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Knowledge, Social Influences, Perceived Risks and Benefits, and Cultural Values Explain the Public's Decisions Related to Prudent Antibiotic Use

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People should use antibiotics (AB) prudently to mitigate antibiotic resistance (ABR). Previous studies—and, subsequently, interventions—on ABR have focused mainly on improving public awareness and knowledge. We investigated a comprehensive theory-based explanatory model to understand the public's decision making regarding prudent AB use, based on, among others, the theory of planned behavior. In a cross-sectional online survey, the psychological determinants of people's decisions about prudent AB use were examined in a sample of 1,228 Swiss adults. The questionnaire assessed respondents' demand for AB, willingness to adopt measures that prevent the need for AB, perceived risks of ABR, perceived benefits of AB, attitudes and social influences regarding AB, knowledge of AB and ABR, and cultural values. Mokken scale analysis revealed three types of knowledge: knowledge of the functioning of AB, of ABR, and of preventive measures. Structural equation modeling indicated that respondents' demand for AB was mostly predicted by social influences, perceived benefits of AB, and knowledge of AB functioning. Willingness to prevent AB use was mainly related to conservative values, perceived risks of ABR, negative attitudes toward AB, and knowledge of preventive measures. Our study suggests that the provision of information about AB and preventive measures is a first step toward changing people's decisions related to prudent AB use. Future interventions that additionally utilize cultural values to convey important messages and target additional factors, such as social influences, the risks of ABR, and the benefits of cautious AB use, can be more successful in promoting prudent AB use.

KEY WORDS: antibiotic resistance; cultural values; knowledge; risk perception; social influences

1. INTRODUCTION

Antibiotic resistance (ABR) is a serious threat to human health worldwide, as the spread of numerous resistant bacteria is increasing (ECDC, 2019b; WHO, 2014). Part of the problem is caused by the imprudent or injudicious use of antibiotics (AB). Imprudent AB use increases the incidence of ABR through community contact (Opatowski, Opatowski, Vong, & Temime, 2021). Prudent AB use means that AB are used only when they benefit the patient while keeping adverse effects, such as ABR, to a minimum (European Commission, 2017). Interventions have been implemented in many countries to raise awareness of ABR and to inform the public of when AB are effective and when they are not. An example of such an intervention is the World Antibiotic Awareness Week held each year in November (WHO, 2020). Evaluations of such public awareness campaigns have produced mixed results.

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Although several interventions have increased the public's knowledge of AB and awareness of ABR, few have succeeded in promoting prudent AB use (Huttner, Goossens, Verheij, & Harbarth, 2010; King et al., 2016; Price et al., 2018). One explanation for the low effectiveness of these campaigns may be that they have not targeted the relevant psychological determinants of people's decisions about AB use and have consequently failed to employ appropriate intervention strategies (Bartholomew Eldridge et al., 2016; McParland et al., 2018). Therefore, the aim of this study was to conceptualize and test a comprehensive theory-based explanatory model of the public's decision making regarding AB use and ABR mitigation that can be used when developing public interventions to promote prudent AB use.

1.1. Antibiotic use and antibiotic resistance in Switzerland

The prevalence of ABR has also been increasing in Switzerland, as shown by the biannual assessments conducted by the Swiss Federal Office of Public Health and the Federal Food Safety and Veterinary Office (2020). Although the resistance development in some bacteria remained stable (e.g., resistance of *Streptococcus pneumoniae* to penicillin) or even decreased, the resistance of others (e.g., vancomycin-resistant *Enterococcus faecium*) increased significantly in 2019. Fewer AB were consumed in Switzerland in both hospital and ambulant settings (1.6 daily defined doses [DDDs] per 1,000 inhabitants per day and 9.1 DDDs, respectively, FOPH & FSVO, 2020)[1] compared to the median consumption rates in Europe (1.8 DDDs, range: 0.8–2.5 and 18.4 DDDs, range: 8.9–32.4, respectively, ECDC, 2019a). Nevertheless, the vast majority of AB (90%) have steadily been prescribed in ambulant settings in Switzerland over the last years (FOPH & FSVO, 2020). AB consumption in ambulant settings has been higher in the French- and Italian-speaking regions (12.6 DDDs and 11.6 DDDs, respectively, in 2019) than in the German-speaking regions (7.9 DDDs). In 2015, the government implemented a national strategy to mitigate the rise of new ABR and prevent bacterial transmission (The Swiss Federal Council, 2015). Part of this strategy focuses on educating the public and introducing measures to prevent bacterial infections, thereby reducing the need for AB.

1.2. Psychological factors explaining the public's use of AB

Overall, it should be noted that most studies on psychological factors explaining AB use have been conducted in high-income countries, such as the United States (Carter, Sun, & Jump, 2016), Sweden (Ancillotti et al., 2018), and South Korea (Huh et al., 2018). A lot of research attention has been given to people's knowledge of AB, based on the so-called knowledge deficit model (Miller, 1983; Siegrist & Árvai, 2020), which predicts that insufficient knowledge results in imprudent AB use. Many people are unaware that AB are ineffective against illnesses caused by viral infections, such as the common cold (Carter et al., 2016; European Commission, 2016; Grigoryan et al., 2007; Gualano, Gili, Scaioli, Bert, & Siliquini, 2015; Kamata, Tokuda, Gu, Ohmagari, & Yanagihara, 2018). Furthermore, many believe that it is not bacteria but the human body that becomes resistant to AB (Andre, Vernby, Berg, & Lundborg, 2010; Brookes-Howell et al., 2012; McCullough, Parekh, Rathbone, Del Mar, & Hoffmann, 2016; Norris et al., 2013).

Compared to citizens of other European countries, the Swiss public has been quite knowledgeable about the need to use AB carefully and the fact that AB are ineffective against seasonal influenza and colds (Demo SCOPE AG, 2020; European Commission, 2018). Still, about 40% of Swiss people are unaware that AB cannot kill viruses (Demo SCOPE AG, 2020). Moreover, the Swiss public's knowledge has not increased since the first survey in 2016 and has been assessed using only four questions.

Studies on other health and environmental issues, such as vaccination, climate change, and carbon capture and storage, have shown that knowledge predicts decision making if it is assessed using a validated scale and is relevant to the decision at hand (L'Orange Seigo, Arvai, Dohle, & Siegrist, 2014; Shi, Visschers, & Siegrist, 2015; van der Linden, 2015; Zingg & Siegrist, 2012). Moreover, people often distinguish between different types of knowledge related to the same issue and are relevant to different types of decisions. Shi et al. (2015), for example, showed that more knowledge related to

[1] Daily defined dose (DDD) is the average dose per day for a drug that is used to treat an adult for the drug's main indication (WHO Collaborating Centre for Drug Statistics Methodology, 2018). It is a statistical value and is not automatically the same as the prescribed daily dose, as the latter depends on the patients' characteristics. The DDD facilitates comparisons of drug usage at different time points and in different environments, as well as between drugs.

climate-friendly behavior is associated with greater willingness to adopt such behavior, while more knowledge of the causes of climate change is associated with greater acceptance of climate mitigation policies.

Knowledge is not the only factor explaining health-related behavior, such as AB use, especially if people do not have access to information or the motivation to use to their knowledge (Bubela et al., 2009; Visschers & Siegrist, 2018). The theory of planned behavior (TPB) postulates that attitudes, subjective norms, and perceived behavioral control (PBC) shape people's behavioral intentions, which in turn determine their behavior (Ajzen, 1991; Fishbein & Ajzen, 1975). Attitudes are general favorability evaluations of behavior, for example, appraising AB as bad for the body. Subjective norms involve opinions about and responses of important others regarding a behavior, for example, experienced pressure from family members and peers to use AB carefully. PBC describes an individual's estimated control over behavior. People who experience more control because they believe that they can execute the behavior and cope with possible barriers are more likely to display that behavior. Attitudes and PBC are founded on knowledge—that is, on beliefs about the attributes and consequences of behavior and on resources and opportunities to execute it (Ajzen, 1991). Using an Australian sample, Byrne et al. (2019) were the first to show that the TPB is well suited to explain self-reported AB use. Moreover, according to a systematic review, people assume that they have low PBC to reduce ABR because they believe that clinicians and other people are responsible (McCullough et al., 2016).

Perceived risks and benefits are other important factors that may explain people's use of AB. Following experts' cost-benefit analysis, laypeople have been assumed to conduct a risk-benefit analysis to decide on the acceptability of technological advancements, such as AB (Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978). Technologies and behaviors that are perceived as riskier are associated with lower acceptance, whereas those with greater perceived benefits are more acceptable. Hence, perceptions of risks and benefits are beliefs that feed decision making about behavior. Studies on the perceptions of AB and ABR have shown that most people perceive ABR as a serious threat to society (Carter et al., 2016; Huh et al., 2018; van Rijn, Haverkate, Achterberg, & Timen, 2019). However, people perceive a low personal risk posed by ABR (Ancillotti et al., 2018; Lechner, Freivogel, Stärk, & Visschers, 2020; McCullough et al., 2016) and simultaneously great benefits of using AB prudently to preserve them for the future (Ancillotti et al., 2018). Higher perceived risks of ABR have been found to be related to a greater intention to use AB prudently and a lower AB use among pig farmers (Visschers et al., 2016; Visschers et al., 2016). The perception of risk has been shown to be predicted by knowledge, implying an indirect relationship between knowledge and behavioral intention (Visschers & Siegrist, 2018).

Another determinant of behavior is people's cultural values, which are the guiding principles of decisions and behavior (Schwartz, 1992). Cultural values are formed early in life and therefore provide stable foundations that affect decisions and behavior. People use their values as criteria in their evaluation of an object (e.g., an event or behavior), as well as to justify their decisions or behavior (Schwartz, 1992). Accordingly, the cultural theory of risk perception postulates that people rely on their cultural values to determine their perceived risks (Douglas & Wildavsky, 1982). In the case of AB use, stronger altruistic values (i.e., helping others) may lead to the perception that ABR poses a high risk for society and the decision to use AB cautiously. Ancillotti et al. (2018) found that altruistic values indeed motivate people to use AB judiciously, whereas egoistic values (i.e., protecting oneself) increase the desire to use AB. Based on a review of the literature and the various taxonomies of cultural values, the following values may be central to decisions about prudent AB use: individualism and self-interest (i.e., egoism in the taxonomy by Stern, Dietz, & Guagnano, 1998), concern for others (i.e. altruism), valuing unity with nature (i.e., biospherism), and respecting tradition and security (i.e., conservatism, Ancillotti et al., 2018; Stern et al., 1998; van Rijn et al., 2019).

2. Aims and hypotheses

Based on the TPB (Ajzen, 1991), the knowledge deficit model (Miller, 1983), the cultural theory of risk perception (Douglas & Wildavsky, 1982), and expressed risk-benefit analysis (Fischhoff et al., 1978), we developed a comprehensive explanatory model of the public's decisions about prudent AB use (Fig. 1). Interventions that focus on and address the constructs in our explanatory model—that is, knowledge, attitudes, subjective norms, PBC, perceived risks and benefits, and cultural values—are most likely to effectively change decisions regarding prudent AB use.

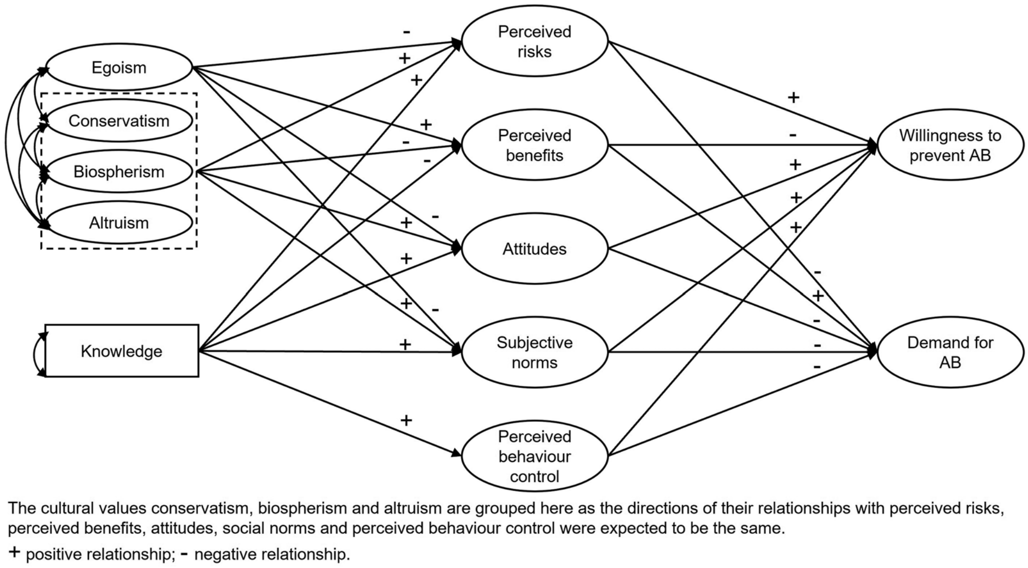

Fig 1. The hypothesized model explaining people's willingness to prevent AB use and demand for AB

Two types of decisions are relevant to prudent AB use: (1) regarding the demand for AB and (2) regarding the willingness to adopt measures that prevent the need for AB. The model depicted in Fig. 1 and the findings of previous studies detailed in Section 1.2 resulted in the following four hypotheses:

(1) The TPB constructs of attitudes against AB, subjective norms regarding prudent AB use, and PBC to use AB prudently are positively associated with the willingness to adopt measures that prevent AB use and negatively associated with the demand for AB.
(2) Higher perceived risks of ABR are related to greater willingness to adopt measures that prevent AB use and lower demand for AB, whereas higher perceived benefits of AB are associated with reduced willingness to adopt measures that prevent AB use and higher demand for AB.
(3) Overall, knowledge of AB and ABR is negatively associated with perceived benefits of AB and positively associated with perceived risks of ABR, negative attitudes toward AB, and PBC. Hence, knowledge is indirectly related to the willingness to adopt measures that prevent AB use and the demand for AB. If knowledge of AB and ABR is divided into subscales, these subscales will have different relationships with perceived risks of ABR, perceived benefits of AB, attitudes against AB, and PBC.
(4) Cultural values are also indirect predictors of the demand for AB and the willingness to adopt measures that prevent AB use through the perceived benefits of AB, perceived risks of ABR, attitudes against AB, and subjective norms favoring prudent AB use. We predict the following:

    a. Stronger egoistic values are related to higher perceived benefits of AB, lower perceived risks of ABR, weaker negative attitudes toward AB, and weaker subjective norms favoring prudent AB use. The reasoning is that the self is more important to individuals with strong egoistic values, and AB provide great benefits to individuals, whereas the burden of ABR concerns society.
    b. Stronger altruistic, biospheric, and conservative values are associated with lower perceived benefits of AB, higher perceived risks of ABR, stronger negative attitudes toward AB, and stronger subjective norms in favor of using AB prudently. The reasoning is that individuals who care about the well-being of others and the natural environment and value traditions and conventions will critically evaluate the effects of prescription drugs on humans and the environment

and listen to the critical opinions of important others who favor prudent AB use.

3. METHODS

3.1. Procedure and sample

Between October and November 2017, an online survey was conducted using a random sample drawn from the German- and French-speaking regions of Switzerland. Before starting the questionnaire, the respondents were informed that the study was about medicines and that their data would remain anonymous, be treated confidentially, and be used only for research purposes. They were also informed of their right to withdraw at any time. The questionnaire took an average of 12 minutes to complete. Respondents who completed the questionnaire received a small remuneration (0.75 euros).

The respondents were recruited through an online access panel of a commercial online marketing and research company (Respondi AG). Quota sampling by language region, gender, age group, and education level was applied to ensure that the sample was representative of the populations in both language regions (see Supporting Information, Table A1). After data cleaning, the final sample consisted of 1,228 respondents, who represented the Swiss population well in terms of distribution in the two language regions and average age (see Supporting Information, Table A1). The sample included slightly more females and individuals with a medium education level than the overall Swiss population (Swiss Statistics, 2020a, 2020b).

3.2. Questionnaire

Based on our literature review, semi-structured in-depth interviews were conducted to examine whether the identified beliefs, misbeliefs, attitudes, and other psychological variables related to AB and ABR were relevant to the Swiss context and should therefore be investigated in the questionnaire. For these interviews, seven German-speaking and three French-speaking laypeople living in Switzerland were recruited through advertisements on online platforms for event announcements, in supermarkets, and in libraries. The questionnaire was then developed in German. A professional translator translated the questionnaire into French, and this version was then checked by a native French speaker within the research team.

The questionnaire began with demographic questions for quota sampling purposes. Next, one item enquired about *recent AB use*: "Have you used an antibiotic during the last 12 months—for example, in tablet, powder, syrup, or cream form?" The respondents could choose *yes*, *no*, or *I don't know*.

The respondents' *demand for AB* was then assessed using three items (Table I). Subsequently, respondents' knowledge of AB and ABR was measured using 16 statements with *true*, *false*, or *I don't know* as possible responses. The statements covered the utility and functioning of AB, the meaning and consequences of ABR, and preventive measures against the need for AB as well against the spread of ABR. Half of the 16 statements were incorrect, and the other half were correct. Examples of the knowledge items are presented in Table II. Experts in human and veterinary medicine checked the items for correctness.

The questionnaire continued with items assessing the respondents' *perceived benefits* of AB, *perceived risks* of ABR, and *negative attitudes toward AB*. Two items investigated the respondents' *PBC* to use AB more prudently. Another two items examined the *subjective norms* related to the prudent use of AB. Three items explored the respondents' willingness adopt measures that prevent the need for AB (*willingness to prevent AB use*). The demand for AB, perceived benefits of AB, perceived risks of ABR, attitudes toward AB, PBC, subjective norms, and willingness to prevent AB use were assessed using 6-point Likert scales, with higher values corresponding to stronger agreement with the statements. All items are presented in Table I.

The respondents' cultural values of *egoism*, *altruism*, *biospherism*, and *conservatism* were measured using four subscales of the inventory of values (Stern et al., 1998). Each cultural value was assessed using three items (i.e., 12 items in total; Table I) and 9-point scales, with higher values corresponding to greater importance.

3.3. Data analysis

Unless stated otherwise, the statistical analyses were performed using IBM SPSS Statistics version 25 (IBM Corp., 2018). The raw survey data ($N = 1{,}890$) were cleaned as follows. First, respondents who did not answer the question about recent AB use were excluded. Second, those who had more than 10%

Table I. Decisions and Perceptions Regarding Prudent AB Use: Item Descriptives, Standardized Factor Loadings (λ) from the Confirmatory Factor Analysis (CFA) and Latent Factor Descriptives

Scales and Items	*M*	*SD*	λ
Demand for AB ($M = 2.12$, $SD = 1.11$)			
1. When I have a cold and feel bad enough to consult a medical doctor, I expect to receive an antibiotic.	1.91	1.32	0.82
2. An antibiotic treatment is the best solution when I have a cold and an important event/meeting is imminent.	2.06	1.36	0.83
3. When I'm ill, I want to have a medicine that quickly cures me, regardless of its negative consequences, such as antibiotic resistance.	2.39	1.40	0.53
Willingness to prevent AB use ($M = 4.41$, $SD = 1.00$)			
4. The next time my physician prescribes antibiotics, I will ask critical questions.	4.04	1.51	0.51
5. I plan to protect myself and my family more against bacterial infections (e.g., more hygiene in the kitchen, washing hands after a hospital visit).	4.36	1.41	0.64
6. Strict personal hygiene in risky situations (e.g., during a hospital visit or when travelling in risky countries) considerably reduces the risk of bacterial infections.	4.83	1.23	0.49
Perceived benefits of AB ($M = 3.93$, $SD = 1.09$)			
7. Antibiotics are easy to apply.	4.46	1.45	0.40
8. When my physician prescribes antibiotics, it confirms that I'm truly ill.	3.74	1.52	0.73
9. Thanks to antibiotics, one gets better quickly.	3.59	1.33	0.71
10. *Perceived risks of ABR* ($M = 4.61$, $SD = 1.06$)			
11. Antibiotic resistance is very dangerous to human health.	4.73	1.36	0.81
12. The problem of antibiotic resistance is extremely exaggerated.[a]	4.48	1.31	0.51
13. There are serious consequences for humans when only a few antibiotics are still effective.	4.63	1.39	0.66
Negative attitudes toward AB ($M = 3.88$, $SD = 1.14$)			
14. Antibiotics have serious and unpleasant side effects.	4.07	1.33	0.63
15. Antibiotics are poisonous to the body.	3.70	1.39	0.66
Social influences ($M = 2.35$, $SD = 1.10$)			
16. It is useless to reduce my antibiotic usage if other people in Switzerland don't attempt to do so as well.	2.15	1.40	0.56
17. I do not need to use antibiotics more cautiously because the pharmaceutical industry can always develop new antibiotics.	1.95	1.26	0.71
18. The people around me see antibiotics as an ordinary, unproblematic medicine.	2.63	1.46	0.40
Egoism ($M = 3.21$, $SD = 1.53$)			
19. Wealth: material possessions, money.[b]	3.19	1.92	0.47
20. Authority: the right to lead or command.[b]	3.33	2.08	0.71
21. Influence: having an impact on people and events.[b]	3.13	1.93	0.70
Altruism ($M = 5.55$, $SD = 1.26$)			
22. Equality: equal opportunity for all.[b]	5.58	1.51	0.73
23. Social justice: correcting injustice, care for the weak.[b]	5.50	1.52	0.79
24. Helpful: working for the welfare of others.[b]	5.56	1.41	0.76

(*Continued*)

Table I. (Continued)

Scales and Items	*M*	*SD*	λ
Biospherism ($M = 5.53$, $SD = 1.36$)			
25. Respecting the earth: harmony with other species.[b]	5.72	1.47	0.86
26. Unity with nature: fitting into nature.[b]	5.06	1.72	0.76
27. Protecting the environment: preserving nature.[b]	5.80	1.40	0.86
Conservatism ($M = 5.60$, $SD = 1.09$)			
28. Honouring of parents and elders: showing respect.[b]	5.67	1.43	0.71
29. Family security: safety for loved ones.[b]	6.15	1.23	0.70
30. Self-discipline: self-restraint, resistance to temptation.[b]	4.98	1.56	0.51

All items assessed on 6-point Likert scales; higher values indicating more agreement with the statement.
[a]Responses to the item were reverse coded before the analyses.
[b]Respondents were asked to evaluate the importance of each value "as a guiding principle in your live" on a 9-point scale ranging from -1 (opposing to my values), 0 (not important) to 7 (extremely important).

missing values for the questionnaire items were excluded. Third, respondents who took less than half the median time to complete the questionnaire were excluded to eliminate random and thus unserious responses. Consequently, respondents who completed the German and French questionnaires in less than 307 s ($Mdn = 614$ s) and 322.75 s ($Mdn = 645.5$ s), respectively, were excluded. After data cleaning, a sample of 1,228 respondents remained.

The knowledge items were cleaned and analyzed as follows. The responses to incorrect knowledge items were reverse-coded. The *I don't know* responses were recoded as incorrect answers, resulting in binary data where 1 = *correct* and 0 = *incorrect/I don't know*. Next, Mokken scale analysis (MSA) was performed to investigate the structural validity of the set of knowledge items and to identify possible subscales (Dima, 2018; Mokken & Lewis, 1982). Unlike, for example, reliability analysis using Cronbach's α, MSA considers the characteristics of both the items (e.g., their level of difficulty) and the respondents on a latent construct: in this case, knowledge. It thereby assumes the existence of so-called double monotonicity: (1) respondents are ordered similarly on all items, that is, a monotonically nondecreasing item response function, and (2) the item ordering should be the same for each respondent, meaning that the difficulty ranking of the items is the same for all respondents (Sijtsma & van der Ark, 2017). Three statistical criteria should be considered when conducting an MSA. First, the degree to which the items of a scale can order the respondents consistently is expressed using the Loevinger's scalability coefficient or H. If $H < 0.3$, the items are unscalable; $0.3 \leq H < 0.4$ is a weak scale; $0.4 \leq H < 0.5$ is a medium scale, and $H \geq 0.5$ is a strong scale (Sijtsma & van der Ark, 2017). Second, an item's scalability is expressed by H_i and should be ≥ 0.3. Third, the reliability of a scale of items should also be considered. In an MSA, ρ (also known as the Mokken scale statistic) is used as an unbiased alternative to the Cronbach's α. The MSA was performed in R using the "mokken" package (van der Ark, 2017). Based on the identified scale or subscales, the sum score of the items belonging to each (sub)scale was calculated and used in the subsequent analyses.

We conducted an exploratory factor analysis (EFA) with varimax rotation with all items related to decisions concerning prudent AB use, perceptions of AB and ABR, and predictors from the TPB. The cultural values were not included in the EFA since they came from established scales (de Groot & Steg, 2008; Shi, Visschers, Siegrist, & Arvai, 2016). The internal reliability of the identified scales was assessed using Cronbach's α. Descriptive statistics were then used to describe the scales identified using MSA and EFA.

Confirmatory factor analysis (CFA) was performed as preparation for the structural equation model (SEM) to test our hypotheses (Fig. 1). SEM is based on a combination of CFA to validate the measurement of the latent constructs and regression analysis to investigate the paths between the

Table II. Items of the Three Knowledge Subscales and their Response Distributions, Scalabilities (H_i) and Scale Statistics

	Response Distribution			
Subscales and Items	% correct	% incorrect	% I don't know	H_i
Knowledge of AB functioning: $H = 0.44$, $\rho = 0.48$, $M_{\%\text{correct}} = 48\%$, $Mdn = 67\%$				
1. If you feel better, you can reduce your antibiotic dose.[a]	75	14	11	0.43
2. Antibiotics are effective against viruses (e.g., the flu or a cold).[a]	57	28	16	0.45
3. If the human body gets too accustomed to antibiotics, it will become resistant against them.[a]	12	79	9	0.42
Knowledge of ABR: $H = 0.40$, $\rho = 0.61$, $M_{\%\text{correct}} = 64\%$, $Mdn = 75\%$				
4. Antibiotic resistance means that bacteria are able to resist the effects of various antibiotics.	80	3	18	0.45
5. Infections with multi-resistant bacteria are difficult to treat because only a few antibiotics are effective against them.	71	6	23	0.42
6. Antibiotic resistance can result from mutations (i.e., spontaneous changes) in the genes of the bacteria.	59	6	35	0.38
7. Only the imprudent use of antibiotics (e.g., a false diagnosis or inappropriate dosage) in animal husbandry is responsible for antibiotic resistance in humans.[a]	45	20	34	0.36
Knowledge of preventive measures: $H = 0.34$, $\rho = 0.34$, $M_{\%\text{correct}} = 50\%$, $Mdn = 0.50\%$				
8. Personal hygiene (e.g., handwashing) is an effective measure against the spread and transmission of antibiotic resistance.	62	20	19	0.34
9. Vaccinations against viruses (e.g., against the seasonal flu) can significantly reduce the need for antibiotics among humans.	38	31	31	0.34

H = Loevinger's scalability coefficient; ρ = reliability coefficient; H_i = item's scalability coefficient.
[a]The statement is false; its responses were therefore reverse coded before the analyses.

latent constructs. The parameters were estimated using the maximum likelihood method in IBM SPSS Amos version 27 (IBM Corp., 2020). Respondents with missing values in any variables analyzed in the CFA and SEM were deleted beforehand, resulting in a sample of 1,226 respondents.

First, the measurement model was determined using CFA of all the items that loaded on one of the factors identified in the EFA, as well as the cultural value items (see Table I). Next, the structural model hypothesized in Fig. 1 was fitted to the data using SEM—that is, besides the manifest and latent variables tested in the CFA, the knowledge scale (or multiple subscales) identified by the MSA was (or were) included as a manifest variable (or manifest variables), one sum score per (sub)scale. Among latent constructs that were estimated by only two items, the parameters for error values of variables were constrained to require only one error value to be estimated per construct.

The chi-square test easily shows significant results for large samples and is therefore insufficient for assessing the goodness-of-fit in CFA or SEM. We therefore evaluated the comparative fit index (CFI), standardized root mean square residual (SRMR), and root mean square error of approximation (RMSEA) as goodness-of-fit criteria for the models (Hu & Bentler, 1999; Iacobucci, 2010). The values of all three statistics range from 0 to 1. More specifically, for a model that fits the data well, the SRMR is ideally close to or below 0.09, the RMSEA is equal to or lower than 0.05, and the CFI is close to 0.95 or higher.

For an item to be accepted in the factor structure, its latent factor loading should be substantial ($\lambda > 0.40$) and significant, meaning that its critical ratio (CR)—that is, the item's estimate divided by its standard error—should be greater than 1.96 ($p < 0.05$) (Byrne, 2001). Nonsignificant paths were removed, and SEM was repeated on the remaining model. For *post hoc* model improvements, we considered the modification indices (MIs) among error, manifest, and latent variables and their respective expected parameter change (EPC) in combination with the model's theoretical background (Iacobucci, 2010). After one or more paths were added, the chi-square difference test was used to assess the improvement in the new model, and we checked whether all paths remained significant.

4. RESULTS

4.1. Knowledge scales

The MSA revealed that of the initial 16 items, nine could be categorized into three subscales. We labeled the first subscale *knowledge of the functioning of AB*. It included three items and had moderate scalability ($H = 0.44$, $\rho = 0.48$, Table II). On average, the respondents answered almost half (48%) of the items about the functioning and utility of AB correctly. More than half (57%) of the respondents knew that AB are not effective against viruses (Table II, item 2). Few (12%) respondents knew that resistance does not mean that the body develops tolerance to an AB (Table II, item 3). The second subscale was labeled *knowledge of ABR*. It included four items and had moderate scalability ($H = 0.40$, $\rho = 0.61$; Table II). Overall, the respondents answered 61% of these items correctly. Most (80%) respondents knew the correct definition of ABR (Table II, item 4). However, 55% incorrectly believed or were uncertain about the statement that AB use in animal husbandry is responsible for ABR in humans (Table II, item 7). The third subscale was labeled *knowledge of preventive measures* and consisted of two items. Because of the small number of items, it had relatively low scalability ($H = 0.34$, $\rho = 0.35$, Table II). On average, the respondents answered 50% of the items correctly. Few (38%) respondents knew that vaccines against viruses can also reduce the need for AB to treat bacterial infections (Table II, item 9).

4.2. Scales for assessing decisions and perceptions related to prudent AB use

The results of the EFA with varimax rotation largely revealed the scales that we had in mind when developing the questionnaire: demand for AB, willingness to prevent AB use, perceived risks of ABR, perceived benefits of AB, and negative attitudes toward AB (Supporting Information, Table A2). Surprisingly, the subjective norms and PBC items loaded on the same factor. We labeled the scale *social influences* against prudent AB use because all four items described social and external influences (e.g., from the pharmaceutical industry) that disfavored the prudent use of AB. However, item 17 was excluded from the scale because its factor loading was < 0.30, and the internal reliability analysis results showed that Cronbach's α would be higher if item 17 were removed (Supporting Information, Table A2). Item 3 had a higher loading on the first factor (social influences) than on the fourth factor (demand for AB). However, since content-wise it had a better fit to the latter, it was included in that factor.

To conclude, the EFA identified six scales: demand for AB, willingness to prevent AB use, perceived benefits of AB, perceived risks of ABR, negative attitudes toward AB, and social influences against prudent AB use. The correlations between the six scales were in the expected directions (see Supporting Information, Table A3).

4.3. Descriptive statistics of decisions and perceptions related to prudent AB use

More than a quarter of the respondents (27%, $n = 336$) reported having used an AB during the previous 12 months, 71% ($n = 875$) had not taken AB during that time, and 1% ($n = 17$) were unsure. The respondents reported a relatively low demand for AB ($M = 2.12$, $SD = 1.11$, $Mdn = 1.67$ on 6-point Likert scales) and were quite willing to adopt preventive measures ($M = 4.41$, $SD = 1.00$, $Mdn = 4.33$).

The perceived risks of ABR were rated as relatively high on average ($M = 4.61$, $SD = 1.06$, $Mdn = 4.67$). The respondents indicated moderately negative attitudes toward AB ($M = 3.88$, $SD = 1.14$, $Mdn = 4.00$) and moderate perceived benefits of AB ($M = 3.93$, $SD = 1.09$, $Mdn = 4.00$). Moreover, they reported rather strong social influences against prudent AB use ($M = 2.35$, $SD = 1.10$, $Mdn = 2.33$).

4.4. Model explaining the demand for AB and the willingness to prevent AB use

The CFA tested the items per latent variable as identified in the EFA, as well as the cultural values. The resulting model had an acceptable fit, $\chi^2(333) =$

Table III. Model Statistics from the Structural Equation Models Explaining Willingness to Prevent AB Use and Demand for AB

Nr.	χ^2	*df*	$\Delta\chi^2$	*df*	CFI	RMSEA	SRMR	Model Changes Compared to Previous Model
1.	2073.66***	421	*na*		0.859	0.057	0.075	*na*
2.	2099.59***	437	*na*		0.858	0.056	0.076	Deleted: paths from altruism (except for altruism → biopherism, altruism → conser-vatism); biospherism → egoism; conservatism → negative attitudes, perceived benefits, perceived risks, social influences; knowledge AB functioning → negative attitudes; knowledge ABR → perceived benefits, negative attitudes; knowledge preventive measures → negative attitudes, perceived risks; social influences → WTP AB use[a]
3.	2099.63***	438	*na*		0.858	0.056	0.076	Deleted: biospherism > perceived benefits
4.	1926.10***	435	173.53***	3	0.873	0.053	0.067	Added: knowledge AB functioning → social influences; knowledge ABR → social influences; perceived risks → social influences
5.	1926.10***	436	*na*		0.873	0.053	0.067	Deleted: perceived risks → demand for AB
6.	1859.22***	435	66.88***	1	0.879	0.052	0.067	Added: knowledge preventive measures → WTP AB use
7.	1859.40***	436	*na*		0.879	0.052	0.067	Deleted: perceived benefits → WTP AB use
8.	1769.12***	435	90.28***	1	0.886	0.050	0.062	Added: conservatism → WTP AB use
9.	1771.90***	436	*na*		0.886	0.050	0.062	Deleted: egoism → attitude
10.	1757.03***	435	14.86***	1	0.887	0.050	0.062	Added: knowledge AB functioning → demand for AB
11.	1742.94***	434	14.09***	1	0.888	0.050	0.061	Added: perceived benefits → social influences
12.	1732.76***	433	10.18***	1	0.889	0.050	0.060	Added: perceived benefits → negative attitudes

***$p < 0.001$.
[a]WTP AB use = willingness to prevent AB use.

1587.27, $p < 0.0001$, CFI = 0.885, RMSEA = 0.055, SRMR = 0.059. According to the MIs, the inclusion of five relationships between seven error terms would significantly improve the model fit. Hence, the error term of the third item assessing the demand for AB was connected with the error terms of the three items measuring social influences, and the error term of the last conservatism item was connected with the error terms of the last two egoism items. The addition of these relationships indeed improved the model fit significantly, $\chi^2(328) = 1403.99$, $p < 0.0001$, $\Delta\chi^2(5) = 183.28$, $p < 0.0001$, CFI = 0.902, RMSEA = 0.052, SRMR = 0.057. All standardized factor loadings of the final measurement model were significant and large (λs > 0.40, CRs > 10.16, ps < 0.0001; Table I).

The SEM that included all manifest variables, latent variables, predicted relationships shown in Fig. 1, and relationships between the error terms resulted in a model fit that could do with improving, $\chi^2(421) = 2073.66$, $p < 0.0001$, CFI = 0.859, RMSEA = 0.057, SRMR = 0.075 (Table III, Model 1). Seventeen nonsignificant paths were deleted (Table III, Models 2 and 3). Next, we considered *post hoc* model modifications suggested by the MIs. The MIs indicated that adding paths from knowledge of AB functioning, knowledge of ABR, and perceived risks of ABR to social influences would significantly improve the model fit, which was theoretically justifiable since better knowledge of how AB work and of the consequences of ABR may prompt people to examine how their social environment acts and thinks about AB (Table III, Model 4). Similarly, we added paths between knowledge of preventive measures and willingness to prevent AB use (Table III, Model 6) and between conservatism and willingness to prevent AB use (Table III, Model 8). It seemed meaningful to add the former path because knowing more about effective preventive measures may directly increase the desire to implement them. Regarding the latter path, having conservative values may be directly related to traditional and conventional practices, such as hygiene measures and prudent medication use. The path between knowledge of AB functioning and demand for AB was also added (Table III, Model 10), since knowledge of how and when AB work determines whether people consider an AB for their health complaints and thus their demand for AB. Lastly, the paths from perceived benefits of AB to social influences and negative attitudes toward AB

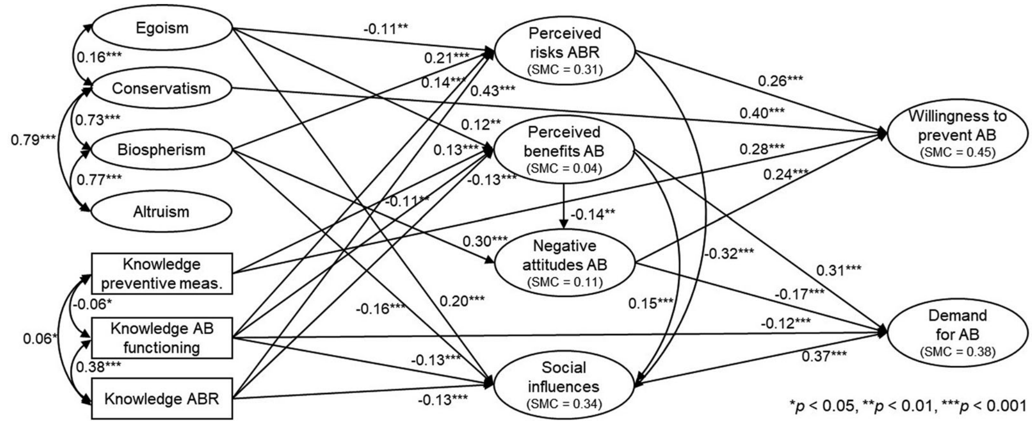

Fig 2. Results from the structural equation modelling (SEM) procedure for the final model predicting the willingness to prevent AB use and the demand for AB; values indicate standardized regression weights and standardized multiple correlations (SMCs)

Table IV. Standardized Direct, Indirect, and Total Effects of the Model Variables on Willingness to Prevent AB Use and Demand for AB

	Willingness to Prevent AB use			Demand for AB		
	Direct Effects	Indirect Effects	Total Effects	Direct Effects	Indirect Effects	Total Effects
Perceived risks ABR	0.26	0.00	0.26	0.00	−0.12	−0.12
Perceived benefits AB	0.00	−0.03	−0.03	0.31	0.08	0.39
Negative attitudes AB	0.24	0.00	0.24	−0.17	0.00	−0.17
Social influences	0.00	0.00	0.00	0.37	0.00	0.37
Egoism	0.00	−0.03	−0.03	0.00	0.13	0.13
Conservatism	0.40	0.00	0.40	0.00	0.00	0.00
Biospherism	0.00	0.13	0.13	0.00	−0.13	−0.13
Altruism	0.00	0.00	0.00	0.00	0.00	0.00
Knowledge preventive measures	0.28	0.00	0.27	0.00	0.05	0.05
Knowledge AB functioning	0.00	0.04	0.04	−0.12	−0.11	−0.22
Knowledge ABR	0.00	0.11	0.11	0.00	−0.10	−0.10

were added based on high MIs, since the TPB postulates that perceptions, attitudes, and social influences are interrelated (Ajzen, 1991). The addition of these paths indeed improved the model's fit (Table III, Models 11 and 12). The final model had a good fit to the data, $\chi^2(433) = 1732.76$, $p < 0.0001$, CFI = 0.889, RMSEA = 0.050, SRMR = 0.060. The model explained 44% of the variance (standardized multiple correlation [SMC]) in the willingness to prevent AB use and 38% of the variance in the demand for AB.

The willingness to prevent AB use was to a great extent explained by conservative values (Fig. 2). Furthermore, negative attitudes toward AB, perceived risks of ABR, and knowledge of preventive measures had significant direct associations with the willingness to prevent AB use. Specifically, stronger conservative values, more negative attitudes toward AB, higher perceived risks of ABR, and more knowledge of preventive measures increased the willingness to prevent AB use. Knowledge of AB functioning, knowledge of ABR, and biospherism had positive indirect effects on the willingness to prevent AB use, mainly through perceived risks of ABR and perceived benefits of AB (Fig. 2 and Table IV). Egoism and perceived benefits of AB had negative indirect relationships with the willingness to prevent AB use, mainly through perceived risks of ABR and negative attitudes toward AB. Altruism and social influences were not associated with the willingness to prevent AB use.

The demand for AB was to a great extent predicted by social influences and the perceived benefits of AB (Fig. 2). Knowledge of AB functioning and negative attitudes toward AB were also significantly related to the demand for AB. Specifically, stronger social influences against prudent AB use and greater perceived benefits of AB increased the demand for AB, whereas more knowledge of AB functioning and stronger negative attitudes toward AB reduced it. Further, the demand for AB was indirectly increased by stronger egoistic values and more knowledge of preventive measures and indirectly reduced by stronger biospheric values and higher perceived risks of ABR (Table IV). Knowledge of AB functioning and the perceived benefits of AB had both direct and indirect effects on the demand for AB, whereas altruism showed no association.

5. DISCUSSION

5.1. Explanatory model of decisions related to prudent AB use

In this cross-sectional online survey, we examined the Swiss public's perceptions and decision making related to AB and ABR. To explain decisions related to prudent AB use, we tested a comprehensive model comprising the TPB, perceived risks and benefits, knowledge, and cultural values. We hypothesized that the TPB constructs (attitudes, subjective norms, and PBC) would be positively related to people's willingness to prevent AB use and negatively related to their demand for AB (*Hypothesis 1*). Our findings confirmed this hypothesis only partly because our questionnaire items could not be categorized into a subjective norms factor and a PBC factor. Therefore, greater willingness to prevent AB use was associated only with stronger negative attitudes toward AB. Moreover, the demand for AB was negatively related to negative attitudes toward AB and positively related to social influences against prudent AB use (i.e., a combination of subjective norms and PBC). Social influences appeared to be a strong predictor of the demand for AB. The impact of the social environment on decisions related to prudent AB use has rarely been investigated. This may be because the TPB has only recently been used in research on AB use among laypeople and on AB prescription behavior among general practitioners (Byrne et al., 2019; Walker, Grimshaw, & Armstrong, 2001). Moreover, most previous studies have been based on little theory and have mainly focused on knowledge and attitudes (Brookes-Howell et al., 2012; Gualano et al., 2015; McCullough et al., 2016).

Hypothesis 2 was also partly confirmed by our results. Higher perceived risks of ABR were positively associated with greater willingness to prevent AB use but were not related to the demand for AB, and higher perceived benefits of AB were associated with a higher demand for AB, but not to the willingness to prevent AB use. Further, the findings revealed that respondents had ambiguous attitudes toward AB. They appreciated the benefits of AB (e.g., efficient and effective cure) but also expressed concerns about their side effects and about ABR.

Thus, our study confirmed that decisions related to prudent AB use can be explained by TPB constructs (Byrne et al., 2019). Perceived benefits and risks provide an added value, beyond attitudes, to the explanation of relevant decisions and may thus be considered specific beliefs about the consequences of AB use and ABR, which shape attitudes (Ajzen, 1991).

We also predicted that knowledge is negatively associated with the perceived benefits of AB and positively associated with the perceived risks of ABR and negative attitudes toward AB and is therefore indirectly related to the willingness to prevent AB use and the demand for AB (*Hypothesis 3*). Our findings partly confirmed this hypothesis. More knowledge of AB functioning and ABR indeed increased the perceived risks of ABR and reduced the perceived benefits of AB, whereas knowledge of preventive measures increased the perceived benefits of AB. The latter association may seem counterintuitive, since knowing which measures obviate the need for AB (i.e., vaccinations and hand hygiene) and how elaborate they are may make people appreciate the ease of using AB. Although knowledge was not related to negative attitudes toward AB, knowledge of AB functioning and ABR was additionally found to be associated with social influences, apparently because it makes people realize that the social environment does not promote prudent AB use and should therefore not be relied upon.

Our findings also confirmed that knowledge was mostly indirectly related to the willingness to prevent AB use and the demand for AB (also *Hypothesis 3*). However, knowledge was also directly associated with these two decisions. More knowledge of preventive measures directly resulted in greater willingness to prevent AB use, while more knowledge of the functioning of AB decreased the demand for AB both directly and indirectly (mainly through social influences). The immediate impact on decisions related to prudent AB use may be because both knowledge subscales included rather practical and behavior-related issues (e.g., knowledge of AB functioning, item 1: 'If you feel better, you can reduce your AB doses'). Thus, to decide whether an AB treatment is worth demanding, people mainly apply their understanding of the functioning of AB. In contrast, to determine their willingness to take measures to avoid the need for AB, they rely on their knowledge of such measures without further ado.

Thus, overall, our findings are in line with the knowledge deficit model (Miller, 1983), since more knowledge of AB functioning, ABR, and preventive measures and ABR were associated with decisions resulting in prudent AB use. However, a note of caution is in order here, as more knowledge of preventive measures was associated with higher perceived benefits and thus, indirectly and minimally, to a higher demand for AB. Since different types of knowledge appeared to be related to the different decisions about prudent AB use and their determinants, it seems worthwhile to apply a multidimensional scale of knowledge of AB, ABR, and preventive behavior. A multidimensional scale can identify the types of information that people need for the different types of decisions related to prudent AB use.

In *Hypothesis 4*, we expected that cultural values would be important indirect determinants of people's demand for AB and their willingness to prevent AB use. The results indeed indicated that stronger egoism and self-interest predispose people to focus on the personal health benefits of AB, to rely on social influences, and to disregard the risks of ABR. Greater consideration of the biosphere and naturalness increased awareness of the risks of ABR and negative attitudes toward AB and minimized social influences. Cultural values thus had mainly indirect associations with decisions related to prudent AB use through the perception and attitude variables. Simultaneously, stronger conservative values directly increased the willingness to prevent AB use, indicating that the guiding principle of appreciating traditions, containment, and security directly motivates people to take preventive measures without first influencing their attitudes toward or perceptions of the issue. Our results are partly consistent with the findings of a qualitative study in Sweden showing that prudent AB use is affected by conflicts between individualistic and egoistic values and altruistic and societal values (Ancillotti et al., 2018). However, altruism appeared irrelevant in our data, probably because it strongly correlated with biospherism, which includes a significant altruistic aspect: protecting the environment as a form of protecting others.

Moreover, we found that both cultural values and knowledge were significantly related to decisions about prudent AB use, which suggests that knowledge of hazardous and preventive behaviors is an important determinant of decisions about these behaviors regardless of people's cultural values. This is in line with previous findings about AB use (van Rijn et al., 2019) and, for example, about climate change (Shi et al., 2015).

5.2. Practical implications

Most interventions to mitigate ABR have been aimed at providing relevant information. Based on our findings, and in line with McParland et al. (2018), we recommend four actions to promote decisions favoring prudent AB use. First, providing information about AB and ABR should continue. Spreading knowledge and correcting misconceptions can have favorable effects on decisions related to prudent AB use. Better knowledge of AB functioning and ABR can indirectly affect these decisions by reducing the expected benefits of AB and raising awareness of their risks (see also van Rijn et al., 2019), two important direct determinants of decisions related to prudent AB use. Further, practical information about when AB work and measures that obviate the need for AB can have direct effects on the demand for AB and the willingness to prevent AB use, respectively. Our study confirmed a few important knowledge gaps about AB that were found in other countries (e.g., European Commission, 2018; van Rijn et al., 2019), such as the facts that it is not the human body but bacteria that develop resistance to AB and that AB cannot kill viruses. Our study additionally revealed that only a small part of our Swiss sample understood that ABR is a problem not only in veterinary but also in human medicine, and that certain vaccines, such as those against seasonal influenza, can reduce the need for AB. These knowledge gaps must be addressed.

Second, since social influences are strongly related to the demand for AB, we recommend promoting personal control and changing subjective norms regarding judicious AB use. It should be emphasized that important peers believe that AB ought to be used sparingly and that they behave accordingly—for example, '95% of Swiss people having a severe cold do *not* take antibiotics.' Addressing subjective norms and peer modelling have been shown to effectively reduce alcohol, cigarette, and marijuana consumption and to increase seatbelt use (Reid, Cialdini, & Aiken, 2010).

Third, the benefits of prudent AB use should be communicated. Although we found that greater perceived benefits are related to a higher demand for AB, this strong association suggests that changing the perceptions of what kind of benefits AB provide can have a substantial impact on the demand for AB.

Fourth, certain cultural values, especially conservatism, should be taken into consideration when communicating with the public to increase the willingness to prevent AB use. Cultural values are fundamental principles that cannot be changed by short-term interventions. Nonetheless, they may still be utilized to frame a risk message (Bubela et al., 2009). Messages that emphasize the conventional and secure characteristics of measures that obviate the need for AB can convince people with strong conservative values. Also, in line with the recommendation by Ancillotti et al. (2018), egoistic values can be reframed as an individual responsibility to secure AB for the future. Messages that highlight the personal benefits of prudent AB use can also conform to egoistic values. Moreover, conveying messages in a biospheric context can reduce people's demand for AB and increase their adoption of preventive measures. An example of such a message is 'handwashing keeps you and the environment healthy'.

5.3. Limitations and suggestions for future research

An important limitation of our study is the relatively low proportion of explained variances (SMCs) and internal reliability of some of our latent factors, which may be due to the small number of items and their heterogeneity in some factors. However, Cronbach's α has been strongly criticized due to researchers' heavy reliance on it (Taber, 2018). Our CFA results indicated that our factors had good construct validity. Nevertheless, we strongly recommend that future studies apply our scales to assess their generalizability.

Moreover, rather than relying on self-reported measures or decisions about prudent AB use, future research should include an objective measure of people's AB use and/or their implementation of preventive measures, such as following hygiene practices in hazardous situations—for example, when preparing meat (Nauta et al., 2008) or entering a medical care facility (Vaidotas et al., 2015). People's behavior related to prudent AB use in real life can also be affected by external factors, such as their physicians' opinions and recommendations, health insurance models, and national healthcare systems (Blommaert et al., 2013; Filippini, Masiero, & Moschetti, 2006). Therefore, future research should include additional variables to assess such external factors (Thorpe, Sirota, Juanchich, & Orbell, 2020). Their addition may also increase the proportion of explained variances of the model's two dependent variables, for which there is room for improvement.

6. CONCLUSIONS

Our study is one of the few to develop and test a comprehensive theory-based model to explain people's decisions related to prudent AB use. Our findings show that addressing the following factors in public interventions can promote prudent AB use most effectively: knowledge of AB functioning and of measures that obviate the need for AB, social influences, benefits of the prudent use of AB, and conservative values.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

Table A1. Distributions of the demographic characteristics set for the quota and collected in the sample
Table A2. Decisions and perception regarding prudent AB use: Item factor loadings from the exploratory factor analysis (EFA), as well as proportions explained variances and internal reliabilities
Table A3. Pearson correlations between all variables, and each variable's mean and standard deviation