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Pills, Rebel Yells, and Red Dye Spills: Preventing the Misuse of Antibiotics via Language and Color Cues

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ABSTRACT

Antibiotic resistance is an urgent global health crisis that requires effective communication strategies to encourage public engagement in preventive behaviors. The current study explores the impact of multimodal design features, including threat agency (human *vs*. bacteria), nominalized forms (antibiotic misuse *vs*. antibiotic misuser), and color cues (blue *vs*. red) in health communication messages about antibiotic resistance. A $2 \times 2 \times 2$ between-subjects experimental design was employed with a sample of 386 participants randomly assigned to one of eight conditions. Results indicated that messages assigning agency to humans led to greater perceived freedom threat compared to assigning bacteria as the agent. The interaction effects between threat agency and nominalized forms predicted perceived response efficacy and self-efficacy. The interaction between threat agency and color cues predicted intention to engage in antibiotic misuse. Additionally, the combination of nominalized forms and color cues predicted negative emotional reactions toward the fact sheet. The key takeaways from the study are that linguistic and sensory features often interact with each other to shape people's health beliefs, and it is important to understand how to strategically present (or mask) human involvement when humans are a primary cause of the health threat. The study's implications, limitations, and future research directions are discussed.

Antibiotic resistance is an urgent global health crisis, driven in part by the widespread misuse of antibiotics. Inappropriate prescribing, over-the-counter availability in some regions, and patient nonadherence have contributed to a rise in resistant pathogens, undermining the effectiveness of once-reliable treatments (Ventola, 2015). Public health authorities increasingly emphasize that responding to this crisis requires not only innovation in drug development and changes in medical practice but also large-scale shifts in public behavior. Persuasive health communication is a central tool in efforts to shape those behaviors. However, these campaigns must walk a fine line: They must convey the seriousness of antibiotic resistance without stigmatizing audiences or provoking disengagement, especially when addressing behaviors that are widespread or culturally ingrained.

To achieve this balance, public health messages frequently rely on highly condensed formats—brief posters, infographics, social media banners—that combine linguistic and visual design elements to influence perception, judgment, and motivation. Research indicates that even small changes in message language or presentation can shape how people interpret health information. For instance, variations in lexical choice, syntax, or visual layout have been shown to affect attention, recall, and persuasion (Houts et al., 2006; King & Lazard, 2020; O'Keefe, 2003). In the context of antibiotic stewardship, message designers might subtly influence readers' perception by manipulating sentence structure to shift perceived responsibility, selecting different word forms to either personalize or abstract the behavior, or using color schemes that affect how threatening or neutral the message appears.

This study focuses on three message features that appear frequently in public health messaging: agency assignment, nominalization, and color. These features differ in modality —grammatical, lexical, and visual—but often appear in combination in persuasive health materials, and their effects are likely to be interdependent. Drawing on dual-process theories of information processing (Evans & Stanovich, 2013; Petty & Cacioppo, 1986), we argue that such features primarily influence heuristic processing by shaping affective and intuitive judgments with little conscious deliberation. Prior research has demonstrated that agency assignment can influence how health information is interpreted, including how readers understand causality, responsibility, and behavioral implications (McGlone et al., 2013). Nominalization has also been shown to affect perceptions of behavioral identity and moral evaluation, particularly when actions are framed as enduring traits or categories rather than behaviors (Bryan et al., 2011). Color cues such as red and blue have been linked to differences in emotional arousal and perceived urgency (Elliot et al., 2007). Because these features often co-occur in authentic messaging and may reinforce or counteract one another's effects, examining them together provides insight into how subtle linguistic and visual elements collectively influence public responses to health threats like antibiotic resistance. In this vein, message combinations can produce outcomes that are both intended (e.g., enhanced perceptions of threat and efficacy) and

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unintended (e.g., elevated negative affect and freedom threat). Attending to both types provides a more comprehensive picture of how combinations may function in practice. Given that dual processing cues are not inherently tied to a single route, any cue – whether linguistic or visual – may be processed centrally or peripherally depending on audience motivation and ability (Petty & Cacioppo, 1986), it is important to understand the impact of dual process on the intended and unintended outcomes of the message combinations regarding agency assignment, nominalization, and color.

Dual-process model

The dual process model posits two distinct systems for understanding reasoning, decision-making, and social cognition (Evans, 2008; Evans & Stanovich, 2013). Stanovich (1999) employed System 1 and System 2 to label the properties that belong to two different routes – Type 1 and Type 2. Type 1 describes a fast and intuitive process, while Type 2 is slow, effortful, and reflective. The dual process model has a wide range of applications. For example, Kahneman (2011) elaborated these two systems in his work on decision-making, distinguishing intuitive from deliberate reasoning in terms of fast and slow responses (also see Kahneman, 2002). Building on Type 1 heuristic processing, Schwarz and Clore (1983) proposed that individuals often rely on affective responses as a basis for judgment, using mood as a source of information. Further, Schwarz (2002) showed that mood states, such as sadness, can moderate individuals' systematic processing when making judgments. As an important type of dual-process model in persuasion, the Elaboration Likelihood Model (ELM) similarly distinguishes between high-effort (central route) and low-effort (peripheral route) information processing (Petty & Cacioppo, 1986). These routes offer different pathways to persuasion, and message designers as well as researchers may strategically appeal to one or both depending on the audience and communicative goals.

In the context of health communication aimed at promoting awareness of antibiotic resistance and discouraging antibiotic misuse, we draw on this dual-process framework to examine how linguistic features and visual cues such as color (which facilitate heuristic processing) influence individuals' health beliefs and behavioral intentions. Specifically, both textual and visual features can elicit systematic or heuristic processing depending on receivers' motivation and ability. Building on this perspective, we examine whether textual information and color cues, individually or together, enhance message effectiveness by offering distinct routes for engagement that may vary in intuitive and reflective emphasis. Further, in light of the persuasive and social influence goals embedded in dual-process communication, we also take the notion of perceived freedom into consideration. As Brehm (1966) noted, anything that is difficult for people to exercise their freedom to choose constitutes a threat to freedom. Such a freedom threat could be operationalized as an intertwined form of negative emotion and critical cognition (Dillard & Shen, 2005), which is in accordance with our examination of persuasion outcomes and dual process mechanisms. As such, we focus on examining threat appraisal (perceived severity and susceptibility), efficacy appraisal (response and self-efficacy), and affective and motivational reactions (negative emotions, freedom threat, and behavioral intentions) in the current study. In the sections that follow, we describe each of the message features in detail, including their theoretical foundations and relevance to public health messaging.

Linguistic features

Linguistic agency assignment

While subtle linguistic or visual cues may trigger affective and heuristic processing, in-depth engagement with the information content can promote systematic processing of the message (Chaiken et al., 1989; Petty & Cacioppo, 1986). It is important to view linguistic and color cues via the dual processing mechanisms. Specifically, linguists have highlighted the centrality of agency in language use such that all languages have ways of encoding agency (Duranti, 2004). In English, agency is grammatically encoded through the assignment of semantic roles in relation to the verb in a sentence such that the proto-agent role is associated with agency (Dowty, 1991; Jackendoff, 1972). Numerous studies have demonstrated the effectiveness of strategically assigning agency between the health threat and people who are susceptible to that threat (Jia & Zhang, in press; McGlone & Jia, in press; McGlone et al., 2023). For instance, shifting linguistic agency from humans to the health threat has a persuasive advantage because it implies that the threat is metaphorically taking control over the human recipient, motivating individuals to take actions to control such danger. For example, McGlone et al. (2013) investigated the persuasiveness of linguistic agency assignment in communicating the risks of the H1N1 pandemic. In their study, the agency was either assigned to influenza (e.g., "H1N1 can strike in any month of the year") or to humans (e.g., "People can contract H1N1 in any month of the year"). The results revealed that assigning agency to influenza rather than to humans significantly elevated participants' levels of perceived severity, susceptibility, and intention to get vaccinated. However, another study focusing on antibiotic resistance and stewardship found that human agency could effectively elevate people's intentions to engage in antibiotic stewardship (Zhang et al., 2023).

In addition to the effect of threat agency assignment on health threat appraisals, previous research also reported an intriguing "spill-over" effect of threat agency assignment on efficacy perceptions. For example, McGlone et al. (2013) found that individuals tended to perceive getting vaccinated as a more effective strategy to safeguard against H1N1 when the experimental materials assigned transmission agency to the virus than to people. A similar effect was also observed in Bell et al.'s (2014b) research on the HPV vaccine. A replication study in the Chinese language also showed a similar spill-over effect of viral agency assignment on people's positive attitudes toward mandatory HPV vaccination (Zhang & McGlone, 2019).

Apart from elevating people's perceptions of threat and efficacy, agency assignment may also undermine people's perceptions of control and induce negative emotions. This is because a consequence of agency assignment is to make people feel that they are losing control over an event by placing them

in the proto-patient position in a sentence (e.g., "antibiotic-resistance bacteria prey on people"). Consistent with findings reported in studies on fear appeals (Witte & Allen, 2000), previous studies have shown that people may react negatively, and are less likely to comply with recommendations when they perceive their freedom is being threatened (Dillard & Shen, 2005; Rains & Turner, 2007).

Nominalized forms

Another linguistic factor examined in the present study is different forms of nominalization (i.e., actor vs. activity nouns) (McGlone & Glowacki, 2018). Linguists have pointed out that while some words were first coined as nouns (e.g., *cup*, *medicine*, *antibiotics*), others were nominalized through various word formation processes such as conversion (e.g., *he cheats* vs. *he is a cheat*) and derivation (e.g., *he cheats* vs. *he is a cheater*; Wierzbicka, 1986; Yule, 2020). Prior research has shown that individuals are motivated to mitigate an undesirable behavior-identity link by discounting or qualifying their behaviors (Bryan et al., 2013; Ng & Bradac, 1993). For example, people are less likely to cheat for personal gains when they are placed in the actor's identity condition (e.g., "Please don't be a cheater") rather than the action condition (e.g., "Please don't cheat"; Bryan et al., 2013). Identity threat occurs when individuals feel that their sense of self or identity is being challenged or undermined (Sherman et al., 2013), which can be achieved by strengthening the link between the negative behaviors and their associated undesirable identities.

Communication scholars have also pointed out that different forms of nominalization can lead to subtle differences in communicative outcomes (McGlone & Giles, 2011; McGlone & Glowacki, 2018). For example, McGlone and Glowacki (2018) demonstrated participants' person positivity bias when exposed to commentary essays using activity or actor nouns. Specifically, participants favored complimentary essays using actor nouns (e.g., cosmetic surgeon) but were more receptive to critical essays using activity nouns (e.g., cosmetic surgery). This suggests that people may experience less discomfort when encountering criticism framed with activity nouns, as these terms focus on actions rather than directly associating behaviors with one's identity. When communicating the threat of antibiotic resistance, health professionals can criticize antibiotic misuse (activity noun), which refers to the incorrect use of antibiotics, such as using antibiotics to treat viral infections or stopping treatment early. They can also criticize the antibiotic misuser (actor noun), which refers to a person who commits to an incorrect habitual behavior that falls outside of the antibiotic use guidelines. Given that actor nouns associate behaviors with one's identity, they are more likely to provoke negative emotional responses and increase perceived freedom threat, making individuals more defensive against criticism of their antibiotic misuse. Meanwhile, person positivity bias (Sears, 1983) suggests that actor nouns may further induce psychological reactance, as individuals perceive a threat to their autonomy. However, what remains underexplored is how nominalized forms may provide a persuasive advantage in raising awareness of antibiotic resistance and discouraging misuse behaviors. To examine the main effects of two linguistic features individually, we pose the following research question:

RQ1: What are the main effects of linguistic features – specifically, linguistic agency assignment and nominalized forms – on individuals' (a) perceptions of threat regarding antibiotic resistance (b) efficacy beliefs of antibiotic stewardship, (c) negative emotional responses toward the fact sheet content, (d) intentions to engage in antibiotic misuse, and e) perceptions of freedom threat elicited by the fact sheet?

As an exploration, we also examine the interaction effects of these two linguistic features on individuals' perceptions of threat, efficacy, emotional responses, intentions as well as perceptions of freedom threat. Specifically, the combination of linguistic agency assignment (bacteria *vs.* human) and nominalized forms (misuse *vs.* misuser) may influence how people interpret the source of action and responsibility in causing the public health issue (e.g., McGlone & Glowacki, 2018; McGlynn & McGlone, 2019). Certain combinations may reinforce or counteract one another's effects. Given that the emergence of the "superbugs" is a collective-oriented issue involving individuals' attributions and interpretation of responsibilities, we pose the following research question to examine this interaction:

RQ2: Do linguistic agency assignment and nominalized forms interact to influence individuals' (a) perceptions of threat regarding antibiotic resistance, (b) efficacy beliefs of antibiotic stewardship, (c) negative emotional responses toward the fact sheet content, (d) intentions to engage in antibiotic misuse, and e) perceptions of freedom threat elicited by the fact sheet?

Sensory features

Color cues

Multimodal design features such as color cues may also play a key role in message framing by influencing people's perceptions and emotional responses to the message. In line with the Elaboration Likelihood Model (Petty & Cacioppo, 1986), peripheral cues (e.g., color) in a fact sheet are influential when the involvement of information processing is low. In real-life situations, people are often affected by the color of the reading materials they encounter. Certain colors may elicit people's strong emotions and perceptions of a threat, which may further impact their behaviors at a later stage. For example, an experiment conducted by Elliot et al. (2007) showed that individuals briefly exposed to the color red (as opposed to gray or green) performed poorly on intelligence tests. The authors attributed this finding to the idea that red can evoke the fear of failure in an academic context due to learned associations between red ink marks on a term paper or exam and failing a class. Consequently, the fear of failure triggers avoidance motivation and leads to reduced performance on the test. Similarly, Wauters et al. (2014) noted that individuals tend to associate the red color with danger and risk, which is likely to decrease undesired behavior. In light of these findings, we hypothesize that people who read the misuse of antibiotics in

the red color would perceive higher levels of risk and subsequently report lower intentions to engage in antibiotic misuse.

While the color red may achieve effective persuasive outcomes when used to capture attention or convey urgency, it may also lead to negative perceptions and hinder persuasion. Specifically, the color red can affect people's perceptions biologically and culturally by invoking anger (Chittaro, 2016). For example, people tend to experience more anger when they are obstructed by a red car as compared to a car of other colors (Guéguen et al., 2012). In addition, the color red can be both a manifestation and a means of communication for threats to people's health. Its association with blood, injury, and infection makes red color a common trigger for such images (Elliot & Maier, 2014; Gerend & Sias, 2009). Although red can elevate threat appeal to people, it can also impose freedom threat or trigger psychological reactance. As suggested by Armstrong et al. (2021), red exacerbates the degree to which freedom-threatening language elicits perceived freedom threat and reactance. Since the current study is contextualized in American society, we focus on the comparison between red and blue colors. However, the question of how color cues may provide a persuasive advantage in communicating efficacy still needs to be investigated. Thus, we propose the following:

RQ3: What are the main effects of color cues (red *vs*. blue) on individuals' (a) perceptions of threat regarding antibiotic resistance, (b) efficacy beliefs of antibiotic stewardship, (c) negative emotional responses toward the fact sheet content, (d) intentions to engage in antibiotic misuse, and e) perceptions of freedom threat elicited by the fact sheet?

Multimodal message design: linguistic features interact with sensory features

A primary focus of the current study is how the aforementioned linguistic and sensory features can jointly influence individuals' processing of health messages. In real-life communication, textual and sensory cues, such as language and visual design, are often combined to enhance message persuasiveness and improve communication effectiveness. Prior research on multimodal narratives has suggested that different modalities work together to stimulate imagination and communicate stories in a more engaging way beyond traditional textual narratives (see Meier, 2022). When cues are combined across modalities, outcomes may reflect not just additive effects but also their interactions. It is plausible that cue congruence enhances processing when linguistic and visual elements point in the same direction, reinforcing one another's impact (e.g., Hur et al., 2020). Such convergence may facilitate fluency and enhance persuasiveness. As Schwarz (2004) noted, the cognitive experience of message processing can vary along a continuum from effortless to effortful, with corresponding metacognitive sensations that influence judgment and persuasion. In contrast, incongruent or competing cues may create attention competition, demand greater cognitive effort, or induce ambivalence, thereby diminishing or redirecting processing. Together, these mechanisms suggest that multimodal messages can shape health perceptions and behavioral outcomes through both convergent and divergent cue interactions.

Informed by the aforementioned dual-process perspective, we view this interaction in terms of how message features align—or fail to align—with intuitive versus deliberative processing tendencies. Color typically serves as a rapid affective signal, processed with minimal effort, while linguistic forms like agency assignment and nominalization can invite deeper reflection or function as subtle cues, depending on salience and context (Chaiken, 1980; Evans & Stanovich, 2013; Petty & Cacioppo, 1986). Agency assignment influences how people locate responsibility or control in health scenarios, potentially evoking fear or urgency (Fausey & Boroditsky, 2010; Heider, 1958; McGlynn & McGlone, 2019). Likewise, nominalization affects whether behaviors are perceived as actions or traits, shaping defensiveness and perceived autonomy (McGlone & Glowacki, 2018).

These features may work in concert—or in tension. For example, assigning agency to antibiotic-resistant bacteria while also using impersonal activity nouns may reinforce perceptions of external threat without provoking reactance. But combining human agency with actor nouns and a visually alarming cue like red may amplify defensiveness and diminish message effectiveness. Given that such combinations may either amplify persuasive outcomes or inadvertently undermine them, it is essential to examine their interactive effects.

Accordingly, we pose the following question:

RQ4: Do linguistic features (i.e., linguistic agency assignment and nominalized forms) interact with color cues (i.e., red *vs*. blue) in influencing individuals' (a) perceptions of threat regarding antibiotic resistance, (b) efficacy beliefs about antibiotic stewardship, (c) negative emotional responses toward the fact sheet content, (d) intentions to engage in antibiotic misuse, and (e) perceptions of freedom threat elicited by the fact sheet?

Method

A priori power analysis was conducted using G*Power (Faul et al., 2007) for a $2 \times 2 \times 2$ between-subjects factorial design. Assuming a medium effect size ($f = 0.25$), $\alpha = .05$, and power $(1\text{-}\beta) = .80$, the analysis indicated a required sample size of 237 participants (approximate 29 per condition) to detect main and interaction effects. Considering attrition, we aimed to collect more than the expected. Data were collected through two crowdsourcing platforms *Amazon's Mechanical Turk* ($N_1 = 134$) and *Prolific* ($N_2 = 422$). Participants aged 18 years or older who self-reported being native English speakers were recruited. Following Sheehan's (2018) recommendations for ensuring data quality, MTurk workers whose HIT approval ratings equal to and above 99% were recruited as participants. Additionally, the majority of our participants were recruited from *Prolific* which has shown high data quality as these participants tend to complete online surveys carefully and honestly (Peer et al., 2021). We applied two criteria to deal with missing values: a) participants who spent less than 80 seconds—the minimum amount of time participants were

required to spend reading the fact sheet—were excluded ($n = 31$); and b) those who had more than 50% missing responses ($n = 20$); these cases were listwise deleted. This online experiment took approximately 10 minutes to complete. Participants recruited from *MTurk* were provided $0.80, and respondents from *Prolific* were awarded $1.50 for completing the survey, both of which are typical prices for a 10-minute survey on these two crowdsourcing platforms, respectively. Five attention check questions were created to further screen participants. Following previous recommendations (Chmielewski & Kucker, 2020), individuals who failed to answer at least three out of the five questions were excluded from the analysis ($n = 112$). Additionally, given that we focused on the effect of color cues, participants who reported color-blindness were excluded ($n = 7$). In the end, a total of 386 participants were retained for the subsequent analyses, all of whom were from *Prolific*.

The sample consisted of 190 females (49.2%) and 192 males (49.7%). Four people reported in other gender categories (1.1%). Respondents' age ranged from 18 to 75 years and averaged 37.0 years ($SD = 13.30$, $Mdn = 34$). Their race includes White or Caucasian ($n = 308$, 79.8%), Asian or Pacific Islander ($n = 51$, 13.2%), Black or African American ($n = 25$, 6.5%), Hispanic or Latino ($n = 55$, 14.2%), Native American ($n = 11$, 2.9%), and multiple ethnicities ($n = 11$, 2.9%). Since participants' knowledge of antibiotic resistance may moderate their attitudes regarding the fact sheet (Hermsen et al., 2020), we also collected data on participants' history of talking with their primary care physician about antibiotic resistance. Among them, 84 (21.8%) participants stated that a doctor has talked to them about antibiotic resistance, 18 (4.7%) revealed that a doctor had told them that they were at risk for getting antibiotic-resistant bacterial infections, and 94 (24.4%) reported that they had taken action to prevent antibiotic resistance. The demographic details of the sample are summarized in Table 1.

Table 1. Demographic profile of the sample ($N = 386$).

Measure	n	%
Female	190	49.2
Age (years)		
18–29	126	35.5
30–39	106	27.6
40–49	58	14.9
50–59	59	15.3
60 and older	26	6.8
White or Caucasian	308	79.8
Education		
High school or less	56	14.6
Some college	83	21.5
2-year college degree	46	11.9
4-year college degree	150	38.9
Graduate degree	43	11.1
Employment Status		
Employed full-time	158	40.9
Employed part-time	70	18.1
Unemployed and looking for work	58	15.0
Full-time student	38	9.8
Homemaker	14	3.6
Retired	19	4.9
Other	29	7.5
Marital Status		
Married	108	28
Not married but in a committed relationship	75	19.4
Separated	4	1.0
Divorced	30	7.8
Widow/Widower	6	1.6
Never married	163	42.2

Experimental design and stimulus materials

In the current study, a 2 (threat agency: antibiotic-resistant bacteria vs. human) × 2 (nominalized form: antibiotic misuser vs. misuse) × 2 (color cue: blue vs. red) between-subjects factorial design was employed. After consenting to participate in this study, participants were randomly presented with one of the eight experimental versions (unknown to them) of the antibiotic resistance fact sheet. To ensure that participants read the fact sheet carefully, they were asked to read it for at least two and a half minutes before they could advance to the next screen. The stimulus material was a two-page educational fact sheet on antibiotic resistance and practicing antibiotic stewardship. The information in the fact sheet was adapted from the United States' Centers for Disease Control and Prevention website (CDC, 2024; https://www.cdc.gov/antibiotic-use/data-research/facts-stats/index.html) and was attributed to a fictitious institution called the National Association of Health Services. Sample language manipulations are provided in Table 2. Each version of the fact sheets included seven linguistic manipulations of threat agency, eight of nominalized nouns, and one of color cues. All versions were comparable in length (range = 283 – 291 words). For illustrative purposes, sample versions of the fact sheet are provided in the Appendix (conditions: bacteria-misuse-blue, human-misuser-red).

Measures

After reading the fact sheet, participants were asked about their attitudes and perceptions of antibiotic resistance, as well as their impressions of the fact sheet. Following Bell et al. (2014a, 2014b), the back function was disabled to prevent participants from reading the fact sheet when answering the attention check questions. We collected data on the perceived severity, susceptibility, response efficacy, self-efficacy, behavioral intentions, negative affect, evaluation of the fact sheet, and freedom threat. Unless otherwise noted, all variables were assessed using 7-point Likert-type scales (1 = strongly disagree, 7 = strongly agree). Correlations appear in Table 3. A confirmatory factor analysis was conducted using the *lavaan* package in R to examine the measurement structure of perceptions of threat regarding antibiotic resistance, efficacy beliefs related to antibiotic stewardship, negative emotional responses toward the fact sheet content, intentions to engage in antibiotic misuse, and perceptions of freedom threat elicited by the fact sheet. The initial model demonstrated poor fit, χ^2 (608) = 1785.2, $p < .001$, CFI = .87, TLI = .86, RMSEA = .07, SRMR = .08. Inspection of modification indices suggested strong residual correlations between the first two susceptibility items, as well as between affective items with overlapped wording (i.e., scared and afraid, ashamed and guilty, hostile and irritable). Allowing these item residuals to correlate resulted in

Table 2. Sample language manipulations in the educational fact sheet of antibiotic resistance, defined by 2 × 2 × 2 (threat agency × nominalized form × color) experimental design.

Threat agency: Bacteria assignment	Threat agency: Human assignment
Headline: The Risks of Antibiotic-Resistance Bacteria	Headline: Human Infection of Antibitoic-Resistant Bacteria
Body: Bacteria associated with antibiotic resistance spread among people across continents …	Body: Individuals spread antibiotic-resistance bacteria across continents.
Body: Antibiotic-resistant bacteria can take advantage of people's inappropriate antibiotic consumption …	Body: People can contract antibiotic-resistant bacteria when practicing inappropriate antibiotic consumption …
Body: Each year in the U.S., serious forms of antibiotic-resistant bacteria invade more than 2.8 million people, and kill at least 35,000 of them …	Body: Each year in the U.S., more than 2.8 million people catch serious forms of antibiotic-resistance bacteria and at least 35,000 of them die …
Nominalized forms: Antibiotic misuse	**Nominalized forms: Antibiotic misuser**
Headline: Antibiotic Misuse	Headline: Antibiotic Misuser
Body: Antibiotics can save lives, but antibiotic misuse can contribute to the development of antibiotic resistance …	Body: Antibiotics can save lives, but antibiotic misusers can contribute to the development of antibiotic resistance …
Body: Antibiotic misuse happens when …	Body: An antibiotic misuser appears when …
Body: Such antibiotic misuse is likely to cause side effects ranging from minor to very severe health problems …	Body: Such antibiotic misusers are likely to suffer from side effects ranging from minor to very severe health problems …

Note. To avoid repetition, the color effect (red *vs*. blue) is not included. The color change is shown in the Appendix.

Table 3. Correlations among the study variables ($N = 386$).

	1	2	3	4	5	6	7	8
1. Severity	–							
2. Susceptibility	.25**	–						
3. Response efficacy	.50**	.03	–					
4. Self-efficacy	.44**	.01	.63**	–				
5. Negative feelings	−.02	.12*	.01	−.10	–			
6. Freedom threat	−.34**	−.07	−.27**	−.34**	.28**	–		
7. Intention to engage in antibiotic misuse behaviors	−.36**	−.23**	−.35**	.31**	.07	.32**	–	
8. Evaluation of the fact sheet	.39**	.08	.48**	.40**	−.02	−.18**	−.32**	–

Note. *$p < .05$; **$p < .01$.

improved model fit, χ^2 (604) = 1428.62, $p < .001$, CFI = .91, TLI = .90 RMSEA = .06, SRMR = .08. All modifications were theoretically justified and limited to within-factor item residuals. All items loaded significantly onto their respective factors ($ps < .001$), with standardized loadings ranging from .45 to .91, indicating acceptable to strong relationships between the latent constructs and observed indicators.

EPPM construct

This questionnaire was adapted from previous research using the EPPM framework to study agency assignment effects (Chen et al., 2015; Zhang et al., 2023). The items were modified to fit the current investigation. Five items assessed the perceived severity (e.g., "Antibiotic resistance poses a serious risk to health"; Cronbach's $\alpha = .94$; $M = 5.99$, $SD = .92$). Four items assessed perceive susceptibility (e.g., "I am at risk for antibiotic resistance."; Cronbach's $\alpha = .81$; $M = 4.54$, $SD = 1.11$). Four items assessed response efficacy (e.g., "Practicing antibiotic stewardship can fight off antibiotic resistance."; Cronbach's $\alpha = .76$; $M = 5.75$, $SD = .80$), and four items assessed self-efficacy (e.g., "It could be easy to practice antibiotic stewardship if I wish to do so."; Cronbach's $\alpha = .86$; $M = 5.78$, $SD = .93$).

Negative affect

Respondents were asked to think about the content described in the fact sheet and indicate to what degree they felt a variety of negative emotions. Ten negative affect items from Watson et al. (1988) Positive Affect and Negative Affect Scale (PANAS; *i.e.*, hostile, jittery, ashamed, guilty, scared, afraid, distressed, upset, nervous, and irritable) were used. Participants rated these items on a scale from 1 (*very slightly or not at all*) to 7 (*extremely*). The 10 items were combined into one overall negative affect variable (Cronbach's $\alpha = .90$; $M = 1.75$, $SD = .90$).

Freedom threat

The degree of perceived freedom threat was measured with a four-item scale adapted from Lee et al.'s (2012) study (e.g., "The fact sheet threatens my freedom of action."; Cronbach's $\alpha = .88$; $M = 2.34$, $SD = 1.20$).

Behavioral intention

Six items adapted from Smith et al. (2020) were used to assess participants' intentions to engage in antibiotic misuse behaviors after reading the fact sheets (also see Smith et al., 2015; e.g., "I intend to ask health providers to prescribe me an antibiotic when I am sick."; Cronbach's $\alpha = .87$; $M = 2.34$, $SD = 1.10$).

Evaluation of the fact sheet

Participants were asked to report their evaluations of the fact sheet using a 16-item semantic differential scale ranging from −5 to 5. This scale was borrowed from another study on antibiotic resistance (Zhang et al., 2023). In case of containing negative values, we transformed the scale to a 1 – 11 scale (e.g., "inaccurate – accurate, unprofessional – professional"; Cronbach's $\alpha = .97$; $M = 9.45$, $SD = 1.69$).

Results

Randomization checks

The association between the manipulated message factors (i.e., threat agency, nominalized form, color) and participants characteristics (e.g., sex, educational level, employment status, and marital status) were examined through cross-tabulation. Chi-square tests indicated no significant association ($ps > .05$) between demographic factors and the message framing factors, suggesting that randomization functioned well in the design.

Main analysis

Main effects

To control for inflation of Type I errors, all research questions and hypotheses were tested together through a multivariate analysis of covariance (MANCOVA). The evaluation of the fact sheet was included as a covariate. The results indicated that individuals' evaluation of fact sheet varied on the set of dependent variables [$\lambda = .68$, $F(8, 370) = 21.73$, $p < .001$, $\eta_p^2 = .32$]. The results from MANCOVA found support for a main effect of threat agency on participants' perceived freedom threat [RQ1e; $F(1, 377) = 3.88$, $p = .05$, $\eta_p^2 = .01$] but not for other dependent variables (RQ1a-RQ1d). Also, the results did not show statistically significant main effects of color cues (RQ3). The experimental instructions requiring participants to remain attentive may have minimized any differences in attention levels that color cues would typically induce in a natural setting, potentially explaining the non-significant color effects observed. Further, a pairwise comparison using the Bonferroni technique was performed to determine which type of threat agency assignment was more effective in communicating antibiotic resistance. Contrary to our hypothesized direction in RQ1e, participants in the human agency condition reported greater freedom threat than those who read the bacteria agency condition ($M_{difference} = .24$, $p = .05$). The univariate results and marginal means for each of the dependent variables are provided in Table 4.

Linguistic agency × nominalized forms

RQ2 explores the interaction effects among the three message influence factors. The univariate analyses showed that the interaction between threat agency assignment and the form of nominalization was significant for response efficacy [$F(1, 377) = 9.23$, $p = .003$, $\eta_p^2 = .024$] and self-efficacy [$F(1, 377) = 4.83$, $p = .029$, $\eta_p^2 = .013$]. Under the misuse condition, participants who read the bacteria agency fact sheet evaluated the recommended antibiotic stewardship practices as more effective than those who read the human agency version (response efficacy; $M_{Misuse\ (bacteria\text{-}human)} = .24$, $SE = .10$, $p = .019$; see Figure 1). As for self-efficacy, the results revealed that threat agency assignment was effective when activity noun but not actor noun was used to describe the misuse behavior. Specifically, people who read the bacteria agency fact sheet tended to believe in their own ability to fight off antibiotic resistance as compared to those who read the human agency version (self-efficacy; $M_{Misuse\ (bacteria\text{-}human)} = .29$, $SE = .12$, $p = .017$; see Figure 2). These results indicated that the desirable combination of bacteria agency and action noun framing effectively enhanced both self-efficacy and response efficacy, which aligned with the intended goal of promoting antibiotic stewardship practices.

Linguistic agency × color cues

RQ4 was proposed to explore how linguistic features interacted with color cues. The univariate analysis showed that the interaction between threat agency and color cues for intentions to engage in antibiotic misuse behaviors approached significance [$F(1, 377) = 3.59$, $p = .059$, $\eta_p^2 = .009$]. In the human agency condition, individuals who were exposed to the fact sheet in red tended to have higher intentions to engage in antibiotic misuse behaviors as compared to those who were exposed to the blue version ($M_{Human\ (red\text{-}blue)} = .31$, $SE = .15$, $p = .042$). However, this effect was not identified in the bacteria agency condition. Figure 3 is added to show the interaction effect.

Nominalized forms × color cues

We also found that nominalized forms interacted with color cues in predicting negative affect [$F(1, 377) = 3.41$,

Table 4. Estimated marginal means, standard errors and univariate results from MANCOVA ($N = 386$).

	Threat Agency				Nominalized Forms				Color Cues			
	Human $n = 194$ *M (SE)*	Bacteria $n = 192$ *M (SE)*	Univariate *F*	η_p^2	Misuse $n = 190$ *M (SE)*	Misuser $n = 196$ *M (SE)*	Univariate *F*	η_p^2	Blue $n = 189$ *M (SE)*	Red $n = 197$ *M (SE)*	Univariate *F*	η_p^2
Severity	5.94 (.06)	6.05 (.06)	1.57	.004	6.05 (.06)	5.94 (.06)	1.42	.004	6.01 (.06)	5.99 (.06)	.05	.00
Susceptibility	4.53 (.08)	4.54 (.08)	.02	.00	4.57 (.08)	4.50 (.08)	.38	.001	4.54 (.08)	4.53 (.08)	.01	.003
Response efficacy	5.74 (.05)	5.77 (.05)	.11	.00	5.76 (.05)	5.75 (.05)	.002	.00	5.79 (.05)	5.72 (.05)	1.21	.00
Self-efficacy	5.72 (.06)	5.83 (.06)	1.49	.004	5.77 (.06)	5.78 (.06)	.02	.00	5.76 (.06)	5.79 (.06)	.09	.00
Negative affect	1.72 (.07)	1.78 (.07)	.45	.001	1.77 (.07)	1.74 (.07)	.12	.00	1.71 (.07)	1.79 (.07)	.76	.002
Freedom threat	2.46 (.09)	2.22 (.09)	3.88*	.10	2.33 (.09)	2.36 (.08)	.07	.00	2.27 (.09)	2.42 (.08)	1.51	.004
Intention to engage in antibiotic misuse behaviors	2.36 (.08)	2.32 (.08)	.12	.00	2.27 (.08)	2.42 (.07)	1.99	.01	2.29 (.08)	2.39 (.07)	.96	.003

Note. *$p \leq .05$.

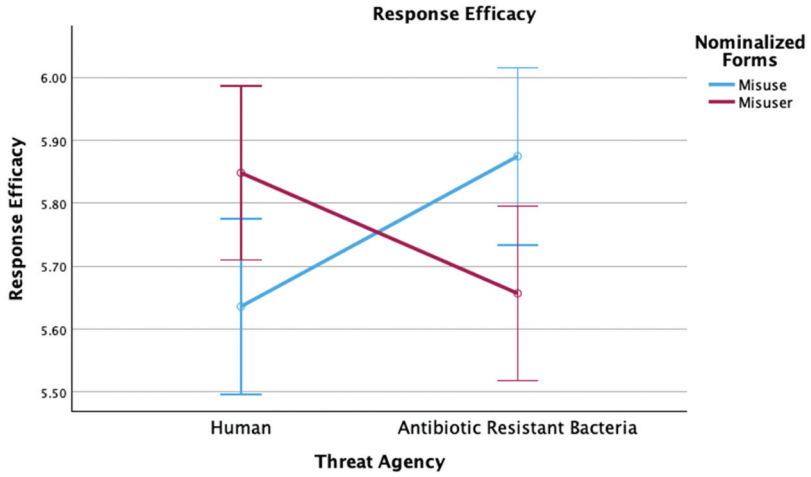

Figure 1. Interaction between threat agency and nominalized form in predicting response efficacy. *Notes*. Covariates appearing in the model are evaluated at the following values: Evaluation of the fact sheet = 9.45 Error bars: 95% CI.

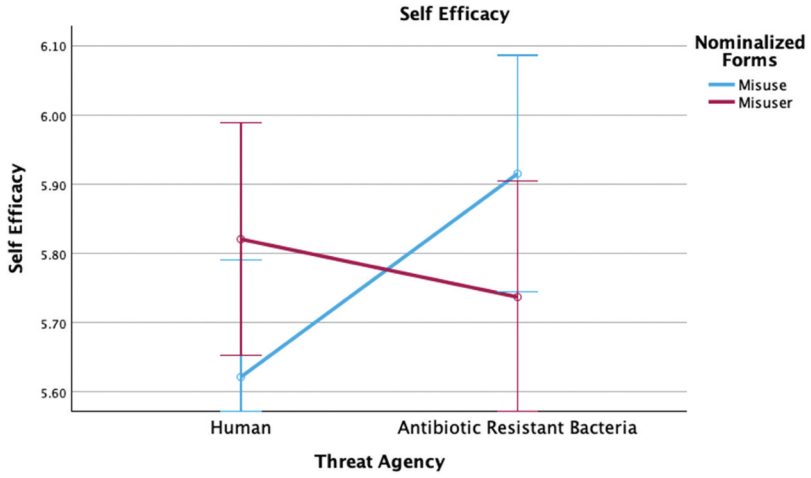

Figure 2. Interaction between threat agency and nominalized form in predicting self-efficacy. *Notes*. Covariates appearing in the model are evaluated at the following values: Evaluation of the fact sheet = 9.45 Error bars: 95% CI.

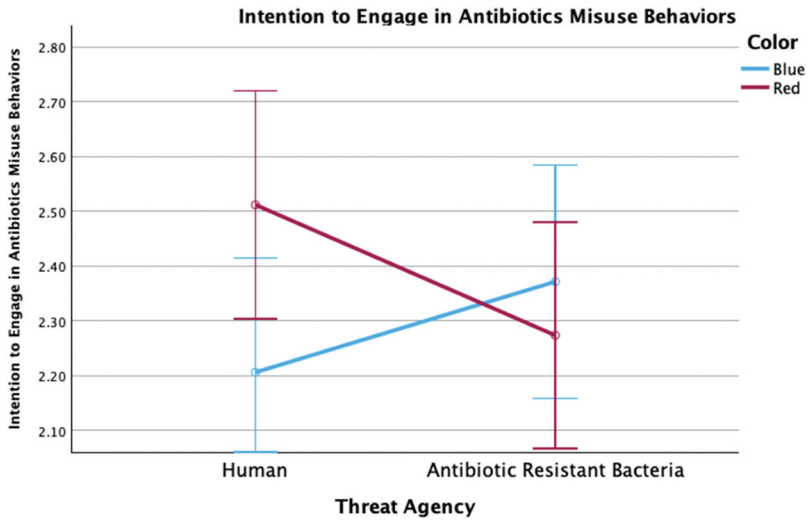

Figure 3. Interaction between threat agency and color in predicting intention to engage in antibiotic misuse behaviors. *Notes*. Covariates appearing in the model are evaluated at the following values: Evaluation of the fact sheet = 9.45 Error bars: 95% CI.

$p = .042$, $\eta_p^2 = .011$]. Specifically, the results indicated that under the condition of activity nouns, people who read the fact sheet in red reported greater negative feelings toward antibiotic resistance as compared to the blue version ($M_{Misuse\ (red\text{-}blue)} = .25$, $SE = .13$, $p = .05$). The effect did not show in the misuser condition (see Figure 4 for specific interaction effect).

Discussion

This study examined how linguistic and sensory message features—threat agency, nominalized forms, and color cues—individually and interactively influence perceptions of antibiotic resistance and intentions toward antibiotic misuse. While the main effects of these variables were largely nonsignificant, several notable interaction effects emerged. This pattern signals that the cues did not function independently, but alter one another's interpretive meaning when combined. Accordingly, the clearest take-away is not that any single feature is inherently persuasive or counter-persuasive, but that message effects depended on how linguistic and visual cues co-occurred to shift how readers locate agency, interpret responsibility, and appraise autonomy. Keeping this interactive framing in mind helps make sense of the otherwise heterogeneous results that follow.

One of the most important findings was the interaction between threat agency and nominalized forms in shaping efficacy perceptions. Specifically, we observed that using bacteria agency framing combined with action nouns (e.g., "misuse") led to higher levels of both self-efficacy and response efficacy, illustrating a desirable combination of linguistic cues for promoting recommended health behaviors. Highlighting these desirable combinations contributes to the growing evidence on the role of linguistic framing in health communication and suggests actionable strategies for crafting messages aimed at reducing antibiotic misuse. In addition, messages that described humans as the source of the threat and used actor-based nominalizations—e.g., "antibiotic misusers"—led to lower perceptions of efficacy than other combinations. This aligns with earlier work showing that language linking undesirable behavior to identity can provoke defensiveness and diminish perceived control (McGlone & Glowacki, 2018). At the same time, attributing threat to human agents likely heightened personal relevance and responsibility (McGlynn & McGlone, 2019). Taken together, these effects suggest that pairing human agency with identity-relevant nominalizations may discourage belief in the reader's ability to take effective action—an outcome that may undercut public health goals. These findings reinforce the value of a multimodal approach to message design, particularly when message elements are likely to be processed in tandem.

However, the study also found that some message combinations reinforced negative outcomes, amplifying undesirable effects rather than canceling each other out. For example, pairing human threat agency with red—already known to evoke associations with danger and punishment (Armstrong et al., 2021; Elliot et al., 2007; Gerend & Sias, 2009)—led to higher levels of perceived threat and emotional arousal. Similarly, combining actor-based nominalization with red intensified negative emotional responses, which illustrates how both linguistic and visual cues can, under some conditions, evoke intuitive, affect-laden reactions when processed heuristically, while under other conditions the same cues prompt more deliberative elaboration (Evans & Stanovich, 2013; Petty & Cacioppo, 1986). These outcomes highlight the risk of overloading messages with cues that may be interpreted as accusatory, identity-threatening, or overwhelming—especially when those cues converge rather than diverge. Such findings underscore the importance of designing messages in which individual features work in concert, not at cross-purposes.

Our findings offer actionable insights for designing antibiotic resistance messages. They highlight the importance of considering both linguistic and sensory cues in designing health messages. Further, O'Keefe (2003) observed that it is challenging for health practitioners to implement recommendations if communication researchers focus on effect-based definitions (e.g., defining fear appeal as message strategies that can increase

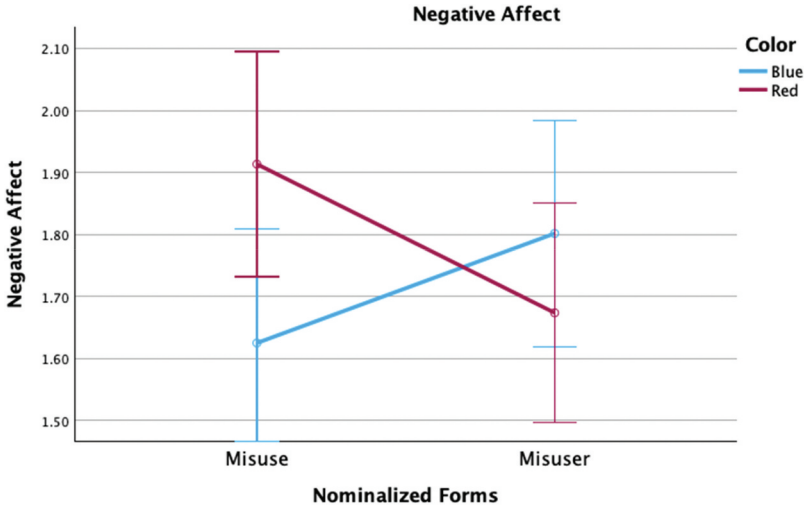

Figure 4. Interaction between nominalized form and color in negative affect. *Notes*. Covariates appearing in the model are evaluated at the following values: Evaluation of the fact sheet = 9.45 Error bars: 95% CI.

fear). In contrast, the three message design features examined in this study (i.e., agency assignment, nominalization, and color) are easy to understand and implement in evidence-based health communication by health practitioners. Health communicators should consider emphasizing bacterial agency over human agency to enhance perceived efficacy without inducing freedom threat (Ma & Miller, 2021). Using activity nouns instead of actor nouns may help avoid identity-based defensiveness while still conveying the importance of behavioral change (McGlone & Glowacki, 2018). Additionally, careful management of color choices is necessary, particularly avoiding red in contexts where reactance is a concern (Elliot et al., 2007, 2011). By integrating these considerations into public health campaigns, communicators can create more effective messages that promote antibiotic stewardship without triggering unintended resistance to behavioral change. While individual message features—such as agency assignment, nominalization, and color cues—may exert limited standalone effects, their strategic combination can meaningfully influence audience perceptions of message efficacy and processing. Notably, the observed interaction effects underscore the importance of designing health messages in which linguistic and visual elements function synergistically rather than in isolation. These findings contribute to a growing body of work emphasizing the nuanced role of message design in public health communication and suggest that thoughtful coordination of multimodal elements may enhance persuasive impact.

Beyond the practical implications for message design, these findings also speak to the dual-processing model, which suggests that the same feature may invite central or peripheral processing contingent upon an audience's state. Our results align with a more flexible interpretation of dual processing, in which multimodal features serve as opportunity structures for elaboration or heuristic responding. From this perspective, the contribution of multimodal design lies not in predetermining processing outcomes, but in creating conditions that make different processing modes possible. This finding may advance dual-processing theory by emphasizing the importance of audience states in shaping how multimodal cues are taken up.

Despite its contributions, this study has several limitations. First, the sample was predominantly White and educated, limiting generalizability to more diverse populations, particularly those with different cultural or linguistic sensitivities to health messaging. Future research should explore whether these effects hold across different demographic groups (Nadimpalli et al., 2021). Second, while the study identified key interaction effects, it remains unclear why certain combinations produced the observed effects. Follow-up studies incorporating qualitative measures could provide deeper insights into participants' reasoning and emotional responses. Third, although the sample size met the requirements of our power analysis, the complexity of the measurement model relative to the available sample may have influenced model fit indices. As such, while the CFA demonstrated acceptable item–factor relationships and improved fit following theoretically justified modifications, these results should be interpreted with some caution. Future studies with larger samples are encouraged to further confirm the stability of the factor structure and fit of the measurement model. Fourth, the focus of freedom threat was driven by an interest in face threat and perceived constraint, particularly in the context of health messaging. However, we acknowledge that including a more comprehensive measure of reactance would provide a comprehensive understanding of audience responses. Future research could consider incorporating validated multi-item reactance scales to better capture the interplay between message framing, autonomy threat, and emotional resistance. Additionally, as prior research suggests, the interplay between agency assignment and freedom threat may be context-dependent, warranting further investigation across different health domains (McGlone et al., 2023). Fifth, a marginal main effect of agency assignment was observed on perceived freedom threat, such that participants in the human-agency condition reported slightly higher levels of freedom threat than those in the bacteria-agency condition ($p = .05$). This finding is theoretically consistent with the notion that attributing blame to humans may elicit stronger feelings of interpersonal pressure or face threat. However, given the lack of significant differences across other outcome variables, this result should be interpreted with caution. It might be possible that the observed effect is sample-specific or due to random variation. Future research is needed to further examine the conditions under which agency framing may influence perceived threat or resistance. Finally, given the ongoing public health discourse on antibiotic resistance, participants' prior exposure to related messaging (e.g., during COVID-19) may have influenced their reactions (Zhao et al., 2024). Future research could account for message fatigue and prior health communication exposure to refine message effectiveness.

Overall, this study highlights the importance of considering both linguistic and sensory elements in health message design. While no single feature had a uniformly positive effect, the interplay of message elements significantly influenced health beliefs and behavioral intentions. These findings emphasize the value of strategic, evidence-based health communication approaches that balance persuasive intent with potential perceived freedom threat, ultimately improving public engagement with antibiotic stewardship efforts. Furthermore, building on the work of McGlone et al. (2013) and Bell et al. (2014a), this study provides further evidence that agency assignment in health messaging can contribute to both persuasion and resistance. Additionally, research by O'Keefe (2003) suggests that subtle variations in message structure can have significant downstream effects on how public health risks are understood and acted upon. These insights highlight the need for clear and strategic communication to influence public perceptions and behaviors, making health messages persuasive while limiting perceived freedom threat and unintended negative effects.

Disclosure statement

No potential conflict of interest was reported by the author(s).

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Appendix

Educational fact sheet about antibiotic resistance for the bacteria agency (linguistic agency)/antibiotic misuse (nominalized forms)/blue (color cue) experimental conditions.

The Risks of Antibiotic-Resistant Bacteria

Antibiotic resistance, also referred to as antimicrobial resistance, is recognized as a growing threat. It occurs when germs like bacteria and fungi develop the ability to defeat the human body and drugs designed to kill them.

Antibiotics can save lives, but antibiotic misuse can contribute to the development of antibiotic resistance. Resistant bacteria infect people, causing them to encounter serious health consequences. Bacteria associated with antibiotic resistance spread among people across continents. Each year in the U.S., serious forms of antibiotic-resistant bacteria invade more than 2.8 million people, and kill at least 35,000 of them.

Antibiotic Misuse

Antibiotic-resistant bacteria can take advantage of people's inappropriate antibiotic consumption. Antibiotic misuse happens when a person is prescribed antibiotics when they're not needed, such as for colds and flu. Under this situation, the antibiotic misuse may create the "superbug," which will be difficult to kill in the future.

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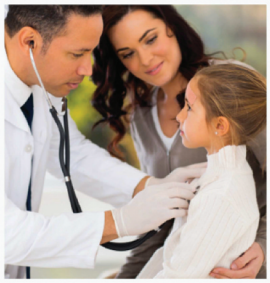
Antibiotic misuse also happens when a person is taking antibiotics for infections that are sometimes caused by bacteria that do not always need antibiotics, like many sinus infections and some ear infections. Such antibiotic misuse is likely to cause side effects ranging from minor to very severe health problems.



Antibiotic Stewardship

Antibiotics aren't always the answer when a person is sick. Antibiotic stewardship can help fight off antibiotic resistance. It's important to use antibiotics ONLY when they are needed in order to protect people from harms caused by antibiotic misuse and combat antibiotic resistance. Therefore, antibiotic use needs to come under the monitor of healthcare professionals:

- Take antibiotics only as prescribed
- Talk with healthcare professionals if any side effect is developed
- Stay healthy and keep others healthy by cleaning hands and getting recommended vaccines

National Association of Health Services

Educational fact sheet about antibiotic resistance for the human agency (linguistic agency)/antibiotic misuser (nominalized forms)/red (color cue) experimental conditions.

Human Infection of Antibiotic-Resistant Bacteria

Antibiotic resistance, also referred to as antimicrobial resistance, is recognized as a growing threat. It occurs when the human body and designed drugs lose the ability to kill germs like bacteria and fungi.

Antibiotics can save lives, but antibiotic misusers can contribute to the development of antibiotic resistance. People contract resistant bacteria, causing themselves to encounter serious health consequences. Individuals spread antibiotic-resistant bacteria across continents. Each year in the U.S., more than 2.8 million people catch serious forms of antibiotic-resistant bacteria and at least 35,000 of them die.

Antibiotic Misuser

People can contract antibiotic-resistant bacteria when practicing inappropriate antibiotic consumption. An antibiotic misuser appears when a person is prescribed antibiotics when they're not needed, such as for colds and flu. Under this situation, the antibiotic misusers may create the "superbug," which will be difficult to kill in the future.

National Association of Health Services

An antibiotic misuser also appears when a person is taking antibiotics for infections that are sometimes caused by bacteria that do not always need antibiotics, like many sinus infections and some ear infections. Such antibiotic users are likely to suffer from side effects ranging from minor to very severe health problems.

Antibiotic Stewardship

Antibiotics aren't always the answer when a person is sick. Antibiotic stewardship can help fight off antibiotic resistance. It's important to use antibiotics ONLY when they are needed in order to protect people from harms caused by antibiotic misusers and combat antibiotic resistance. Therefore, antibiotic users need to come under the monitor of healthcare professionals:

- Take antibiotics only as prescribed
- Talk with healthcare professionals if any side effect is developed
- Stay healthy and keep others healthy by cleaning hands and getting recommended vaccines

National Association of Health Services