculation, tachypnea, and dyspnea. In the blood tests initiated by you, a CRP shows a maximum of 35 mg/l, Il-6 > 8 ng/l. The blood cultures and newborn smears, received after two days, were without pathogen detection.	23
5	Newborn of the 38th gestational week, at the age of two days. Admission to the NICU and start of an antibiotic therapy after an abnormal physical examination. In blood test, maximal CRP 15 mg/l, Il-6 < 8 ng/l. The CSF findings were normal. In the blood culture, detection of Staphylococcus epidermidis. The child's vital signs and physical examination are currently normal.	19
6	Newborn with a gestational age of 39 weeks at the age of 20 hours. In the physical examination, the child is hypotonic with impaired microcirculation and hypothermia. In blood test, CRP > 75 mg/l, Il-6 150 ng/l. The CSF findings are negative. In the blood culture detection of Staphylococcus epidermidis.	24
7	Newborn at 41 weeks of gestation, at the age of five days. In the clinical examination, the infant shows hyperexcitability and a gray skin color, tachypnea, dyspnea and fever (max. 39°C). In the laboratory analyses initiated by you, the CRP is 90 mg/dl, and the interleukin 6 (Il-6) is 1,450 ng/l. In cerebrospinal fluid (CSF), there were 80 leukocytes/µl. The culture of the CSF remained negative. In the blood culture, E. coli was detected.	5
8	Preterm infant with spontaneous vaginal delivery after 32 weeks of pregnancy. Prenatal maternal antibiotic prophylaxis and a history of rupture in the 29th week of gestation. Mother GBS status negative. Initially slight respiratory distress syndrome. The patient is stabilized by nasal continuous positive airway pressure (nCPAP) quickly, CRP < 5 mg/dl, Il-6 < 8 ng/l. The respiratory support could be terminated at the second day of life.	13
9	Preterm infant after spontaneous vaginal delivery in the 33rd week of pregnancy. Rupture of membranes at birth, positive maternal GBS status, and antenatal IV antibiotic treatment three hours before birth. Initial slight respiratory distress syndrome. The patient rapidly stabilizes under nCPAP. The ventilatory support can be terminated at the second day of life. Initiation of the antibiotic therapy in the delivery room. In the blood test, initiated by you on the second day of life, CRP 15 mg/l and Il-6 < 8 ng/l.	31
10	Twin preterm infant at the 32nd week of gestation. Spontaneous vaginal birth. The GBS-positive mother received an intravenous antibiotic treatment six hours before birth. Initial respiratory distress syndrome (III°). Surfactant application and further respiratory support with nCPAP in the first hours of life. Initiation of an antibiotic treatment in the labor ward. CRP 30mg/l, Il-6 120 ng/l. Blood cultures and neonatal smears were negative.	15

11	Premature infant with a gestational age of 28 weeks. Caesarean section due to maternal HELLP syndrome. Initial slight respiratory distress syndrome. Rapid stabilization of the respiratory state under nCPAP. Implantation of a silastic catheter. On the fifth day of life deterioration of general condition, gray patchy skin color, capillary refill prolonged and increasing oxygen demand. Removal of the catheter. Improvement of the clinical condition after application of an antibiotic therapy. In blood, maximal CRP 35 mg/l and Il-6 148 ng/l. The blood cultures and newborn smears were negative.	32
12	Premature infant at the 25th week of gestation after three cycles of antibiotic therapy because of systemic in inflammatory response syndrome (SIRS) and catheter sepsis. O2-supply via nasal prongs, oral nutrition. At the age of eight weeks, poor feeding, vomiting, and abdominal distension. With suspected septicemia or necrotizing enterocolitis initiation of an antibiotic treatment. The CRP value was 35 mg/l, Il-6 was 480 ng/l. The blood cultures were negative. In the neonatal smears, detection of Staphylococcus epidermidis, Enterobacter species, and Candida albicans. Immediate improvement of the clinical condition after the initiation of the therapy.	17
Infections of the CNS		
13	Six-year-old boy with sudden fever between 39°C and 40°C. His temperature cannot be reduced with physical and pharmacological measures. Severe headaches, neck pain, and vomiting. Admission with suspected meningitis and implementation of an antibiotic treatment. In CSF: turbid appearance, leukocyte count > 1,000/µl. CSF culture: negative.	27
14	Eight-year-old girl with severe headache and neck pain. High fever up to 40°C since the previous day. By suspected meningitis admission in your clinic and initiation of an antibiotic therapy. CSF results: turbid, cell count > 1,000/µl. In the rapid test and in the CSF culture, detection of meningococcus.	7
15	Ten-year-old boy with infection of the respiratory tract for one week. Fever up to 39°C, headache, and photophobia since the previous night. Admission to the hospital with suspected meningitis. CSF findings: cell count > 1,000/µl, protein 500 mg/l, lactate 4.5 mmol/l. Pneumococcus species were detected in the blood culture.	6
16	Two-year-old former premature infant with ventriculoperitoneal shunt. High fever up to 40°C, drowsiness, and vomiting since the previous day. CSF after puncture of the shunt valve: cell count > 1,000/µl. In CSF, detection of Staphylococcus. The ventriculoperitoneal shunt was explanted shortly after admission.	38
Bone and joint infections		
17	12-year-old boy with pain in his left foot since the previous day. Pain when standing, redness and swelling and effusion in the area of the ankle. Trauma history negative and no visible external injury. Hospital admission for puncture and antibiotic therapy. In the puncture, detection of Staphylococcus aureus. Significant improvement of the clinical symptoms and normalization of the inflammation parameters within the first week of antibiotic treatment.	10
Upper respiratory tract infections		
18	Three-year-old child with acute ear pain, infection of the upper respiratory tract, serous rhinitis, and a maximal body temperature of 38.5°C. Otoscopy: redness and withdrawal of the tympanic membrane.	1
19	Eight-month-old infant in poor general condition. Apparent ear pain until the day before. Infection of the upper respiratory tract with purulent rhinitis and temperature up to max. 40°C. Otoscopic findings: purulent otorrhea with perforated eardrum.	12
20	Seven-year-old child with ear pain, infection of the upper respiratory tract, serous rhinitis, and fever up to max. 40°C for three days. Otoscopic findings: redness of the eardrum.	26
21	Ten-year-old girl in good general condition with serous rhinitis and coughing for one week. Frontal headache when tilting the head since the previous day.	3
22	12-year-old girl in good general condition with serous rhinitis and cough for two weeks. Severe facial pain for five days. Fever > 39°C during the clinical examination.	16
23	Eight-year-old boy with purulent rhinitis and cough for one week. Fever > 39°C and strong frontal headache for two days.	35
24	Eight-year-old boy with fever up to 39.8°C, fine maculate, slightly elevated, pale red rash, glossitis, and erythematous tonsils. Positive streptococcal rapid test.	36
25	Five-year-old girl with difficulty in swallowing, red tonsils, and swelling of the cervical lymph nodes without fever. Positive streptococcus A rapid test.	2

26	Ten-year-old girl with rapidly rising fever, pain and malaise. The tonsils are swollen and red, and there is a cervical lymph node swelling. Streptococcal A rapid test positive.	18
Urinary tract infections		
27	Detection of bacterial species > 10^5/ml in the investigation of the midstream urine of a 13-year-old female adolescent. The routine clinical examination was unremarkable.	30
28	15-year-old girl with dysuria, pollakiuria, and temperature up to 38.5°C. In the urinary analysis, leukocyturia and bacteriuria.	9
29	16-year-old girl with frequent, imperative urinary urgency and hematuria for two days. On the day of examination, strong malaise, fever up to 40.5°C and flank pain. In the urine analysis, 3,000 leukocytes/µl, massive bacteriuria, and 300 isomorphic erythrocytes/µl. In the blood, 19,000 leukocytes/µl and CRP 120 mg/l. In the ultrasound examination, the kidneys were normal and there was no urinary obstruction.	21
30	15-year-old girl with dysuria for the first time, pollakiuria, flank pain, and fever up to 40°C. On the urine strip test (midstream urine) leukocytes ++, nitrite ++. In blood test leukocytosis and a CRP value of 100 mg/l. In the ultrasound examination, the left kidney was enlarged and partly echogenic, no urinary obstruction.	11
31	Four-month-old male infant with fatigue and fever up to 40.5°C. The CSF findings were normal. In the urine probe after catheterization: 500 leukocytes/µl. In blood test, leukocytes 24,000/µl and CRP 80 mg /l. The renal ultrasound examination revealed a suspected reflux.	22
32	Five-month-old male infant with fever up to 40°C. Poor general condition without a clear infectious focus. In the blood test: 16,400 leukocytes/µl , CRP 95 mg/l. Urine test strip after bladder puncture: leukocytes +++, erythrocytes ++, nitrite +, proteins +. Urine culture: Detection of E. coli 10^6/ml.	8
Lower respiratory tract infections		
33	A six-week-old infant has been suffering from rhinitis for three days, fever up to 38°C, and increasingly dry cough. The child is pale, with nasal flaring, tachypnea, dyspnea, and subcostal chest retractions. Bilateral attenuated respiratory sound, fine crackles, and expiratory wheezing. The rapid test for respiratory syncytial virus (RSV) is positive. In the blood test, 5,300 leukocytes/µl and CRP 20 mg/l.	34
34	A nine-month-old female infant has been suffering from fever up to 38°C for one week, rhinitis, and dry cough. Symptomatic therapy with suspected viral infection. Since the previous day, deterioration of the general condition and fever up to 40°C. Bilateral attenuated breath sounds and occasional fine crackles and expiratory wheezing in the auscultation. The RSV rapid test is positive. In blood, leukocytes 15,000/µl, CRP 70 mg/l.	40
35	Three-month-old infant with tachypnea and cough resembling whooping cough. Postnatal purulent conjunctivitis. Chlamydia trachomatis pneumonia is suspected.	14
36	Five-year-old boy with fever up to 39.5°C and abdominal pain. Auscultation: inspiratory fine crackles and attenuated breath sounds. Laboratory findings: leukocyte 27,800/µl, CRP 38 mg/dl. The x-ray reveals a lobar pneumonia.	28
37	Seven-year-old girl with severe abdominal pain and fever up to 39°C. In the physical examination: basal attenuated breath sounds in the auscultation and basal damping in the percussion; the abdomen is normal. In blood, 13,500 leukocytes/µl and CRP 77 mg/l. The chest x-ray revealed pneumonia.	37
38	Six-year-old girl with severe cough, purulent rhinitis, and fever up to 40°C. In the auscultation, fine inspiratory crackles and expiratory wheezing. Laboratory findings: 17,500 leukocytes/µl, CRP 100 mg/l. Bronchopneumonia in the chest x-ray.	25
39	Six-year-old boy with fever up to 40°C and abdominal pain for ten days. The chest x-ray shows pneumonia with basal pleural effusion. After a seven-day-long antibiotic treatment duration, relapse of fever, and occurrence of increasing dyspnea. In the chest x-ray, an abscessing pneumonia is suspected. Surgical application of an abscess drainage.	29
40	Ten-year-old girl with intermittent fever up to 40°C, cough and rhinitis. A therapy with cefuroxime has not lead to an improvement. The chest x-ray reveals central infiltrates with the involvement and compression of the hilum. An atypical pneumonia is suspected.	33

Notes. This table shows the 40 medical cases used in the expert survey and in the experiment. It also shows the six categories of infectious diseases to which the cases can be assigned. The last column provides the randomized order of the cases used in the survey and in the experiment.

A.3.2 Development and Validation of the Cases

The cases had been developed by the clinicians in the research team, (three pediatricians with different sub-specializations) based on textbooks, clinical case reports, and clinical experience (including experience from discussions in regular case conferences).

Afterwards, the cases were validated by five pediatricians of the Department of Pediatrics at the University Hospital Cologne with different sub-specializations (neonatology, infectious diseases, nephrology, neurology, pneumology) and different levels of clinical experience. We asked them to assess the cases with regard to (i) their clarity and comprehensibility, (ii) their relevance in clinical practice, (iii) their plausibility, and (iv) the correctness and completeness of the given information.

As for some infectious diseases, the appropriate length of therapy differs depending on the choice of the antibiotic agent and the dosage; we asked the participants in our study to consider the standard antibiotic agent and the standard dosage for each case when deciding on the length of first-line antibiotic therapy. Therefore, we made sure that each case description comprised all information necessary to determine (an initial clinical diagnosis and) a standard antibiotic agent and dosage. As part of the validation process, we asked the five pediatricians to decide on the length of the therapies and on the agents and dosages they would choose. The case scenarios and all discrepancies in treatment decisions were discussed among the five pediatricians and the research team. For some of the cases, we changed the wording to prevent any misinterpretation of the given information. For some cases, we added further information to rule out any possible differential diagnoses, which were the main reasons for heterogeneous antibiotic treatment decisions made by the five physicians. Furthermore, we matched each case description with the respective treatment recommendation from the handbook published by the German Society for Pediatric Infectious Diseases.[1] By doing so, we made sure that the handbook provided, based on explicitly stated standard antibiotic agents and dosages,[a] a recommendation on the length of the first-line therapy for each case. This ensured comparability between the decisions from the expert survey and the recommendations from the German Society for Pediatric Infectious Diseases.

[a] For the cases for which several antibiotic agents were recommended, all agents except for the standard agent had to be declared as alternatives to be used only in exceptional cases (e.g., in case of resistance or allergies).

A.4 Survey with Directors of German Pediatric Departments

A.4.1 Descriptive Statistics

In total, 20 directors of 50 randomly selected pediatric departments participated in our online survey. The expert sample comprised 19 male pediatricians and one female pediatrician, who were aged between 40 and 62 years. The aggregated expert opinion, i.e., the average length of antibiotic therapy the experts chose for the 40 cases, was 6.42 days (SD 4.94, 95% CI 4.26 to 8.59). This aggregated value served as the 'expert benchmark' in our experiment. See Table C.2 for detailed results of the expert survey.

A.4.2 Comparison with Guidelines

We compared the experts' decisions with published recommendations on the length of antibiotic therapy for each respective case. For this comparison, we only considered recommendations on the length of first-line therapy with the standard antibiotic agent to assess the experts' compliance with recommendations, because the participants in our study were asked to decide on the length of first-line antibiotic treatment with the standard antibiotic agent. We primarily used the recommendations published by the German Society for Pediatric Infectious Diseases.[1] The handbook published by this society provides (based on the use of explicitly stated standard antibiotic agents) a recommendation on the therapy length for each case we used in our study. Moreover, it reflects the consensus of several leading German pediatricians, which leads us to assume that it also reflects local standards of care in pediatric medicine.[b]

Using Fisher-Pitman permutation tests for paired replicates, we analyzed whether the decisions made in the expert survey were significantly different from the recommendations. For each case, we compared the 20 decisions of the experts with the range of recommended numbers of treatment days. We considered decisions as compliant with the recommendations if they were within the range of recommended numbers of treatment days or deviated one day at most (i.e., the recommended intervals were extended by +/-one day). In doing so, we adopted the measure of compliance with recommendations on the length of antibiotic therapy that has been applied by other scholars.[2] The interval was not extended by one day, however, if no antibiotic therapy (zero days) or an explicit maximum or minimum number of days is recommended (e.g., for the recommendation 'from one day up to a maximum of two days', we

[b] Note that the recommendations are very similar to recommendations from national and international guidelines. The handbook is an aggregate of available evidence, which should also be included in those guidelines.

accepted one or two days as compliant with the recommendation. For ‘at least 10 days up to 14 days’, the range between 10 and 15 days was considered appropriate. Note that we did not extend the interval to zero days if the lower boundary is one day). For cases for which the handbook provides no upper or lower boundary (e.g., ‘at least 10 days’), we used recommendations from further national and international guidelines as references (see Table A.2 for details).

In 80 percent of the cases, the experts’ decisions were in line with the recommendations, i.e., only in eight out of the 40 cases (20%) did the decisions significantly differ from what guidelines recommend (with a p-value < 0.05). Comparable studies reporting compliance rates with antibiotic prescribing guidelines are rare. Labenne et al.,[2] which is, to the best of our knowledge, the only study that examines guideline compliance regarding the length of antibiotic therapy for children, reported a compliance rate of 70 percent. Other studies, which lack comparability since they do not consider length of antibiotic therapy, found low average medical guideline compliance rates among physicians of 61 percent[3] or 54.5 percent.[4] Given the experts’ large guideline compliance rate in our survey, we argue that the aggregated expert opinion can be considered a suitable benchmark for an appropriate length of antibiotic therapy.

Table A.2: Results of the expert survey (n=20) and recommendations on length of therapies

Cases (ordered by category)	The experts' decisions in days (n=20)					Recommended length of therapy (in days)	Absolute deviation of the experts (n=20) from the recommendations (in days)				
	Min	Max	Mean	Median (IQR)	s.d.		Min	Max	Mean	Median (IQR)	s.d.
Neonatal infections											
1	0	5	0.65	0 (0-0)	1.63	0	0	5	0.65	0 (0-0)	1.63
2	0	3	0.15	0 (0-0)	0.67	0	0	3	0.15	0 (0-0)	0.67
3	0	10	2.40	0 (0-5)	3.12	1-2 (max.)	1	8	2.05	1 (1-3)	1.93
4	0	10	5.50	5 (5-7)	2.42	5 (-7)	0	4	0.60	0 (0-1)	1.10
5	0	7	2.80	3 (0-5)	2.46	1-2 (max.)	0	5	1.85	1 (1-3)	1.42
6	3	10	6.85	7 (5-9.25)	2.16	7 (-10)	0	3	0.50	0 (0-1)	0.76
7	7	21	11.65	10 (7.5-14)	4.69	21	0	13	8.50	10 (6-12.5)	4.38
8	0	3	1.20	0 (0-3)	1.40	0	0	3	1.20	0 (0-3)	1.40
9	0	10	3.80	3 (2-5)	3.00	1-2 (max.)	0	8	2.40	1 (1-3)	2.39
10	2	10	5.25	5 (3.5-6.5)	2.12	5 (-7)	0	2	0.50	0 (0-1)	0.76
11	2	10	6.30	6 (5-7)	2.03	5 (-7)	1	6	2.50	2.5 (1-3)	1.76
12	5	14	7.35	7 (5.5-7.75)	2.23	5 (-7)	0	6	0.60	0 (0-0)	1.47
Infections of the CNS											
13	3	21	9.70	10 (7-10)	3.66	7-10	0	10	0.95	0 (0-0)	2.39
14	5	21	8.35	7 (7-9.5)	3.92	4-7	0	13	1.45	0 (0-1.5)	3.30
15	7	21	10.50	10 (7.25-13)	3.47	7-10	0	10	1.10	0 (0-2.25)	2.43
16	5	21	11.85	14 (10-14)	3.73	at least 10-14	0	6	1.00	0 (0-2.25)	1.89
Bone and joint infections											
17	7	28	17.45	17.5 (14-21)	6.58	21	0	13	5.00	6 (0-6)	4.36
Upper respiratory tract infections											
18	0	7	1.60	0 (0-4.5)	2.62	0	0	7	1.60	0 (0-4.5)	2.62
19	5	14	7.20	7 (5-7)	2.28	10	0	4	2.35	2 (2-4)	1.35
20	0	7	1.35	0 (0-3.75)	2.43	5-7	0	4	3.00	4 (1-4)	1.78
21	0	10	1.25	0 (0-0)	2.75	0	0	10	1.25	0 (0-0)	2.75
22	0	14	5.65	6 (5-7)	3.63	10 (-14)	0	9	3.70	3 (2-4)	3.03
23	0	14	5.80	7 (1.25-9.25)	4.09	10 (-14)	0	9	3.65	2 (0.5 -7.75)	3.45
24	3	10	7.85	7 (7-10)	2.23	10	0	6	1.60	2 (0-2)	1.79
25	0	10	5.00	6 (0-7)	3.83	5	0	10	5.00	6 (0-7)	3.83
26	0	10	6.95	7 (5-10)	2.67	10	0	9	2.35	2 (0-4)	2.32
Urinary tract infections											
27	0	5	0.35	0 (0-0)	1.14	0	0	5	0.35	0 (0-0)	1.14
28	0	7	3.50	3 (3-5)	2.01	3 (-5)	0	2	0.40	0 (0-1)	0.68

29	5	14	7.65	7 (7-9.25)	2.16	(7-) 10	0	3	0.30	0 (0-0)	0.73
30	7	14	8.40	7 (7-10)	1.96	(7-) 10	0	3	0.15	0 (0-0)	0.67
31	5	14	8.85	10 (7-10)	2.5	10-14	0	4	1.10	0 (0-2)	1.37
32	7	14	8.60	7 (7-10)	2.3	10 (-14)	0	2	1.20	2 (0-2)	1.01
Lower respiratory tract infections											
33	0	7	0.35	0 (0-0)	1.57	0	0	7	0.35	0 (0-0)	1.57
34	0	10	5.85	7 (5-7)	2.85	7	0	6	1.30	0 (0-1.75)	2.13
35	0	21	12.00	14 (10-14)	4.81	at least 10 (10-14)	0	10	1.50	0 (0-2.25)	2.91
36	0	14	8.00	7 (7-10)	2.88	7	0	6	1.50	1.5 (0-2)	1.79
37	5	14	8.10	7 (7-10)	2.49	7	0	6	1.10	0 (0-2)	1.86
38	5	14	7.55	7 (7-9.25)	2.24	7	0	6	0.90	0 (0-1.75)	1.45
39	5	21	13.45	14 (10-14)	4.77	at least 21 (21-28)	0	16	7.55	7 (7-11)	4.77
40	3	14	9.90	10 (10-10)	2.86	10	0	6	1.30	0 (0-3)	1.81

Notes. This table shows the experts' decisions on the length of antibiotic treatment for each case, as well as the recommendations published by the German Society for Pediatric Infectious Diseases[1] and the experts' absolute deviation from the recommendations. The experts' decisions on the length of therapy, aggregated over all cases, were used as the 'expert benchmark' in our experiment. We assessed the experts' compliance with the recommendations by comparing the experts' decisions with the recommended length of therapy for each case. We allowed a deviation of one day from the recommended number of days (+/- 1 day). We did not allow a deviation if the recommendation is exactly zero days or if an explicit upper or lower boundary is recommended ('at least' or 'max.'). Note that for cases 35 and 39, the recommendations of the German Society for Pediatric Infectious Diseases provide no upper boundary. They recommend *at least 10 days* for case 35 and *at least 21 days* for case 39. To get an upper boundary, we used recommendations from further guidelines. For case 35, we set the upper boundary to 14 days, since the American Academy of Pediatrics recommends 14 days of antibiotic therapy.[5] For case 39, the upper boundary was set to 28 days because the Centers for Disease Control and Prevention (CDC), the American Academy of Pediatrics, and the Pediatric Infectious Diseases Society recommend a length of therapy between 18 and 28 days.[6] To determine the mean absolute deviation of the experts from the recommendations, we analyzed each single decision. If the chosen length of therapy was below the lower boundary of the recommended interval, we calculated the absolute deviation from the lower boundary; if the chosen length of therapy was above the upper interval boundary, we calculated the absolute deviation from the upper boundary. For all decisions that were within the interval of recommended length of therapy or exactly the same as the recommendation (if recommendation is not an interval), the absolute deviation was determined to be zero. For each case, we determined the mean absolute deviation from the recommendations by averaging the absolute deviations across all experts.

A.5 Some Photographs from the Experiments

Figure A.2: Some impressions from the experimental sessions

Notes. This figure shows the cubicles of the mobile computer laboratory. The left picture shows cubicles of the mobile laboratory at the Department of Pediatrics at the University Hospital Cologne. The middle picture shows parts of the laboratory at the Children's Hospital of the City of Cologne. The right picture indicates the laboratory during the annual conference for pediatricians in Cologne (Päd-Ass 2015).

A.6 Sample Size Calculations and Power Analyses

A.6.1 A-priori Sample Size Calculation

To calculate the required sample size for the detection of a between-subject effect of feedback, we considered the changes in length of antibiotic therapy (measured in days) between Stage 2 and Stage 3 and compared the changes in the intervention group (where feedback was provided) with the changes in the control group. We reviewed the existing literature for a prior to use for our sample size calculation. A recent Cochrane review by Davey et al.[7] summarizes the effect of different interventions to improve antibiotic prescribing practices for hospital inpatients. This review reports a weighted mean reduction of 1.95 days in total duration of antibiotic treatment (95% CI -2.22 to -1.67) associated with the interventions in 14 RCTs. This equals a mean reduction by 28 percentage points and provides a prior for us to determine what change in length of therapy through our feedback mechanism can be considered meaningful. Yet, the average effect is rather large, and so are the effects of most studies included in the review. Moreover, all 14 RCTs were conducted in a hospital setting, which is why the infectious disease cases considered in the review might require longer treatment courses on average than the cases we used in our experiment. Hence, there might be a greater scope for adaption in length of therapies. In this light, we aimed at detecting a change through the provision of feedback which is smaller than 1.95 days.

Instead of comparing decisions on therapy length made in the two experimental groups, we compare changes between the experimental stages that happen in the two groups, because we did not know beforehand how subjects would decide in the first stages. Considering the changes in both groups to measure the effect of our feedback intervention did not require knowing the start values. The effect of providing feedback was defined as the change in the average length of therapies between Stage 2 and Stage 3 in the intervention group compared to the respective change in the intervention group. We consider an average difference of 0.5 days in the change as the minimum relevant effect that should be detected with a sufficient statistical power. This is conservative in light of the large effects found in other studies.[7]

Using Cohen's d as an effect-size statistic and assuming a standard deviation of 0.65 for the change in both groups, this results in an effect size of 0.769, which we aimed at detecting with a power of 80% (β=0.2) and with an alpha of 0.05. We used G*Power[8] for a two-tailed Mann-Whitney-U test to estimate the required sample size for the detection of a between-subject effect of feedback. In G*Power, the sample size required for a non-parametric test is

determined by multiplying the sample size calculated for an equivalent parametric test by a correction factor, referred to as the asymptotic relative efficiency (ARE). We used the ARE method that defines the power of the Mann-Whitney-U test relative to the two groups t-test and chose the most conservative estimation strategy by setting the ARE to its theoretical minimum, although this resulted in larger required sample sizes. This yielded a minimum sample size of 32 required for each group to detect a significant difference between the groups with regard to the change from Stage 2 to Stage 3 with a power of 80%.

A.6.2 Post-hoc Power Calculation

Further, we analyzed the level of statistical power achieved, again using the 'length of therapy (measured in days)' as a variable of interest and selecting the ARE method (with the ARE set to its theoretical minimum) of a two-sided Mann-Whitney-U test. Changes from Stage 2 to Stage 3 in the treatment group were compared to changes between the same stages in the control group.

The realized sample size in our experiment was n=73, with n=39 in the treatment group and n=34 in the control group. Mean changes from Stage 2 to Stage 3 were 0.60 days in the intervention group and 0.06 days in the control group. The standard deviations of the changes were 0.97 in the treatment group and 0.25 in the control group. As both the sample sizes and the standard deviations differed between the two groups, we used Hedge's g to calculate the achieved effect size, which was 0.740. With an alpha of 0.05, the statistical power of the estimates for the between-subject comparison was 82.26%.

A power analysis for the between-subject effect that we had defined as relevant before conducting the experiment (i.e. a mean difference between the groups of 0.5 days) with an alpha of 0.05, a beta of 0.2, an SD of 0.65, and sample sizes of n=39 for the treatment group and n=34 for the control group, yielded a power of 85.06%.

A.7 Post-Experimental Questionnaire

I. Socio-demographics

Your age: _____ years

Your gender: ☐ Male ☐ Female

What is your medical specialty? _____

Since when are you a consultant (specialist physician)? _____

When did you start practicing in the hospital? _____

II. Social and risk preferences

('Economic preferences', according to Falk et al.[9,10] and Dohmen et al.[11])

1. How do you see yourself – Are you a person who is generally willing to take risks, or do you try to avoid taking risks? *Please indicate your answer on a scale from 0 to 10, where a 0 means "not at all willing to take risks", and a 10 means "very willing to take risks". You can also use the values in-between to indicate where you fall on the scale.*

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7	8	9	10

2. Please imagine that you have won a prize in a contest. Now you can choose between two different payment methods, either a lottery or a sure payment. If you choose the lottery there is a 50 percent chance that you would receive €1,000, and an equally high chance that you would receive nothing.
   What is the smallest sure payment that would make you prefer the sure payment over playing the lottery? Amount € _____

3. How do you see yourself – Are you a person who is generally willing to give up something today in order to benefit from that in the future, or are you not willing to do so? *Please use a scale from 0 to 10, where 0 means you are "completely unwilling to give up something today"" and a 10 means you are "very willing to give up something today". You can also use the values in-between to indicate where you fall on the scale.*

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7	8	9	10

4. How well does the following statement describe you as a person? "I tend to postpone things even though it would be better to get them done right away." *Please use a scale from 0 to 10, where 0 means "does not describe me at all" and a 10 means "describes me perfectly". You can also use the values in-between to indicate where you fall on the scale.*

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7	8	9	10

5. How would you assess your willingness to trust strangers? *Please indicate your answer on a scale from 0 to 10, where a 0 means "not at all willing to trust strangers", and a 10 means "very willing to trust strangers". You can also use the values in-between to indicate where you fall on the scale.*

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7	8	9	10

6. How well does the following statement describe you as a person? "As long as I am not convinced otherwise, I assume that people have only the best intentions." *Please use a scale from 0 to 10, where 0 means "does not describe me at all" and a 10 means "describes me perfectly". You can also use the values in-between to indicate where you fall on the scale.*

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7	8	9	10

7. How do you assess your willingness to share with others without expecting anything in return when it comes to charity? *Please use a scale from 0 to 10, where 0 means you are "completely unwilling to share" and a 10 means you are "very willing to share". You can also use the values in-between to indicate where you fall on the scale.*

☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
0	1	2	3	4	5	6	7	8	9	10

8. Imagine the following situation: You have won €1,000 in a lottery. Considering your current situation, how much would you donate to charity? (*Values between 0 and 1000 are allowed*): _____

9. How well does the following statement describe you as a person? "When someone does me a favor I am willing to return it." *Please use a scale from 0 to 10, where 0 means*

"does not describe me at all" and a 10 means "describes me perfectly". You can also use the values in-between to indicate where you fall on the scale.

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

0 1 2 3 4 5 6 7 8 9 10

10. How do you assess your willingness to return a favor to a stranger? *Please use a scale from 0 to 10, where 0 means you are "not willing to return a favor to a stranger" and a 10 means you are "very willing to return a favor to a stranger". You can also use the values in-between to indicate where you fall on the scale.*

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

0 1 2 3 4 5 6 7 8 9 10

11. How do you see yourself – Are you a person who is generally willing to punish unfair behavior even if this is costly? *Please use a scale from 0 to 10, where 0 means you are "not at all willing to incur costs to punish unfair behavior" and a 10 means you are "very willing to incur costs to punish unfair behavior". You can also use the values in-between to indicate where you fall on the scale.*

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

0 1 2 3 4 5 6 7 8 9 10

12. How well does the following statement describe you as a person? "If someone treats me unjustly, I will try to take revenge at the first occasion." *Please use a scale from 0 to 10, where 0 means "does not describe me at all" and a 10 means "describes me perfectly". You can also use the values in-between to indicate where you fall on the scale.*

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

0 1 2 3 4 5 6 7 8 9 10

III. Personality traits

(according to Gosling et al.[12] and Rammstedt and John[13])

In the following, you can find a number of personality traits that more or less apply to you. Please mark for each statement how well it describes your personality.

	Disagree strongly	Disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Agree	Agree strongly
	1	2	3	4	5	6	7
1. I see myself as someone who is reserved.	☐	☐	☐	☐	☐	☐	☐
2. I see myself as someone who is generally trusting.	☐	☐	☐	☐	☐	☐	☐
3. I see myself as someone who tends to be lazy.	☐	☐	☐	☐	☐	☐	☐
4. I see myself as someone who is relaxed, handles stress well.	☐	☐	☐	☐	☐	☐	☐
5. I see myself as someone who has few artistic interests.	☐	☐	☐	☐	☐	☐	☐
6. I see myself as someone who is outgoing, sociable.	☐	☐	☐	☐	☐	☐	☐
7. I see myself as someone who tends to find fault with others.	☐	☐	☐	☐	☐	☐	☐
8. I see myself as someone who does a thorough job.	☐	☐	☐	☐	☐	☐	☐
9. I see myself as someone who gets nervous easily.	☐	☐	☐	☐	☐	☐	☐
10. I see myself as someone who has an active imagination.	☐	☐	☐	☐	☐	☐	☐
11. I see myself as someone who is considerate and kind to almost everyone.	☐	☐	☐	☐	☐	☐	☐

B. Model Specification

Our experimental data have a panel structure, as each pediatrician decided on the same randomly ordered 40 cases three times. Further, the decisions made in the experiment are nested within the subjects and the subjects are nested within the experimental sessions. To account for the hierarchical structure of our data with clustering on several levels, we applied multilevel mixed-effects panel regression models.[14] Our models include random effects for the experimental sessions, the subjects, and the 40 cases to account for potential within-group correlation of the decisions and for potential session-, subject-, or case-specific unobserved effects.

We employed the following model for a decision in experimental stage i on case j made by subject k, who is nested within session l (denoted by d_{ijkl}):

$$d_{ijkl} = \beta_0 + \beta_1 * \left(Stage2_{ijkl}\right) + \beta_2 * \left(Stage3_{ijkl}\right) + \beta_3 * \left(Treat_{kl}\right) + \beta_4 \left(Treat_{kl} * Stage2_{ijkl}\right) + \beta_5 \left(Treat_{kl} * Stage3_{ijkl}\right) + \beta_0^S * W_{kl}^S + \beta_1^S * W_{kl}^S * \left(Stage2_{ijkl}\right) + \beta_1^S * W_{kl}^S * \left(Stage3_{ijkl}\right) + \beta_1^M * X_{kl}^M * \left(Stage2_{ijkl}\right) + \beta_2^M * X_{kl}^M * \left(Stage3_{ijkl}\right) + u_{000l} + u_{00kl} + u_{10kl} * Stage2_{ijkl} + u_{20kl} * Stage3_{ijkl} + u_{0jkl} + \varepsilon_{ijkl}$$

The fixed-effects part of the model contains the constant β_0, fixed effects for Stages 2 and 3 of the experiment, which allow us to differentiate between the changes from Stage 1 to Stage 2 and the changes from Stage 2 to Stage 3, a treatment group indicator ($Treat_{kl}$), which is time-invariant, and two-way interactions between the treatment group indicator and the stage dummies. β_1 and β_2 denote the average changes over all subjects from Stage 1 to Stage 2 and from Stage 2 to Stage 3, respectively. β_3 is the average difference in the dependent variable between the treatment and the control groups, and β_4 and β_5 are average differences in changes over the stages between the two groups. Further, we included the subjects' individual characteristics in the fixed-effects part of our model. The vector W_{kl}^S (where $W_{kl}^{(1)} \dots W_{kl}^{(S)}$) contains S covariates, which are time-invariant characteristics of the individual subject k. We allow both the intercept and the changes between the experimental stages to vary at the subject level as a function of the subject characteristics S. The vector X_{kl}^M (where $X_{kl}^{(1)} \dots X_{kl}^{(M)}$) includes two-way interactions between the characteristics $m = \{1, \dots, M \leq S\}$ and the treatment-group indicator $Treat_{kl}$.[c]

[c] Note that X_{kl}^M does not stand alone but is either interacted with the Stage 2 or with the Stage 3 indicator. The reason is that we assume the interactions between the characteristics and the treatment-group indicator (denoted by X_{kl}^M) to be associated with the Stage 2 and the Stage 3 effects. In other words, while the effect of individual

The random effects are assumed to be independent of each other between levels and all random effects are independent of the level-one residuals. The residuals ε_{ijkl} are assumed to be independent and normally distributed with a mean of 0 and a constant variance σ^2 across the time points. Therefore, $\varepsilon_{ijkl}=\begin{pmatrix}\varepsilon_{0jkl}\\ \varepsilon_{1jkl}\\ \varepsilon_{2jkl}\end{pmatrix}\sim N(0,D)$, where $D=\begin{pmatrix}{\sigma_1}^2 & 0 & 0\\ 0 & {\sigma_1}^2 & 0\\ 0 & 0 & {\sigma_1}^2\end{pmatrix}$.

Further, we assume $u_{0jkl}\sim N(0,{\sigma_2}^2)$ for the random errors at the case level. The joint distribution of the three random effects associated with subject k (i.e., the random intercept denoted by u_{00kl} and the random slopes for Stage 2 and Stage 3 denoted by u_{10kl} and u_{20kl}, respectively) is $u_{kl}=\begin{pmatrix}u_{00kl}\\ u_{10kl}\\ u_{20kl}\end{pmatrix}\sim N(0,R)$. The random effects at the subject level u_{kl} are assumed to be multivariate normal with means of 0 and a variance-covariance matrix R, which is defined as

$$R=\begin{pmatrix}Var(u_{00kl}) & Cov(u_{00kl},u_{10kl}) & Cov(u_{00kl},u_{20kl})\\ Cov(u_{00kl},u_{10kl}) & Var(u_{10kl}) & Cov(u_{10kl},u_{20kl})\\ Cov(u_{00kl},u_{20kl}) & Cov(u_{10kl},u_{20kl}) & Var(u_{20kl})\end{pmatrix} \text{ or}$$

$$R=\begin{pmatrix}\sigma^2_{(3:intercept)} & \sigma_{(3:intercept,stage2)} & \sigma_{(3:intercept,stage3)}\\ \sigma_{(3:intercept,stage2)} & \sigma^2_{(3:stage2)} & \sigma_{(3:stage2,stage3)}\\ \sigma_{(3:intercept,stage3)} & \sigma_{(3:stage2,stage3)} & \sigma^2_{(3:stage3)}\end{pmatrix}.$$

We add the stage indicators to the random-effects specification at the subject level, as we are interested in the individual subjects' changes between the stages of the experiment. By including random slopes for the effect of the stages at the subject level, we allow for separate random effects within each subject for all stages. We allow correlation between the random effects at the subject level. The random effects at the session level are denoted by u_{000l} and assumed to be $u_{000l}\sim N(0,{\sigma_4}^2)$. We employ the same model specifications and assumptions for the analyses of the length of therapies and the appropriateness of therapy decisions. For regression results, see Table 3 and Table 5 in the main paper.

To analyze the association between pediatricians' individual characteristics and their antibiotic therapy decisions, we employed multilevel mixed-effects models. We used the same econometric model as described above without the panel time variables and the treatment-group indicator, as we considered only the decisions made in the first stage of the experiment when

characteristics is assumed to be unassociated with the treatment group allocation in the first stage, it is in the second and third stages where feedback was announced and given only in the treatment group. Therefore, we included the interaction between the characteristics and the effect of feedback only in the random slopes equations, but not in the random intercept equation at the subject level.

the instructions were the same for pediatricians in the control and the intervention group. For regression results, see Table 4 in the main paper.

C. Robustness Checks

We conducted several analyses to check the robustness of our main results. First, we analyzed the pediatricians' decisions before and after being given feedback on a case-by-case basis. Results of non-parametric statistical analyses support our main results. We found that, for the vast majority of the cases, the length of therapies decreased and the appropriateness of the length of therapies increased. In particular, we observed a decrease or no change in the therapy length for 37 out of the 40 cases, and a decrease or no change in the absolute deviation from the experts for 35 out of the 40 cases. Changes in the opposite direction for the remaining cases were not statistically significant ($p>0.190$ for number of days and $p>0.196$ for absolute deviation from the expert recommendations, Wilcoxon matched-pairs signed-rank tests); for a detailed analysis of the effect of feedback on a case by case basis, see Tables C.1 and C.2.

Table C.1: The effect of feedback on length of antibiotic therapies for each case

Cases (ordered by category)	The subjects' decisions on days of antibiotic therapy						Change in mean number of days	p-values
	Stage 2			Stage 3				
	mean	median	s.d.	mean	median	s.d.		
Neonatal infections								
1	1.46	0	2.35	1.00	0	1.75	-0.46	0.43
2	1.46	0	2.51	1.26	0	2.16	-0.21	0.32
3	4.10	5	3.57	3.62	5	2.88	-0.49	0.11
4	6.95	7	2.79	6.64	7	2.36	-0.31	0.31
5	5.90	5	3.37	6.13	5	3.61	0.23	0.22
6	9.64	10	3.78	8.72	7	3.00	-0.92	0.02
7	14.41	14	5.14	12.72	10	4.98	-1.69	0.00
8	3.05	3	3.68	2.82	3	2.83	-0.23	0.80
9	4.59	5	2.56	4.31	5	2.02	-0.28	0.68
10	7.62	7	3.70	6.10	7	2.23	-1.51	0.01
11	8.74	7	4.17	7.69	7	2.59	-1.05	0.13
12	10.62	10	4.83	9.67	7	4.24	-0.95	0.03
Infections of the CNS								
13	11.33	10	4.35	10.87	10	3.74	-0.46	0.77
14	15.18	14	4.07	14.23	14	3.77	-0.95	0.04
15	14.56	14	3.67	14.41	14	3.19	-0.15	0.95
16	13.85	14	4.69	13.64	14	4.31	-0.21	0.96

Bone and joint infections								
17	15.23	14	6.27	14.87	14	6.33	-0.36	0.21
Upper respiratory tract infections								
18	2.97	0	3.79	1.79	0	2.78	-1.18	0.00
19	7.44	7	3.22	6.69	7	1.91	-0.74	0.05
20	2.21	0	3.47	2.05	0	3.15	-0.15	0.65
21	2.05	0	3.53	2.26	0	3.53	0.21	0.19
22	5.21	7	3.25	4.69	5	3.33	-0.51	0.04
23	4.97	5	3.10	4.62	5	3.22	-0.36	0.16
24	8.49	7	3.14	7.82	7	2.21	-0.67	0.03
25	6.38	7	3.41	5.77	7	3.39	-0.62	0.09
26	7.97	7	3.75	7.49	7	2.63	-0.49	0.17
Urinary tract infections								
27	0.46	0	1.55	0.46	0	1.55	0.00	1.00
28	4.90	5	2.39	4.10	5	2.17	-0.79	0.02
29	8.46	7	3.48	7.77	7	2.76	-0.69	0.06
30	9.79	10	2.74	9.36	10	2.91	-0.44	0.11
31	12.03	10	6.37	10.90	10	6.00	-1.13	0.00
32	10.44	10	3.42	9.23	10	3.17	-1.21	0.02
Lower respiratory tract infections								
33	1.74	0	3.38	1.49	0	2.61	-0.26	0.98
34	5.38	7	3.03	5.54	7	2.97	0.15	0.97
35	11.54	10	3.95	10.82	10	3.58	-0.72	0.10
36	9.87	10	3.14	8.77	7	2.49	-1.10	0.01
37	8.46	7	2.01	8.00	7	1.95	-0.46	0.01
38	8.26	7	2.70	7.51	7	1.54	-0.74	0.02
39	14.90	14	5.54	14.03	14	5.18	-0.87	0.03
40	10.49	10	4.41	9.28	10	3.78	-1.21	0.01

Notes. This table shows the effect of feedback on length of antibiotic therapies at case level. It shows the average number of days subjects in the intervention group (n=39) chose prior to feedback (in Stage 2) and after feedback had been given (in Stage 3). p-values are shown for two-sided Wilcoxon matched-pairs signed-rank tests.

Table C.2: The effect of feedback on absolute deviation from the experts for each case

Cases (ordered by category)	The subjects' absolute deviation from the experts (in days)						Change in mean number of days	p-values
	Stage 2			Stage 3				
	mean	median	s.d.	mean	median	s.d.		
Neonatal infections								
1	1.68	1	1.82	1.28	1	1.22	-0.39	0.42
2	1.51	0	2.39	1.31	0	2.04	-0.20	0.32
3	3.20	3	2.28	2.71	3	1.50	-0.49	0.11
4	2.17	2	2.26	1.83	2	1.85	-0.33	0.10
5	3.61	2	2.80	3.84	3	3.04	0.23	0.51
6	3.08	3	3.55	2.44	2	2.55	-0.64	0.30
7	4.56	2	3.59	4.09	2	2.97	-0.47	0.13
8	2.65	2	3.13	2.42	2	2.16	-0.23	0.27
9	2.05	1	1.70	1.75	1	1.09	-0.30	0.28
10	2.78	2	3.39	1.61	2	1.75	-1.17	0.06
11	3.11	1	3.69	1.93	1	2.21	-1.18	0.02
12	4.10	3	4.13	3.31	2	3.50	-0.79	0.13
Infections of the CNS								
13	3.34	4	3.19	3.02	2.70	2.46	-0.32	0.77
14	6.83	6	4.07	6.02	5.65	3.53	-0.81	0.04
15	4.27	4	3.42	4.06	3.50	2.99	-0.21	0.95
16	3.99	2	3.12	3.60	2.15	2.93	-0.39	0.9
Bone and joint infections								
17	5.84	3.55	3.06	6.02	3.55	3.12	0.18	0.91
Upper respiratory tract infections								
18	3.18	2	2.43	2.41	2	1.35	-0.77	0.00
19	1.83	0	2.64	1.23	0	1.54	-0.60	0.17
20	2.66	1	2.36	2.50	1	1.99	-0.15	0.65
21	2.60	1	2.49	2.67	1	2.48	0.08	0.65
22	2.47	1	2.12	2.56	1	2.29	0.10	0.20
23	2.35	1	2.15	2.53	1	2.29	0.17	0.94
24	2.20	2	2.31	1.76	1	1.3	-0.43	0.15
25	2.92	2	2.19	2.82	2	1.99	-0.10	0.98
26	1.82	2	3.43	1.79	2	1.98	-0.03	0.51
Urinary tract infections								
27	0.74	0	1.37	0.74	0	1.37	0.00	1.00

28	2.14	2	1.74	1.91	2	1.16	-0.23	0.25
29	2.50	2	2.52	2.03	1	1.84	-0.47	0.07
30	2.50	2	1.75	2.49	2	1.74	-0.02	0.33
31	4.52	2	5.47	3.96	2	4.92	-0.56	0.78
32	2.74	2	2.74	2.39	2	2.13	-0.34	0.47
Lower respiratory tract infections								
33	1.91	0	3.10	1.66	0	2.31	-0.26	0.98
34	2.28	1	2.02	2.22	1	1.96	-0.06	0.41
35	3.28	2	2.18	3.13	2	2.04	-0.15	0.96
36	2.69	2	2.45	2.00	1	1.64	-0.69	0.01
37	1.71	1	1.09	1.58	1	1.11	-0.12	0.01
38	1.57	1	2.30	1.14	1	1.01	-0.43	0.33
39	4.04	3	4.01	3.75	3	3.58	-0.29	0.89
40	2.99	3	3.26	2.74	3	2.65	-0.26	0.66

Notes. This table shows the effect of feedback on absolute deviation from the expert recommendations at case level. For each case, the pediatricians' choices were compared to the experts' aggregate opinion for the respective case. It shows absolute differences between the pediatricians' choices and the expert recommendations prior to feedback (in Stage 2) and after feedback had been given (in Stage 3). Only the intervention group (n=39) is considered. p-values are shown for two-sided Wilcoxon matched-pairs signed-rank tests.

Second, instead of using multilevel mixed-effects panel regressions we ran ordinary least squares regression models. The estimation results were qualitatively and quantitatively very similar compared to those of multilevel mixed-effects model; see Table C.3.

Table C.3: OLS regressions on the effect of feedback on antibiotic therapy decisions

Dependent variable	Length of antibiotic therapy (in days)			Absolute deviation from the expert recommendations (in days)		
Model	(1)	(2)	(3)	(4)	(5)	(6)
Feedback (= 1 if intervention)	-0.048 (0.758)	-0.048 (0.760)	-0.526 (0.660)	-0.270 (0.480)	-0.270 (0.481)	-0.823** (0.371)
Second stage (= 1 if second stage)	-0.063 (0.107)	-0.063 (0.107)	-0.063 (0.107)	-0.086 (0.077)	-0.086 (0.077)	-0.086 (0.077)
Third stage (= 1 if third stage)	-0.112 (0.108)	-0.112 (0.108)	-0.112 (0.108)	-0.085 (0.068)	-0.085 (0.068)	-0.085 (0.068)
Effect of announcement (Second stage x Feedback)	-0.082 (0.146)	-0.082 (0.146)	-0.082 (0.147)	-0.068 (0.118)	-0.068 (0.118)	-0.068 (0.118)
Effect of feedback (Third stage x Feedback)	-0.633*** (0.197)	-0.633*** (0.198)	-0.633*** (0.198)	-0.397*** (0.150)	-0.397** (0.150)	-0.397** (0.150)
Individual characteristics						
Female (= 1 if female)			0.728** (0.364)			0.228 (0.223)
			-0.114***			-0.076***

Experience (Years in hospital)			(0.029)			(0.018)
Willingness to take risks			-0.251***			-0.045
			(0.081)			(0.041)
Extraversion			0.066			0.108
			(0.136)			(0.089)
Agreeableness			-0.013			-0.058
			(0.175)			(0.106)
Conscientiousness			-0.522***			-0.479***
			(0.188)			(0.101)
Neuroticism			0.066			0.112
			(0.113)			(0.084)
Openness			0.172			0.067
			(0.117)			(0.070)
Further individual characteristics (Economic preferences)	No	No	Yes	No	No	Yes
Case dummies	No	Yes	Yes	No	Yes	Yes
Constant	7.860***	1.600**	3.068**	3.033***	1.719***	3.594***
	(0.707)	(0.708)	(1.218)	(0.442)	(0.456)	(0.720)
Observations	8,760	8,760	8,760	8,760	8,760	8,760
Subjects	73	73	73	73	73	73
R^2	0.014	0.577	0.612	0.014	0.180	0.239

Notes. This table shows parameter estimates from OLS regressions. The interaction 'Third stage ×Feedback' indicates the effect of showing feedback to subjects. In Models (1) to (3), the dependent variable is 'length of antibiotic therapies (in days)'. In Models (4) to (6), the dependent variable is 'absolute deviation from the expert recommendations', measured in absolute values of the difference between the pediatricians' choices and the experts' recommended therapy length (in days). For each case, the subjects' choices were compared to the experts' aggregate opinion for the respective case. Robust standard errors, clustered at the individual-subject level, are shown in parentheses. 'Economic preferences' comprise validated measures for trust, reciprocity, and altruism, as well as time and risk preferences.[9-11] The variable 'case dummies', which is included in Models (2) to (3) and (5) to (6), indicates 40 dummies, one for each of the 40 medical cases. Furthermore, dummies for each experimental session were included in all models to control for any session effects. *** $p < 0.01$, ** $p < 0.05$, and * $p < 0.10$.

Third, we used two alternative measures for the pediatricians' deviation from the expert recommendations. Rather than the absolute deviation from a mean recommended length of therapy for each case, we used the absolute deviation from the interquartile range (IQR) of the expert decisions. Further, we analyzed how feedback affects the match between the experts' and the pediatricians' decisions. To this end, every decision on length of therapy from the experiment was replaced by the share of experts who chose exactly the same length of therapy for the particular case. The higher the share of experts who made the same decision, the larger was the match between the pediatrician's decision and the expert recommendations. Multilevel mixed-effects panel regressions with these outcome measures further corroborate our main findings regarding the effect of feedback on the appropriateness of care; see Models (1) and (2) in Table C.4.

Finally, we tested whether the changes in the pediatricians' decisions after provision of feedback are related to the difficulty of a case, measured in the case-specific heterogeneity in

the experts' decisions. To this end, we calculated the standard deviation of the experts' recommendations on length of therapies for each case and applied a median split to form two categories: 'difficult to assess' and 'easy to assess'. We interacted our feedback variable with the indicator for the case category in order to analyze whether the effect of feedback was associated with the difficulty to decide on the appropriate length of therapy. The change in the number of days through feedback was not significantly affected by the difficulty of a case, while the change in absolute deviation from the experts was weakly significantly affected. For the latter, the effect of feedback was somewhat smaller for the hard cases; see Models (3) and (4) in Table C.4.

Table C.4: Robustness checks

Dependent variable:	Absolute deviation from IQR of the expert recommendations (in days)	Match with the expert recommendations	Length of antibiotic therapies (in days)	Absolute deviation from the expert recommendations (in days)
Model:	(1)	(2)	(3)	(4)
	Fixed effects			
Feedback (= 1 if intervention)	0.712	-0.022	0.824	0.250
	(0.472)	(0.028)	(0.522)	(0.364)
Second stage (= 1 if second stage)	-0.037	0.001	-0.063	-0.086
	(0.100)	(0.005)	(0.107)	(0.088)
Third stage (= 1 if third stage)	-0.098	-0.002	-0.112	-0.085
	(0.140)	(0.006)	(0.150)	(0.115)
Effect of announcement (Second stage x Feedback)	-0.095	0.008	-0.082	-0.068
	(0.137)	(0.007)	(0.147)	(0.120)
Effect of feedback (Third stage x Feedback)	-0.567***	0.024***	-0.680***	-0.478***
	(0.192)	(0.008)	(0.212)	(0.164)
Case category (=1 if hard to evaluate)			2.955***	1.161***
			(0.178)	(0.085)
Case category x Effect of feedback (Third stage x Feedback)			-0.095	0.161*
			(0.112)	(0.090)
Constant	5.600***	0.290***	6.183***	3.963***
	(1.463)	(0.060)	(1.650)	(0.840)
	Random effects			
Session level				
Var(Constant)	0.143	0.001***	0.289	0.101***
	(0.174)	(0.001)	(0.283)	(0.089)
Subject level				
Var(Stage 2)	0.202***	0.000***	0.226***	0.153***
	(0.057)	(0.000)	(0.066)	(0.044)
Var(Stage 3)	0.530***	0.001***	0.595**	0.342***
	(0.112)	(0.000)	(0.128)	(0.076)
Var(Constant)	1.647*	0.001***	1.638	1.103
	(0.469)	(0.000)	(0.494)	(0.242)
Cov(Stage 2, Stage 3)	0.199***	0.000	0.232***	0.143***
	(0.065)	(0.000)	(0.075)	(0.047)
Cov(Stage 2, Constant)	-0.278**	0.000	-0.245*	-0.286***

	(0.125)	(0.000)	(0.137)	(0.084)
Cov(Stage 3, Constant)	-0.775***	0.000	-0.740***	-0.586***
	(0.051)	(0.000)	(0.215)	(0.124)
Case level				
Var(Constant)	18.666***	0.053***	21.887***	4.369***
	(0.519)	(0.001)	(0.610)	(0.136)
Var(Residual)	2.738***	0.013***	3.321***	2.191***
	(0.051)	(0.000)	(0.062)	(0.041)
Number of observations	8,760	8,760	8,760	8,760
Number of subjects	73	73	73	73
Number of sessions	8	8	8	8

Notes. This table shows parameter estimates from multilevel mixed-effects REML regressions. In Model (1), the dependent variable is 'absolute deviation from the IQR of the expert recommendations (in days)'. The dependent variable in Model (2) is 'match with the expert recommendations', measured as the share of experts who made the same decision as the pediatricians in the experiment. Dependent variables in Models (3) and (4) are 'length of antibiotic therapies (in days)' and absolute deviation from the expert recommendations (in days)', respectively. The interaction 'Third stage × Feedback' indicates the effect of showing feedback to subjects. The variable 'case category' in Models (3) and (4) is an indicator for the heterogeneity in the experts' decisions (difficulty to evaluate the cases). Cases for which the standard deviation of the experts' decisions on length of therapy was above the median were classified as cases that are 'hard to evaluate', while cases for which the standard deviation of chosen therapy durations was below the median, were classified as 'easy to evaluate'. The interaction 'Case category x Effect of feedback' indicates the differential effect of feedback for easy and for hard cases. Standard errors are shown in parentheses. In all models, we control for the subjects' gender, experience, Big Five personality traits,[12,13] and economic preferences, which comprise validated measures for trust, reciprocity, and altruism, as well as time and risk preferences.[9-11] All models include session-, subject-, and case-specific random effects. *** $p<0.01$, ** $p<0.05$, * $p<0.1$

References Appendix

1. Deutsche Gesellschaft für Pädiatrische Infektiologie (DGPI). DGPI-Handbuch Infektionen bei Kindern und Jugendlichen. 7th ed. Stuttgart(Germany): Thieme; 2018.
2. Labenne M, Michaut F, Gouyon B, Ferdynus C, Gouyon JB. A population-based observational study of restrictive guidelines for antibiotic therapy in early-onset neonatal infections. Pediatr Infect Dis J. 2007;26(7):593–9.
3. Grol R, Dalhuijsen J, Thomas S, in't Veld C, Rutten G, Mokkink H. Attributes of clinical guidelines that influence use of guidelines in general practice: observational study. BMJ. 1998;317(7162):858–61.
4. Grilli R, Lomas J. Evaluating the message: the relationship between compliance rate and the subject of a practice guideline. Med Care. 1994;32(3):202–13.
5. American Academy of Pediatrics (AAP). Chlamydia trachomatis. In: Kimberlin DW, Brady MT, Jackson MA, Long SS, editors. Red Book – 2015 Report of the Committee on Infectious Diseases. Elk. Grove Village (IL): Am Acad Pediatrics; 2015. p. 288–94.
6. Shah SS. Mycoplasma pneumoniae. In: Long SS, Pickering LK, Prober CG, editors. Principles and practice of pediatric infectious diseases. 4th ed. Edinburgh: Elsevier Saunders; 2012. p. 993–7.
7. Davey P, Marwick CA, Scott CL, Charani E, McNeil K, Brown E, et al. Interventions to improve antibiotic prescribing practices for hospital inpatients. Cochrane Database Syst Rev. 2017;2, Art. No.: CD003543.
8. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. Behav Res Methods. 2007;39(2):175–91.
9. Falk A, Becker A, Dohmen T, Enke B, Huffman DB, Sunde U. Global evidence on economic preferences. Q J Econ. 2018;133(4):1645–92.
10. Falk A, Becker A, Dohmen T, Huffman DB, Sunde U. The preference survey module: a validated instrument for measuring risk, time, and social preferences. Institute for the Study of Labor (IZA). 2016; IZA Discussion Papers No.9674.

11. Dohmen T, Falk A, Huffman D, Sunde U, Schupp J, Wagner GG. Individual risk attitudes: measurement, determinants, and behavioral consequences. J Eur Econ Assoc. 2011;9(3):522–50.

12. Gosling SD, Rentfrow PJ, Swann Jr WB. A very brief measure of the Big Five personality domains. J Res Pers. 2003;37:(6):504–28.

13. Rammstedt B, John OP. Measuring personality in one minute or less: a 10-item short version of the Big Five inventory in English and German. J Res Pers. 2007;41(1):203–12.

14. Raudenbush SW, Bryk AS. Hierarchical linear models. Applications and data analysis methods. 2nd ed. Thousand Oaks(Calif.): Sage; 2002.