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Boosting human capacities: attitudes toward Human Enhancement and vaccination in the context of perceived naturalness and invasiveness

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Abstract
Vaccinations are instances of Human Enhancement (HE) because, as biotechnologies, they are capable of augmenting the human body's capacities. We hypothesized that vaccination refusal, as observed during the COVID-19 pandemic, indicates a belief system that also determines attitudes toward HE. Rejection of both may be linked to well-known motives: invasiveness and alleged unnaturalness. We tested the relationship between these two phenomena by conducting two online surveys ($N = 314$ and $N = 300$; 81.5%/85.7% vaccinated against SARS-CoV-2 and 18.5%/14.33% not). We also examined if getting enhanced (vaccinated) can induce a relational change toward the environment. Study 1 suggested that greater willingness to use methods to enhance cognitive abilities was more likely when methods must be infrequently used and were deemed natural and non-invasive. An affirmative attitude toward naturalness correlated negatively with the willingness to use. Interaction effects suggested increased importance of naturalness and invasiveness associated variables for unvaccinated participants. Interacting with vaccination status, affirmative attitudes toward naturalness were negatively associated with attitudes toward vaccinations and HE. Qualifying vaccination as HE did not reliably predict attitude toward vaccination or HE. Getting vaccinated led to psychological relief. We explored predictors of vaccination intention. Study 2 showed that unvaccinated perceived the vaccine as less natural but as invasive as vaccinated participants. Perceived naturalness and invasiveness were decisive for vaccination refusal. Findings suggest that rejecting vaccination against SARS-CoV-2 may indicate motives associated with rejecting other HE means and may be a valuable behavioral sample to assess a person's broader belief system.

Keywords Cognitive enhancement · Human enhancement · Naturalness · Vaccinations · Vaccine hesitancy

1 Introduction

Vaccination, intended to improve the natural capacity of the human body, is an example of *Human Enhancement* [1]. This term is used to describe techno-scientific interventions intended to create improved, optimized, or even "better" humans [2–4]. Vaccination exemplifies that one of the key aspects of the embodied technologies employed in Human

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Enhancement is that they are done to ourselves [5].[1] The human target renders the related ethical arguments notoriously utopian or dystopian [4, 5, 7, 8]. Hence, Human Enhancement is a highly controversial phenomenon [4, 9].

Effective April 2023, ~ 13% of the German population older than 18 years have not received any dose of vaccination against SARS-CoV-2 [10]. Even after the extended costless availability of different and far-reaching advertising campaigns, some people refused to receive this enhancement.[2] To increase vaccination uptake, it has been proposed that vaccination advertising campaigns should be tailored to the moral foundation and worldview of the target audience [12, 13]. This requires an understanding that goes beyond the superficial notion of vaccination as a disease-fighting measure everyone should be happy to embrace. Supposing that vaccine skepticism reflects strong core beliefs about the association between agency, nature, spirituality, and individual health [14], this paper seeks to investigate if and how these underlying beliefs are related to the attitude toward technological improvement (specifically, Human Enhancement). Given that Human Enhancement can transform the perception and experience of risk [2], vaccination amid a global pandemic seemed a convenient opportunity to explore the practical psychological effects of Human Enhancement in practice. Moreover, vaccination is a perfect example of how we employ Human Enhancement to adapt ourselves to a potentially hazardous environment [5].

Experts and laypeople can have diverging models and assessments of the ontology, functioning, and risks of vaccination [15, 16]. In scientific and public discussions, how we talk about technical concepts matters [17]. A more differentiated perspective on vaccination as Human Enhancement can improve our understanding of both phenomena and inform the public and policymakers on two highly polarizing issues. Future vaccination campaigns or other mass distributions of Human Enhancement may benefit from a comprehensive overview of possible criticism and conceptual clarity.

Numerous scholarly works have thoroughly examined attitudes towards each subject [18–22], and some authors have raised the issue of classifying vaccination as Human Enhancement [e.g., 1, 6, 23, 24]. However, the current literature has not established a direct empirical link between attitudes toward vaccination, vaccination behavior, and attitudes toward Human Enhancement. To our knowledge, and besides a small pilot study [1], this article is the first attempt to close this gap.

2 The Human Enhancement debate

The debate on Human Enhancement is characterized by a diversity of definitions [25]. Some conceptualizations focus on interventions that surpass the conventional boundaries of human abilities, while others consider the natural functioning of humans as the normative benchmark. Alternative approaches posit that any form of augmentation, regardless of degree, can be categorized as Human Enhancement [25]. The proportion of historical and contemporary techniques/technologies considered Human Enhancement varies depending on the definition used [1, 6, 26]. These "conventional," "natural," or "historical" examples may be seen as less morally suspicious [6, 27, 28]. Nevertheless: Human Enhancement is a fundamental aspect of how we live [29]. Besides all these aspects, Human Enhancement serves the overarching goal of adapting ourselves to the demands placed upon us rather than modifying the environment to mitigate the same demands [5]. In the case of vaccination, this means that instead of adapting the environment to stop disease transmission (e.g., travel restrictions, material obstacles to ensure social distancing), we are intervening with the human body to boost its defense capabilities against the same disease.

In use for centuries, vaccination exemplifies that "historical" does not automatically mean "uncontroversial" [1]. What qualifies vaccination as an instance of Human Enhancement is using (bio)technology to improve human defensive capabilities to a level they do not possess [1]. Although vaccination is not usually explicitly referred to as Human Enhancement, reasons to reject Human Enhancement in general, and vaccinations, in particular, may be two sides of the same coin [1]. Some, for instance, consider the technological process of introducing synthetic biology in vaccination development as an act of "playing God" [15], an all too familiar accusation leveled against specific enhancements and their biotechnological realization [9, 30–33].

[1] Mass distribution of vaccination can of course create positive network effects by mitigating further spread of the disease [1, 6] Still, it is at foremost an intervention that targets a single human being.

[2] 67.5% of the population of Europe and parts of Asia (e.g., Russia, Turkey, Kazakhstan) have at least received one dose of vaccination against SARS-CoV-2 [11].

Critics of Human Enhancement fear backfiring and disastrous side effects such as alienation from our not enhanced peers, losing what makes us human, and sealing the end of our species [7, 27, 31, 34, 35]. The American President's Council on Bioethics warned against the hubris and disrespect of the given if humans consider treating their bodies and minds as mere raw materials open to deliberate manipulation [9]. On the other hand, advocates stress the importance of exploring different modes of being [8] and the beneficial effects of widespread enhancement [36]. The potential for improved performance through Human Enhancement was acknowledged from commercial [37] and military perspectives [38, 39].

Empirical evidence on public attitudes shows that people are concerned about safety, social coercion, and fairness [40]. These arguments translate into a seemingly moderate to strong negative public opinion on Human Enhancement [41]. Laypersons and medical professionals acknowledge certain issues discussed in the academic debate (e.g., losing our humanness, issues of personhood). However, these abstract concerns are often overshadowed by more concrete worries about safety and personal side effects [33, 42–44]. Yet, a recent apprehension is that extreme situations like pandemics function as a backdoor that may render ethically more suspicious forms of Human Enhancement more acceptable [45].

Reflecting on the debate about the overarching concept of Human Enhancement, the discourse surrounding vaccination, with all its hopes and concerns, builds on one central premise: It is considered possible to influence the condition of an individual significantly and eventually an entire species through the use of (bio)technology [1]. The decisive factor is how this goal and the employed means are evaluated.[3]

2.1 The role of (perceived) naturalness

People were found to be less accepting of unknown pharmaceutical pills than natural supplements when used by employees and were less likely to use them themselves. However, there was no difference compared to pharmaceutical pills explicitly framed as safe [47]. Naturalness was an important factor in the moral evaluation of cognitive enhancement, but only when framing the means as explicitly natural or artificial [18]. Marteua et al. [48] report that 41% of their participants would enhance intelligence in their future child using vitamin supplements, but only 11% would employ genetic engineering for the same outcome. Furthermore, research suggests a preference for natural painkillers over their synthetic counterparts [49]. Importantly, these drugs may also fall into the realm of Human Enhancement.

Individual purity concerns, i.e., an aversion against acts considered 'unnatural' or suspected to violate the sanctity of something, play a crucial role in the negative evaluation of cognitive Enhancement [50, 51] and vaccination [12]. Naturalness bias and the belief that natural immunity is superior to vaccination-induced immunity hinder vaccination intention and behavior [52–56]. Perceived unnaturalness is also prevalent in online discourse among vaccination critics [57, 58].

But as with Human Enhancement [25], there is conceptual confusion about what naturalness means. The term may refer to the properties of an object or describe its history [13, 59]. Inconsistent use of the term may contribute to differences in how experts and laypersons understand it in the context of vaccination [15]. The debate over "natural" versus "unnatural" methods of Human Enhancement parallels this confusion [6, 27]. Yet, in both cases, nature is used as a moral standard to evaluate the moral value of technological interventions [60].

2.2 The role of (perceived) invasiveness

People are more reluctant to an enhancement if the method is invasive [18, 47, 51, 61, 62]. One study found that the mode of administration influenced the moral perception of different cognitive enhancement means, with injection being evaluated more negatively than beverages [18].

Efforts to supply vaccination by injection can be tempered by fear of needles [63], and more disgust toward injections was identified as related to one facet of anti-vaccination attitudes [64]. Furthermore, some arguments raised by the anti-vaccination movement build on the alleged detrimental effects of the vaccine [57], which can—logically speaking—only be exercised from within the body. As vaccination is often applied by injection, the association of literally piercing the fleshly boundaries of the bodily self may negatively modulate the reluctance to this type of intervention [65]. Hence, their evaluation may also reside in the broader moral significance attached to invasiveness, which may also transpire in the assessment of other forms of Human Enhancement.

There is an apparent focus within the ethical debate of Human Enhancement on those interventions that directly cross the line between what is considered "outside" and "inside" [27]. This focus has been criticized in the past [5, 6, 26,

[3] For a comprehensive overview about the philosophical debate see [4, 27, 46] and for a review on empirical found concerns see [40, 41].

66]. Still, the debate on Human Enhancement prominently features controversial technologies like genetic engineering, "smart drugs," and invasive brain-computer interfaces, which share a unifying trait: they only function from "within."

3 Hypotheses

The snapshot from the literature fosters the impression that some reasons to reject vaccination mirror general concerns against Human Enhancement. Yet, because vaccination is a manifestation of the overarching concept of Human Enhancement, these concerns are, conceptually speaking, derivations instead of parallels. Both phenomena aim to intervene with the individual body and directly concern important aspects such as autonomy, health, and the relationship between nature and technology. Thus, rejecting a tangible manifestation such as vaccination (e.g., against SARS-CoV-2) is supposed to be indicative of beliefs that also influence the attitude toward Human Enhancement in general. Hence, vaccination behavior should be a meaningful predictor of attitude toward Human Enhancement. Conceptually plausible, this link is testable and demands further empirical inquiry to assess the existence and strength of associations.

A stark hypothesis arises: People who reject a vaccination against SARS-CoV-2 do so mainly because they see it as an unnatural and invasive technological intervention. This rejection, grounded in derivations of concerns against Human Enhancement in general, may be generalized to vaccination behavior against other diseases. However, we must also account for the qualification of vaccination as an instance of Human Enhancement and reasons to reject technological interventions in general. Hence, seen more differentiated, while also acknowledging other important reasons for vaccination hesitancy [21] and the presence of a fundamental belief structure that may underly this behavior [14, 64], we can reformulate this hypothesis as follows: *Reasons for rejecting vaccination against SARS-CoV-2 may be linked to a pronounced emphasis on perceived invasiveness and naturalness. As these factors are also negatively linked to attitudes toward Human Enhancement, these derivations of general concerns about technological improvement might explain vaccination reluctance among the unvaccinated, but also possible rejection of Human Enhancement (H1)*."

Vaccination status is conceived as an indicative behavioral sample for the underlying belief system. When evaluating whether to pursue interventions with the human body, the suggested "pronounced emphasis" should show itself in an intensification of the negative roles of invasiveness, respectively, an intensification of the positive role of perceived naturalness / negative role of unnaturalness. Translated and operationalized to a testable setting, people who reject vaccination against SARS-CoV-2 should demonstrate a different perception and higher affirmation of what is deemed natural [see 56]. Hence, it must be explored how rejection of vaccination is situated within the broad debate about the relationship between humans and nature and how persons evaluate different interventions and phenomena. Suppose vaccination skepticism indicates a fundamental belief about a "natural" approach to health [14]. In that case, this behavior should be positively associated with rejecting other means of technological interventions, especially if they are deemed unnatural. Moreover, we expect that attitudes toward Human Enhancement and vaccination should be negatively linked with a high affirmation of naturalness in general.

In light of the invasive nature of vaccinations and the documented correlation between aversion against invasiveness and vaccine hesitancy [64], we also anticipate that for individuals who remain unvaccinated against SARS-CoV-2, negative effects of perceived invasiveness on the adoption of other means of Human Enhancement should be more substantial.

Perceived unnaturalness and invasiveness are not seen as unimportant for vaccinated people. Nonetheless, we expect meaningful differences between people vaccinated against SARS-CoV-2 and those who are not. Suppose the influence of perceived naturalness and invasiveness is moderated by vaccination status against SARS-CoV-2. In that case, the conclusion that concrete vaccination behavior is partially linked to a stronger emphasis on the related variables is supported. By examining the influence of these motives, we can evaluate whether they are as fundamental as suggested. Our hypothesis also suggests a differing perception of the invasiveness and naturalness of vaccination among vaccinated and unvaccinated and that these perceptions are decisive for vaccine refusal.

Evaluating the psychological effect of vaccine application, we must first note that the necessity to vaccinate presupposes a certain vulnerability and individual or societal risk. This risk is neither completely subjective nor objective but results from the relationship between the individual and the socio-material environment [2]. Indeed, a perception of low risk was also linked to vaccine hesitancy [21]. Human Enhancement may influence this relationship and transform risk and its perception [2]. Put very broadly, a potential transformation of risk means that besides improving a given capacity, *Human Enhancement can also constitute an altered relationship between oneself and the environment (H2)*. We discuss the theoretical foundation of this claim elsewhere and state that the relation-altering capacity of Human Enhancement is one of its most defining features [5]. To operationalize this hypothesis, it is essential to employ a measurement that

assesses whether and how implementing the enhancement (vaccination) alters an individual's subjective perception and evaluation of their environment. Although some fear the power of Human Enhancement to cause irreparable damage to values and relationships [9, 67], the question seems not to be about whether we should change our relationship with the environment but rather about which changes are desirable [2]. This societal discourse will benefit from insights into how exactly specific enhancements affect the relationship of individuals to themselves and their environment.

4 Study 1

We approach the hypothesized connection between Human Enhancement and vaccination attitudes through the lens of the assumed importance of naturalness and invasiveness. By considering vaccinations within the framework of Human Enhancement, we seek to contribute to the ongoing discussion and emphasize the significance of comprehending the motivations and evaluations surrounding a diverse range of enhancements [41, 68]. Besides the possible elucidation of motives for individual vaccine hesitancy, this study may enrich the empirical debate about Human Enhancement by linking the abstract with the concrete and clarifying how attitudes toward "conventional" enhancements like vaccination relate to more futuristic examples. It may further demonstrate the robustness of previous findings on adopting means of Human Enhancement. Lastly, we may be able to locate the rejection of Human Enhancement in a broader system of attitudes and beliefs.

To better situate the belief system of those who reject the SARS-CoV-2 vaccine despite its widespread availability and public awareness of the pandemic in early 2022, we collected data on a broader range of controversial phenomena. This allows assessing beliefs associated with vaccination behavior beyond the "classic" examples like low-risk perception, structural barriers, or safety and efficacy concerns [21].

In a previous study [1] with $N = 67$ (97% vaccinated against SARS-CoV-2 or willing to do so), participants were asked to rate different examples of their qualification as an instance of Human Enhancement. To further investigate public opinion on this issue, we wanted to include a more heterogeneous sample with the number of unvaccinated participants corresponding to the proportion in Germany when the present study was conducted.

4.1 Methods

4.1.1 Participants

An online survey was completed by $N = 316$ persons. Two people were excluded because they indicated they were only checking out the survey or felt compelled to give incorrect answers. No other exclusions were made. The complete dataset comprised $N = 314$ persons (*Male* = 134, *Female* = 172, *Other* = 6, *NA* = 2; $M_{Age} = 34.9$ [Range: 16–65] years). One participant's age was coded *NA* due to its initial statement of being over 120 years old. However, other answers of the participants were not overly suspicious.

We recruited participants from various sources (University e-mail-System, Facebook, Twitter, Reddit, and online survey distributors). To recruit unvaccinated participants, we posted the survey link to several Facebook groups whose names and descriptions suggest a critical attitude towards disease control measures of the corona pandemic or vaccination per se. We also reached out to groups that discussed the SARS-CoV-2 pandemic in general and those that discussed alternative and naturopathic medicine. We are aware of the possible bias through online recruitment, especially regarding anti-vaccination discourse [57, 58]. This method was chosen to spread the survey beyond the usual psychological student-for-course-credit samples, which were also suspected of holding more favorable attitudes toward vaccination. Limitations are discussed in more detail at the end of the paper.

Overall, 256 individuals (81.5%) reported having received at least one vaccination dose against SARS-CoV-2 (*Vaccinated*), and $n = 58$ (18.5%) did not receive vaccination against SARS-CoV-2 (Unvaccinated).[4] At the end of the data sampling, the proportion of German citizens above 18 years who had received at least one dose of vaccine against

[4] This terminology can only be interpreted in regard to the vaccination against SARS-CoV-2. We have no information on whether people have received any other vaccination in their lifetime.

Table 1 Presented means of memory enhancement

Intervention type	Coded application frequency
Administration of a drug in the form of pills*	Once | Daily
Injection of a drug into the arm*	Once | Daily
Administration of a plant-based drug*	Once | Daily
Brain surgery	Once
Implantation of an electronic device into the brain	Once
Completion of a cognitive training program	Once
Special raw food diet	Frequent
Daily meditation	Daily

In the case of Brain surgery, Implantation of an electronic device, completion of a cognitive training program, and raw food diet frequency were not explicitly mentioned but coded afterward. The other interventions were presented and assessed with the respective explicitly named frequencies. *=Intervention was included in the "Interventions with parallel frequencies" model (Table 4). These interventions are also more "classical" examples of Human Enhancement. Heterogeneity of the examples is owed to the fact that there is no definitive definition of Human Enhancement. Depending on conceptualization, some examples do not qualify as Human Enhancement. Examples were chosen to be intuitively linked to memory enhancement and to reflect different conceptualizations as broadly as possible

SARS-CoV-2 was 84.8% [69]. So the ratio of vaccinated to unvaccinated persons in our sample approximated the ones in the overall population.

4.1.2 Measures

If not stated otherwise, items used a 7-point Likert scale on which the maximum represented the highest affirmation. A complete list of questions asked is provided in the Supplementary.

Enhancement rating (15 items)*:* Similar to a previous study [1], participants were introduced to the concept of Human Enhancement. They were told that this term has no standard definition but generally refers to technologies that help expand people's abilities. Participants rated different phenomena on whether they represented an example of Human Enhancement. The examples were self-collected based on what is discussed as an instance of Human Enhancement in the literature and under different conceptualizations.[5]

Attitudes on ethically controversial topics (10 items): People were asked to state their attitude toward phenomena like Human Enhancement, vaccination in general, space colonization, and genetic manipulation of animals, plants, or humans ("Based on what you personally know about the following topics and what is reported in the media. What is your attitude toward:…"). Phenomena were selected to represent practical yet ethically controversial topics, examine potential distinctions between vaccinated and unvaccinated individuals, and gain a deeper understanding of the beliefs held by the unvaccinated.

Willingness to use: Participants were introduced to the following scenario: *Imagine the possibility of changing your memory to the extent that exceeds your current level by far. You would remember things much better and would no longer have to rely on shopping lists reminders on your cell phone or calendar. You would also find it much easier to learn new things. Which of the following means would you use for this? All methods have the same effect and have no adverse side effects.* They were then invited to state their *willingness to use* different means for their benefit and rated how *invasive* and *natural* they perceived these interventions. These variables were meant to examine whether their effect differed across people vaccinated against SARS-CoV-2 and those who were not, i.e., if we can assume a different emphasis. Intervention examples were chosen to reflect a mixture of invasive and natural means to improve cognitive abilities that, depending on the conceptualization [25], qualify as instances of Human Enhancement (Table 1). Measuring the willingness to use an enhancement is common when assessing attitudes toward Human Enhancement [see 33, 44, 62, 70, 71].

[5] Depending on employed conceptualization, some examples would not qualify as Human Enhancement. We nevertheless attempted to map the debate as broad as possible.

Naturalness attitude (7 items)*:* This self-developed scale was meant to reflect on the subjective evaluation of naturalness and an affirmative relationship toward nature. The intention was not to invoke a specific notion of naturalness but leave the interpretation of this term to the participants. Examples: "How much do you agree on the following statements:… What is natural is also good; Humans and nature have separated too much; The so-called conventional medicine (Schulmedizin) is unnatural" This scale was employed to clarify an individual's relationship towards nature and naturalness. Items were inspired by arguments in the back-then COVID-19 discourse [e.g., 72] and tropes in the general Human Enhancement debate [e.g., 4, 73].

Vaccination status, intention, and COVID: People were asked for the number of vaccination doses they have received against SARS-CoV-2, how many they are planning to get in the future (absolute amount), and if they are generally concerned with keeping their vaccination status against other diseases updated.[6] Current and planned vaccinations were accessed categorically (0–3 doses) with the possibility to answer by free text. Participants also indicated whether they were confirmed to be infected with SARS-CoV-2 (Y/N) and how much they identified with their vaccination status. Vaccination status was meant to measure vaccination hesitancy/behavior and related attitudes directly.

Effects of vaccination status (11/9 items): The scale was self-developed and was meant to reflect on the psychological effects of vaccination. It was employed to reveal how enhanced (vaccinated) participants negotiate the relation between themselves and the environment. Example: "Based on the number of doses of vaccine you have received to date against SARS-CoV-2 (coronavirus), how true are the following statements about you: My social environment reacts negatively to my vaccination status." Items were inspired by discourses about individual participation and discriminating experiences based on vaccination status. Higher values suggest more positive effects.

Support of disease control measures (12 items)*:* Examples were self-collected based on what has been discussed to contain the pandemic (general vaccine mandate) or were employed in various countries, including Germany. The scale was meant to clarify whether unvaccinated participants only reject the vaccination or are generally critical against any disease control measures. Example: "I support the following government actions around the spread of coronavirus: mask mandate; curfews".

Improvements after the first (possible) dose (5 items)*:* People were asked if their feelings right after the first vaccine dose improved or worsened compared to the time before. ("Compared to when you did not receive a vaccine dose, how much did your feelings, thoughts, and behavior change at the time just after you received the first vaccination?"). Participants who had not received a vaccination were instructed to refer to the time when they were theoretically able to get vaccinated. Values below four indicated a worsening; four indicated no change, and ratings above indicated an improvement. It was meant to explore how the administration of an example of Human Enhancement influenced the perception and experience of participants amid a pandemic. Any change within the vaccinated suggests a relational change compared to the "pre-enhanced" self.

4.1.3 Procedure

To test our hypotheses, we conducted an online study using *LimeSurvey* [74] that was in full accordance with the ethical guidelines of the University of Bamberg. The link was distributed by the sources mentioned in the *Participants* section. It was approved by an umbrella evaluation for psychophysical testing of the university of Bamberg ethics committee (Ethikrat der Universität Bamberg) on August 18, 2017.

After consenting to the use of their data, participants filled out sociodemographic information and completed the measures as stated above. University students and participants from online survey distributors could apply for course credit or other benefits from the particular website. The survey language was German. Data sampling occurred from January 1st, 2022, to January 14th, 2022. Data analysis occurred once the sampling was stopped at $N = 316$.

4.2 Results

Data analysis was primarily conducted with *R* (4.2.2). Models were calculated using the *brms* library (2.18) [75]. Bayesian models ran four sampling chains, 10,000 iterations, with 5,000 warm-up iterations each. When equality of variance was not present, degrees of freedom were corrected using the Welch approximation. All *p*-values are two-sided. If not stated otherwise, data from all 314 participants were included.

[6] At the time of data sampling, people vaccinated with a single dose of Janssen® by Johnson & Johnson had the legal status of being fully vaccinated. Participants were instructed to count a first dose of this vaccine as two and add subsequent doses by one.

Table 2 Distribution of vaccination status

Received doses of vaccines at the time of the data sampling		
0 Doses	58	Sum of unvaccinated people: 58
1 Dose	4	Sum of vaccinated people: 256
2 Doses	65	
3 Doses	187	
Planned number of doses		
0 Doses	54	
1 Dose	0	
2 Doses	18	
3 Doses	132	
3 + Doses	20	
As much as needed	74	
Undecided	3	
NA	13	

Many people used the free-text option to answer the question about the planned vaccinations, stating that they either consider getting as many vaccine doses as needed or required (as needed) or a specific number of doses greater than three (3 +). Some people were unsure (undecided) or left an incomprehensible answer (*NA*). Eight participants (2.55%) reported that they planned to receive fewer doses than they already had. It is possible they misread the question and stated the relative amount of planned doses, not the absolute. Their planned vaccine doses were also coded *NA*

4.2.1 Overview and rationale of analysis

After a descriptive account of vaccination status during sampling and intended doses (*Current and planned vaccinations*), we proceed with internal consistencies and differences between unvaccinated and vaccinated participants (*Scales and comparison between vaccinated and unvaccinated*). We conducted these analyses to investigate whether unvaccinated individuals exhibit more positive attitudes toward nature. Additionally, we aimed to contextualize the decision to reject vaccination within broader controversial discussions and the COVID-19 discourse. Subsequently, we aimed to examine the psychological effects of receiving the vaccine by analyzing the self-reported psychological effects of getting vaccinated.

To better understand public perception, we compared ratings on whether a phenomenon qualifies as Human Enhancement (*Human Enhancement Ratings*). We aimed to shed light on a possible gap between academic and public perception of the issue and determine what interventions might be relevant to the general discourse.

Hereafter, we investigated whether vaccination status indicates a stronger emphasis on perceived naturalness and invasiveness and how this relates to the willingness to use other means considered Human Enhancement. This was done by examining the willingness to use means for memory enhancement and potential differences between invasiveness and naturalness ratings of the same interventions (*Willingness to use, perceived naturalness, and perceived invasiveness of cognitive enhancement methods*).

We then analyzed potential parallels between predictors of attitude towards vaccination and Human Enhancement. This was mainly done to clarify the role of the suspected importance of the general attitude toward naturalness for unvaccinated participants and to investigate if participants reject vaccination because they see it as Human Enhancement (*Attitude toward vaccination/Human Enhancement*).

We lastly, predicted future vaccination intention (*Vaccination intention – More doses?/Exact number of doses*) to further elaborate on the importance of naturalness attitude and attitude toward Human Enhancement and vaccination for prospective vaccination behavior. Here, we also examined whether the perceived benefits of the vaccination predict the intention to receive more. For readability and because this question was not the decisive factor for this study, most of the related analyses and discussion can be found in the Supplementary.

4.2.2 Current and planned vaccinations

Table 2 shows the distribution inside the groups. Figure 1 shows the association between current and planned received doses in the absolute amount of received and planned doses. A comprehensive overview can be found in the Supplementary.

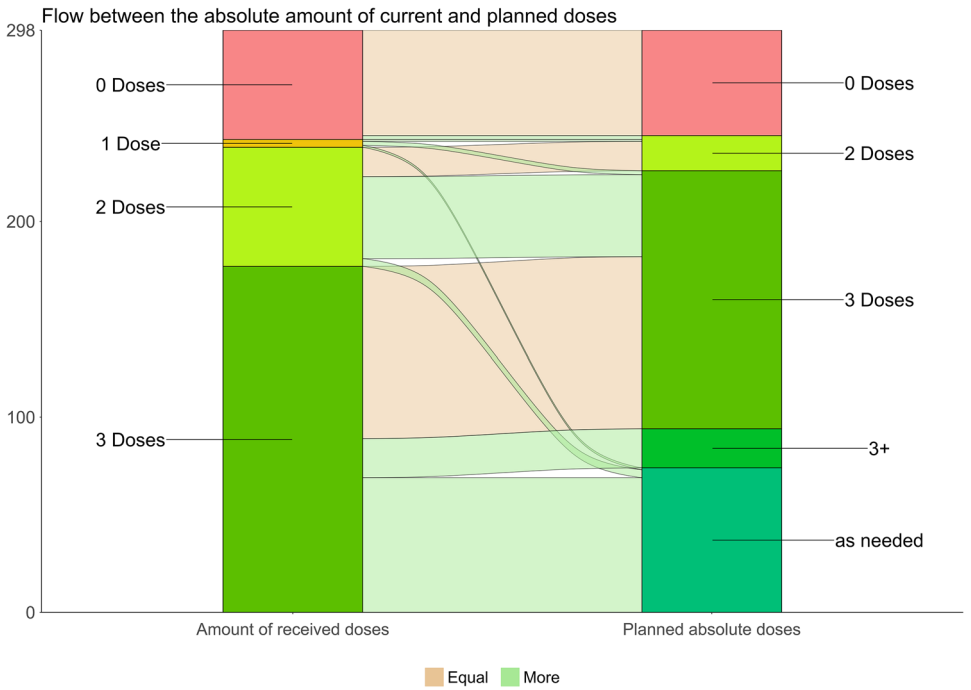

Fig. 1 Association between the absolute received and absolute planned doses. NA's and "Undecided" of planned doses are not shown. Of the three undecided persons, one had received three, one two, and one zero doses. Hence, n = 298. Complete numeric overview is provided in the supplementary

4.2.3 Scales and comparison between vaccinated and unvaccinated participants

Sum-scores of the effects of the vaccination status (internal consistency, Cronbach's α = 0.76, Confidence Interval = $CI_{95\%}$ [0.72, 0.80]), improvements after (possible) first dose (α = 0.83, $CI_{95\%}$ [0.81, 0.86]), naturalness attitude (α = 0.79, $CI_{95\%}$ [0.76, 0.83]), and approval for disease control measures attitude (α = 0.94, $CI_{95\%}$ [0.93, 0.95]) were calculated. Some items were reverse-coded after the *check.keys* method of the R *psych* (2.1.9.) package [76] identified them as negatively correlated with the first component of the employed principal component analysis (PCA). Since the effects of the vaccination status scale contained items directly referring to the vaccination ("I feel better than before the vaccination," "I feel technologically enhanced"), these two items were dropped when analyzing sum scores between vaccinated and unvaccinated and resulted in a Cronbach's α = 0.72 $CI_{95\%}$ [0.68, 0.77]. An overview can be found in the supplementary. Table 3 shows selected differences, and Fig. 2 detailed answers to the improvements after the first (possible) dose scale for vaccinated participants only.

4.2.4 Human Enhancement ratings

Cybernetic prostheses ($M = 5.54$, $SD = 1.80$), Cochlear implants ($M = 5.46$, $SD = 2.01$), followed by neuroenhancement drugs ($M = 4.92$, $SD = 1.84$), were rated most exemplarily for being an enhancement among all participants (Max = 7). Vaccinations ranked eight of fifteen ($M = 3.51$, $SD = 2.25$). A graphical overview of the enhancement ratings is provided in the Supplementary.

Unvaccinated participants rated drugs to increase life expectancy ($t_{(312)} = -3.41$, $p < 0.001$, $d = -0.50$ [− 0.79, − 0.21]) and neuroenhancement drugs ($t_{(312)} = -2.32$, $p = 0.021$, $d = -0.34$ [− 0.63, − 0.05]) as less exemplarily for being an instance of Human Enhancement. There were no differences regarding the other phenomena (all $p > 0.09$), including vaccinations ($t_{(312)} = -0.63$, $p = 0.529$, $d = -0.09$ [− 0.38, 0.20]).

Table 3 Differences between vaccinated and unvaccinated participants

		Unvaccinated		Vaccinated		*t* (df)	*d* [CI95%]
		Mean	*SD*	*Mean*	*SD*		
Attitude toward…	Vaccination	2.76	1.58	6.47	1.00	− 17.12 (67.70)*	− 3.29 [− 3.67, − 2.90]
	Space colonization	2.69	2.00	3.65	2.02	− 3.28 (312)*	− 0.48 [− 0.77, − 0.19]
	Human interference with nature	3.40	1.46	4.02	1.40	− 3.03 (312)*	− 0.44 [− 0.73, − 0.15]
	Human Enhancement	3.43	1.69	4.75	1.32	− 5.60 (73.48)*	− 0.95 [− 1.25, − 0.66]
	Homeopathy	4.98	1.83	2.52	1.81	9.33 (312)*	1.36 [1.05, 1.66]
	Alternative healing practitioners	5.33	1.69	2.75	1.76	10.11 (312)*	1.47 [1.16, 1.78]
	Genetic engineering of plants	1.71	1.18	3.73	1.82	− 10.49 (126.5)*	− 1.17 [− 1.47, − 0.87]
	Genetic engineering of animals	1.28	0.77	2.49	1.62	− 8.50 (186.84)*	− 0.81 [− 1.10, − 0.51]
	Genetic engineering of humans	1.31	0.90	2.46	1.62	− 7.40 (152.82)*	− 0.76 [− 1.05, − 0.47]
	Anthroposophy	4.17	1.81	2.61	1.61	6.53 (312)*	0.95 [0.65, 1.25]
Vaccination status important for identity		3.62	2.53	4.16	2.04	− 1.51 (74.81)	− 0.25 [− 0.53, 0.04]
Support of disease control measures		25.38	14.91	62.14	13.60	− 18.25 (312)*	− 2.65 [− 3.00, − 2.30]
Naturalness attitude		37.22	7.91	26.97	7.83	8.99 (312)*	1.31 [1.00, 1.61]
Keeping up with vaccinations generally		3.03	2.19	5.08	1.81	− 7.46 (312)*	− 1.09 [− 1.38, − 0.79]
Improvement after the (possible) first dose		17.12	3.72	23.33	4.36	− 10.04 (312)*	− 1.46 [− 1.77, − 1.15]
Effect of vaccination status (reduced)		33.46	9.61	46.48	7.68	− 9.64 (74.36)*	− 1.61 [− 1.93, − 1.30]
I feel vulnerable		3.28	2.28	2.84	1.89	1.54 (312)	0.22 [− 0.06, 0.51]
I feel liberated		3.45	2.56	4.46	1.61	− 2.88 (67.60)*	− 0.55 [− 0.84, − 0.26]
I am relaxed as I go through the world		4.48	2.04	3.59	1.60	3.11 (73.81)*	0.53 [0.24, 0.82]
The disease appears less dangerous to me		4.22	2.36	4.06	1.89	0.49 (73.34)	0.08 [− 0.21, 0.37]
I feel left out		4.98	2.10	1.39	1.09	12.67 (64.12)*	2.70 [2.34, 3.06]

Indented items are exemplary items of the effect of the vaccination status scale. A graphical overview is provided in Additional file 1. *= $p < 0.05$, and the credibility interval of the posterior of mean differences does not include 0. *SD* = Standard deviation. *d* = Cohen's *d* with 95% confidence interval. Size of the effects according to Cohen [77]: 0.2–0.5: small, 0.5–0.8: medium, > 0.8: large. Max values: attitude toward items, vaccination status importance, keeping up with vaccinations, and indented items = 7; support of disease control measures = 84; naturalness attitude = 49; improvements after first possible dose = 35; effect of vaccination status (two items dropped) = 63. Welch approximation was conducted when degrees of freedom (*df*) are not 312

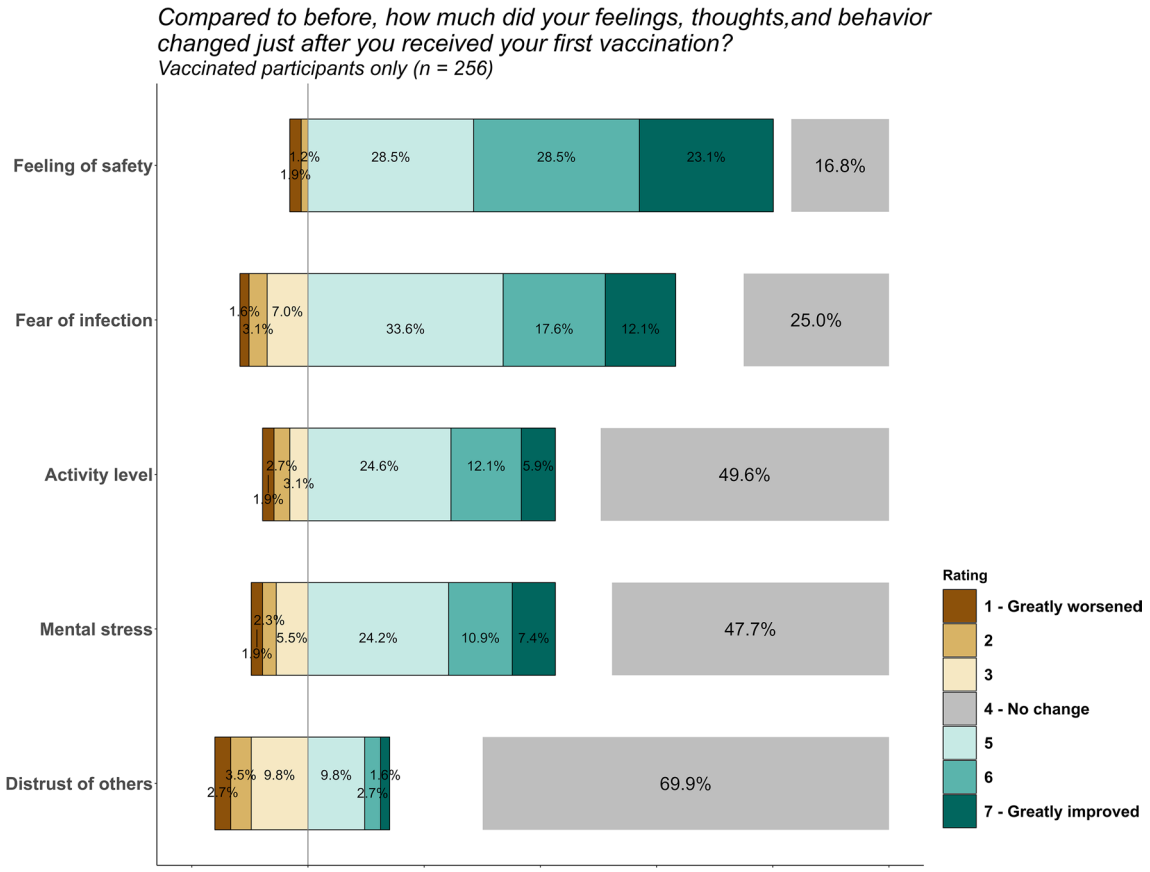

Fig. 2 Detailed answers of the Improvements after first (possible) dose scale for vaccinated participants only. We interpret responses to these items as indicative of the psychological effect of vaccination, i.e., Human Enhancement

4.2.5 Willingness to use, perceived naturalness, and perceived invasiveness of cognitive enhancement methods

Unvaccinated participants rated the one-time administration of a drug in the form of pills ($t_{(312)} = 5.90$, $p < 0.001$, $d = 0.86$ [0.56, 1.15]), one-time injection of a drug into the arm ($t_{(312)} = 6.67$, $p < 0.001$, $d = 0.97$ [0.67, 1.27]), one-time administration of a plant-based drug ($t_{(312)} = 2.91$, $p = 0.004$, $d = 0.42$ [0.13, 0.71]), daily administration of a drug in the form of pills ($t_{(312)} = 4.96$, $p < 0.001$, $d = 0.72$ [0.43, 1.01]) and the daily injection of a drug into the arm ($t_{(312)} = 3.85$, $p < 0.001$, $d = 0.55$ [0.27, 0.84]) higher in invasiveness than vaccinated participants. Credible intervals of posterior differences also did not include 0. There were no significant differences in the other examples (all p's > 0.09).

Concerning perceived naturalness, unvaccinated participants rated the one-time administration of a drug in the form of pills ($t_{(312)} = -4.07$, $p < 0.001$, $d = -0.59$ [− 0.88, − 0.30]), one-time injection of a drug into the arm ($t_{(312)} = -4.65$, $p < 0.001$, $d = -0.68$ [− 0.97, − 0.39]), daily administration of a drug in the form of pills ($t_{(312)} = -3.11$, $p = 0.002$, $d = -0.45$ [− 0.74, − 0.16]) and the daily injection of a drug into the arm ($t_{(312)} = -2.89$, $p = 0.004$, $d = -0.42$ [− 0.71, − 0.13]) as less natural than vaccinated participants. Credible intervals of posterior differences also did not include 0. There were no significant differences in the other examples (all p's > 0.06).

Ratings of willingness to use, perceived naturalness, and perceived invasiveness displayed a rating tendency to the extreme (Fig. 9). We chose a mixed-model Bayesian ordered cumulative regression to account for these non-Gaussian distributions. Attitude toward Human Enhancement, perceived invasiveness, perceived naturalness, application frequency, vaccination status, and interactions with vaccination status, except application frequency, were set as population-level effects. These effects represent effects that should be consistent across examples [78]. Participant and intervention type (left column Table 1, drugs, diet, etc.) were set as group-level effects. This allows for variation around group means that

Table 4 Estimates of willingness to use an intervention to boost cognitive performance

Predictor	All interventions					
	Model 1			Model 5		
	Odds ratio (OR; Median)	95% credible interval (CI)	pd	OR	95%CI	pd
Perceived invasiveness	0.76	0.72–0.81	100.00%	0.59	0.52–0.67	100.00%
Perceived naturalness	1.61	1.52–1.71	100.00%	2.24	2.00–2.52	100.00%
Attitude Human Enhancement	1.44	1.23–1.68	100.00%	1.41	1.05–1.88	98.60%
Naturalness attitude	0.97	0.94–0.99	99.20%	0.96	0.90–1.01	92.30%
Vaccinated	2.24	1.25–4.06	99.70%	1.77	0.13–24.39	66.20%
Vaccinated × perceived invasiveness				1.37	1.20–1.56	100.00%
Vaccinated × perceived naturalness				0.66	0.58–0.75	100.00%
Vaccinated × att. Human Enhancement				1.06	0.76–1.48	63.40%
Vaccinated × naturalness attitude				1.01	0.95–1.07	59.50%
Frequent use	0.72	0.08–6.86	62.20%	0.80	0.08–9.11	57.20%
One-time use	5.31	4.40–6.43	100.00%	6.1	5.04–7.38	100.00%
Group-level effects						
Sd (Intervention type)	3.34	2.07–10.10		3.99	2.32–14.49	
Sd (Participant)	5.47	4.64–6.62		5.83	4.91–7.06	
LOO-information criterion	9615.2 (112.0)			9448.7 (113.4)		
Predictor	Interventions with parallel frequencies					
	Model 6			Model 10		
	OR	95%CI	pd	OR	95%CI	pd
Perceived invasiveness	0.63	0.56–0.70	100.00%	0.55	0.43–0.69	100.00%
Perceived naturalness	1.87	1.68–2.09	100.00%	3.15	2.55–3.93	100.00%
Attitude Human Enhancement	1.84	1.39–2.44	100.00%	1.44	0.87–2.37	92.20%
Naturalness attitude	0.94	0.90–0.99	99.00%	0.88	0.81–0.97	99.70%
Vaccinated	7.80	2.83–22.83	100.00%	0.85	0.03–23.44	53.70%
Vaccinated × perceived invasiveness				1.20	0.92–1.56	91.10%
Vaccinated × perceived naturalness				0.51	0.41–0.64	100.00%
Vaccinated × att. Human Enhancement				1.39	0.81–2.43	88.70%
Vaccinated × naturalness attitude				1.07	0.98–1.18	93.00%
One-time use	10.9	8.48–14.03	100.00%	12.64	9.78–16.46	100.00%
Group-level effects						
Sd (Intervention type)	1.80	1.23–10.86		1.88	1.25–12.38	
Sd (Participant)	22.94	16.48–33.25		25.37	18.17–37.58	
LOO-information criterion	4383.5 (88.6)			4323.4 (90.3)		

Note. Information on the posterior distribution of the calculated mixed-model Bayesian ordered cumulative regression. Daily use and not being vaccinated were reference categories to the respective predictors. Priors for the predictors: N (0,2). Thresholds (not shown) and *sd* = Student's *t*-distribution, v = 3, μ = 0, σ = 2.5 (brms default). Parallel frequency (Models 6–10) means that we included only those interventions that were explicitly recorded twice in terms of the required frequency of use (Daily or Once, see Table 1). In these models, no interventions needed "frequent" use. More information is provided in the Supplementary. Number of data points for models 1–5 = 3454; models 6–10 = 1884. pd is the probability of direction, i.e., the probability that the effect is greater or smaller than 0 (or one if converted to OR), as indicated by the coefficient median. Linear combination and interpretation of coefficient estimates may be eased by transforming them back via log transformation

may differ from the general average [78]. We did so because we were interested in the general role of the fixed effects across various interventions that may differ in their mean willingness to use. Interaction effects with vaccination status were modeled to test for the special emphasis unvaccinated participants were expected to put on these variables.

2 × 5 models were constructed to explore possible interaction effects and account for frequency and type asymmetry. Models 1–5 considered all interventions, and Models 6–10 only included interventions whose required application frequency was assessed symmetrically (i.e., once as a daily and once as a one-time intervention). For a comprehensive comparison, Table 4 features the models without interactions and those that employed interactions between perceived

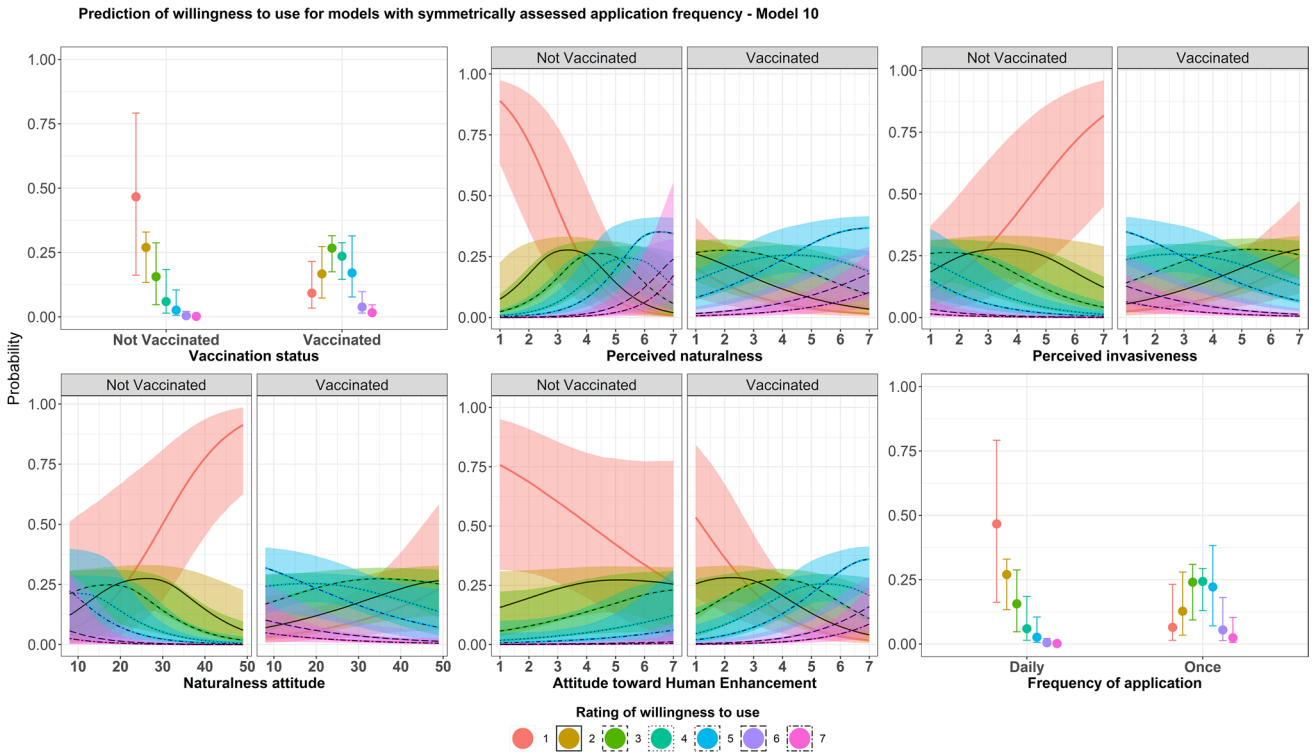

Fig. 3 Visualization of the conditional prediction of willingness to use for models with symmetrically assessed application frequency. Table 4—Model 10. Shaded areas represent 95% credible intervals. Curves correspond to the draws from the expected value of the posterior predictive distribution. For better visibility, group level effects are not displayed. Each curve represents the probability (Y-axis) to respond with the respective rating (color and linetype) given value of the predictor (X-axis). When conditioning on one predictor, the others are by default set to their mean/reference category by *brms*

naturalness, perceived invasiveness, attitude toward Human Enhancement, and naturalness attitude. A complete overview can be found in the Supplementary. Figure 3 depicts effects of model number 10.

4.2.6 Attitude toward vaccination

Estimates of conducted linear Bayesian regression are shown in Table 5 and represent two different models, one with and one without interaction terms. Five models, each with another interaction term, were constructed to explore the role of the different variables and approximate the variable combination that provided the best fit. The complete overview can be found in the supplementary. Figure 4 shows the predictions of Model 5.

We constructed a different model to explore possible post hoc effects among the vaccinated. We employed the positive effect of vaccination status, improvement after first dose, identification with enhancement status, naturalness attitude, and attitude toward Human Enhancement as predictors. The choice of predictors was guided by the idea that these variables may reflect post hoc relevant processes that may eliminate the effect of naturalness attitude and attitude toward Human Enhancement. Results suggest a positive effect of effects of vaccination status $\beta = 0.23$, $CI_{95\%}$ [0.14–0.33] probability of direction = 100%, the identification with the vaccination status $\beta = 0.07$, $CI_{95\%}$ [0.01–0.14] probability of direction = 98.70%, and a negative effect of naturalness attitude $\beta = -0.18$, $CI_{95\%}$ [− 0.24 - − 0.11] probability of direction = 100%. Other effects were less clear (probabilities of direction = 51.4–53.5%). The model can be found in the Supplementary.

4.2.7 Attitude toward Human Enhancement

After visually inspecting the correlations between the coefficient distributions of our Bayesian linear regression, we observed that predictor weights of attitude on vaccination and vaccination status were rather highly correlated. Although

Table 5 Estimating Attitude toward vaccination

Predictors	Model 1			Model 5		
	β (Median)	95% Credible Interval (CI)	pd	β	95%CI	pd
Enhancement Rating vaccinations	0.02	− 0.04 - 0.08	73.50%	0.16	0.02 - 0.30	98.70%
Attitude Human Enhancement	0.09	0.02 - 0.16	99.50%	0.28	0.15 - 0.42	100.00%
Vaccinated	1.60	1.42 - 1.78	100.00%	1.32	1.10 - 1.54	100.00%
Naturalness attitude	− 0.28	− 0.35 - − 0.21	100.00%	− 0.44	− 0.61 - − 0.27	100.00%
ER vaccinations × vaccinated				− 0.14	− 0.30 - 0.02	95.80%
Att. HE × vaccinated				− 0.26	− 0.42 - − 0.10	100.00%
Naturalness attitude × vaccinated				0.20	0.02 - 0.38	98.40%
R^2 Bayes	0.70			0.72		
LOO-information criterion	524.7 (46.1)			508.7 (52.0)		

Note. Information on the posterior distribution of the calculated Bayesian linear regression. Priors for the predictors: *N*(0,1). Intercept = Student's *t*-distribution, ν = 3, μ = 0.7, σ = 2.5 (*brms* default). *Sd* = Student's *t*-distribution, ν = 3, μ = 0, σ = 2.5 (*brms* default). Estimates are standardized effect sizes. LOO-information criterion (standard error in parentheses): Lower values indicate a better model fit. Each model ran four sampling chains with 1e4 iterations and 5000 warm-up draws. pd is the probability of direction, i.e., the probability that the effect is greater or smaller than 0, as indicated by the coefficient median

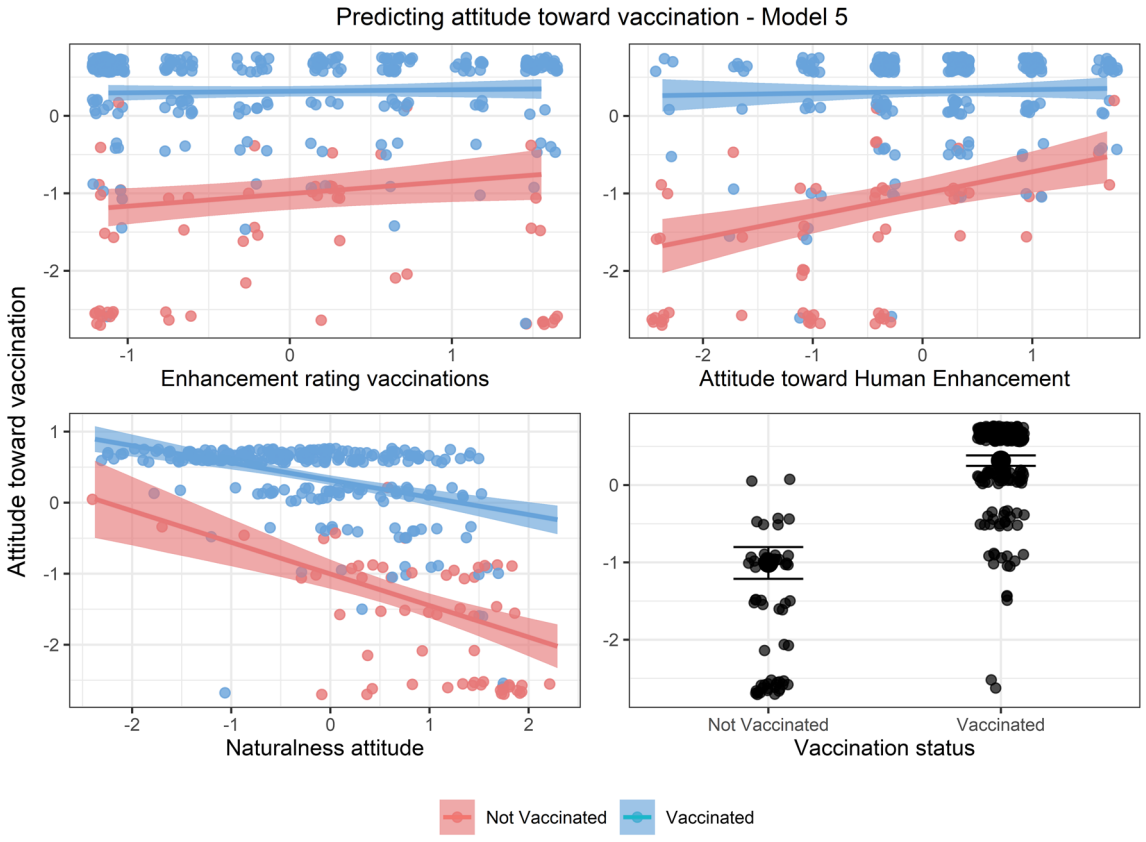

Fig. 4 Conditional interaction effects and effects of the vaccination status of the model with the lowest LOO-information criterion (Table 5—Model 5). The shaded area represents 95% credible interval. Values are scaled and centered. When conditioning on one predictor, the others are, by default, set to their mean/reference category by *brms*. Curves correspond to the draws from the expected value of the posterior predictive distribution. Points represent empirical data and are jittered for better readability

interaction effects inevitably create predictor correlations, we wanted to reduce the potential influence of multicollinearity on this model at least a bit while maintaining a theoretical foundation of predictor choices. Vaccination status was theorized to be the more concrete reflection of attitudes toward vaccination and the underlying belief system. Hence, we dropped attitude on vaccination as a predictor and calculated the models presented here.

Table 6 Estimating attitude toward Human Enhancement

Predictors	Model 1			Model 4		
	β (Median)	95%CI	pd	β	95%CI	pd
Enhancement Rating vaccinations	0.17	0.07 - 0.27	100.00%	− 0.22	− 0.45 - 0.01	97.10%
Vaccinated	0.51	0.22 - 0.79	100.00%	0.38	0.04 - 0.72	98.50%
Naturalness attitude	− 0.31	− 0.42- − 0.20	100.00%	− 0.49	− 0.74 - − 0.24	100.00%
ER vaccinations × vaccinated				0.47	0.23 - 0.73	100.00%
Naturalness attitude × vaccinated				0.22	− 0.05 - 0.50	94.40%
R^2 Bayes	0.219			0.264		
LOO-information criterion	823.5 (26.00)			809.7 (25.7)		

Information on the posterior distribution of the calculated Bayesian linear regression. Priors for the predictors: normal distributed, μ = 0, σ = 1. Intercept = Student's t-distribution, v = 3, μ = 0.7, σ = 2.5 (*brms* default). *Sd* = Student's *t*-distribution, v = 3, μ = 0, σ = 2.5 (*brms* default). Estimates are standardized effect sizes. LOO-information criterion (standard error in parentheses): Lower values indicate a better model fit. Each model ran four sampling chains, each with 1e4 iterations and 5000 warm-up draws. CI = Credible interval. pd is the probability of direction, i.e., the probability that the effect is greater or smaller than 0, as indicated by the coefficient median

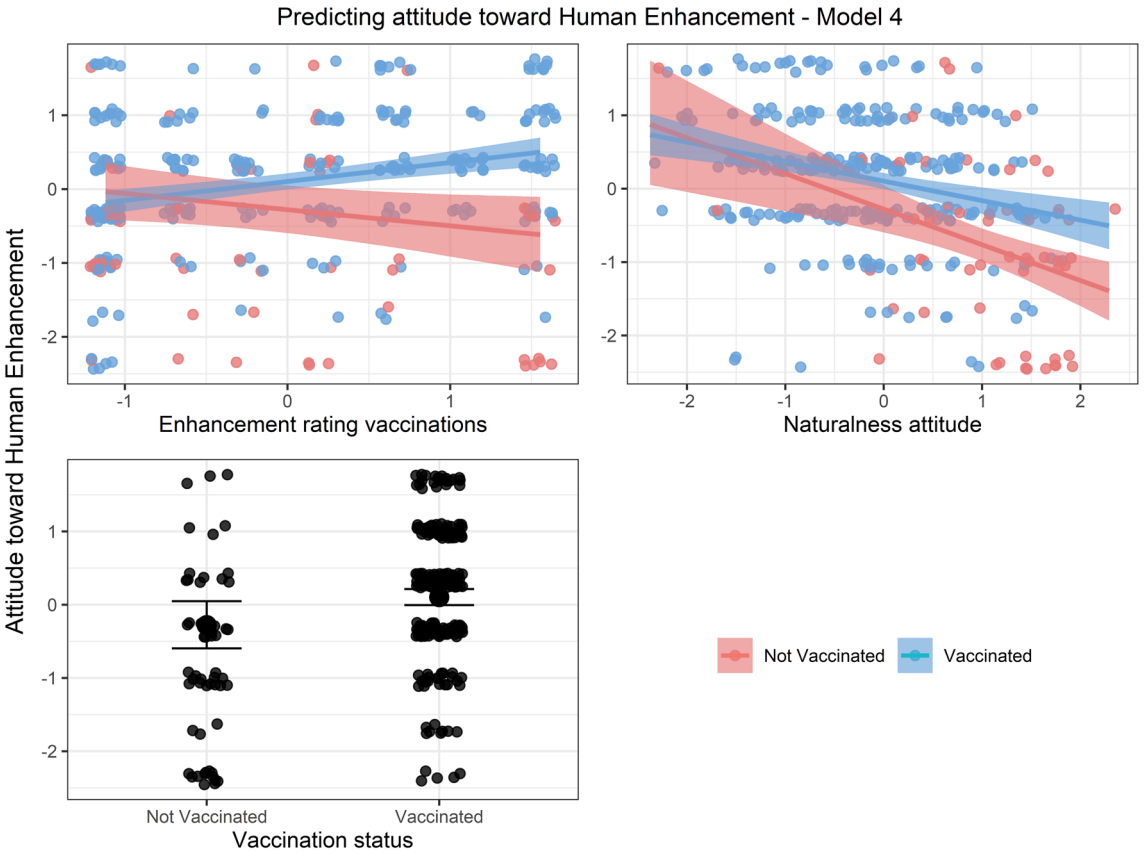

Fig. 5 Conditional interaction effects and effects of the vaccination status of the model with the lowest LOO-information criterion (Model 4). The shaded area represents 95% credible interval. Curves correspond to the draws from the expected value of the posterior predictive distribution. Values are scaled and centered. When conditioning on one predictor, the others are, by default, set to their mean/reference category by *brms*. Points represent empirical data and were jittered for better readability

Four models, each employing different interaction terms, were constructed. After noticing the model-dependent change of effect direction of rating vaccinations as an example of Human Enhancement and its interaction with vaccination status, we explored a three-way interaction between these variables. For better comparison with Fig. 4 and as it has a slighter better model fit, we visualize the coefficients from Model 4 (Table 6) in Fig. 5. Still, including the three-way interaction suggests that the interaction effect between vaccination status and enhancement rating of vaccinations

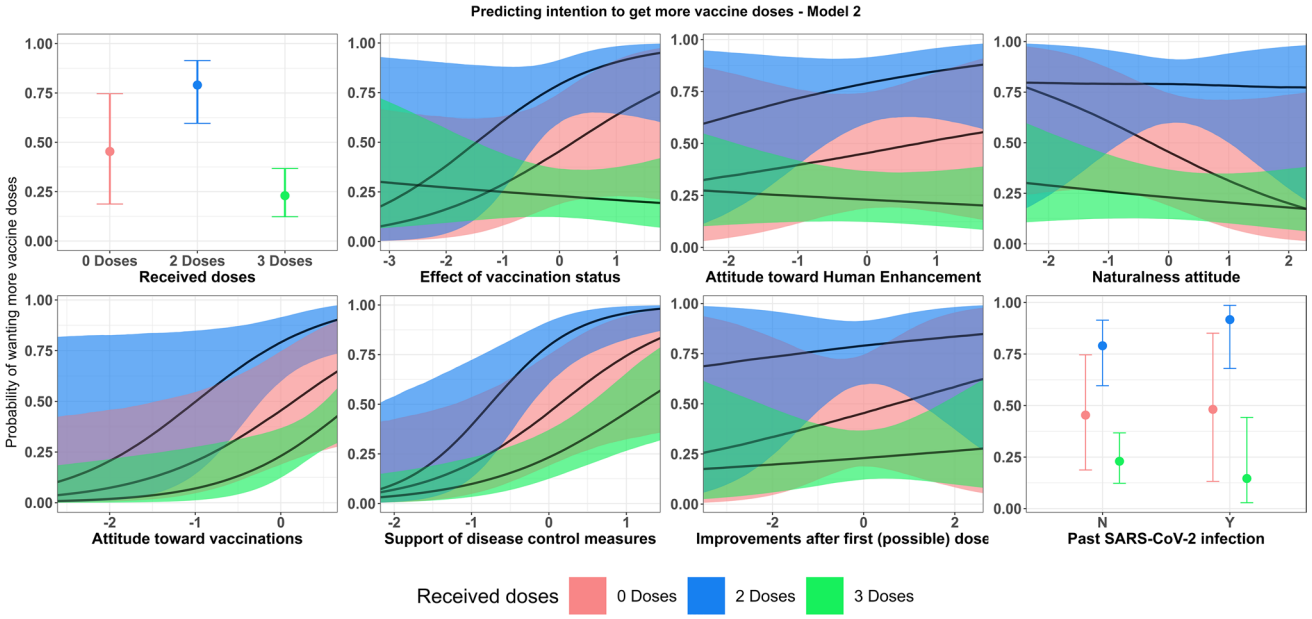

Fig. 6 Results of Model 2 that only included participants with 0, 2, or 3 received doses. The shaded areas represent 95% credible intervals. Curves correspond to the draws from the expected value of the posterior predictive distribution. Values are scaled and centered. When conditioning on one predictor, the others are by default set to their mean/reference category by *brms*. This model excluded participants that have only received one doses and those whose answers on vaccination intention could not be interpreted. Since it used data of unvaccinated participants, we employed the reduced effect of vaccination status scale in which two items were dropped. Prior for predictors = *N* (0,1). Attitude toward vaccination was retained as predictor along received doses because we were interested if there are meaningful differences among groups

increases the attitude toward Human Enhancement for vaccinated participants only. The coefficients of all models can be found in the Supplementary.

4.2.8 Vaccination intention—more doses?

The supplementary features logistic regressions exploring which variables predict participants' intention to receive more doses. Figure 6 visualizes the effects of one of the models, excluding the participants who received only one dose.

Another important finding was that in a different model that solely used the data of the unvaccinated participants, the most certain effect on whether to receive more doses (i.e., get vaccinated at all) was the negative influence of naturalness attitude $OR = 0.26$, $CI_{95\%}$ [0.06, 1.03], probability of direction = 97.20%.

4.2.9 Vaccination intention—exact number of doses

As the decision to get no more doses is not equivalent to the decision to not get vaccinated at all, bayesian ordinal regressions were calculated considering only participants who had already received two or three doses. We separated the data as the number of received doses cannot logically predict each outcome (boostered participants cannot plan to get only two doses). We did not predict the exact number of doses for unvaccinated participants and those who received only one dose because the sample size was too small. A full overview can be found in the Supplementary. Figure 7 visualizes the effects of the two models with the best fit.

5 Study 2

In response to extensive feedback from multiple peer reviewers, who pointed out the absence of data regarding public perception of the vaccine against SARS-CoV-2, we aimed to address this gap by conducting a second study. This was meant to test our hypothesis' prediction that people not vaccinated against SARS-CoV-2 deem the vaccination more unnatural and more invasive than vaccinated people and that these factors play a crucial role in their decision

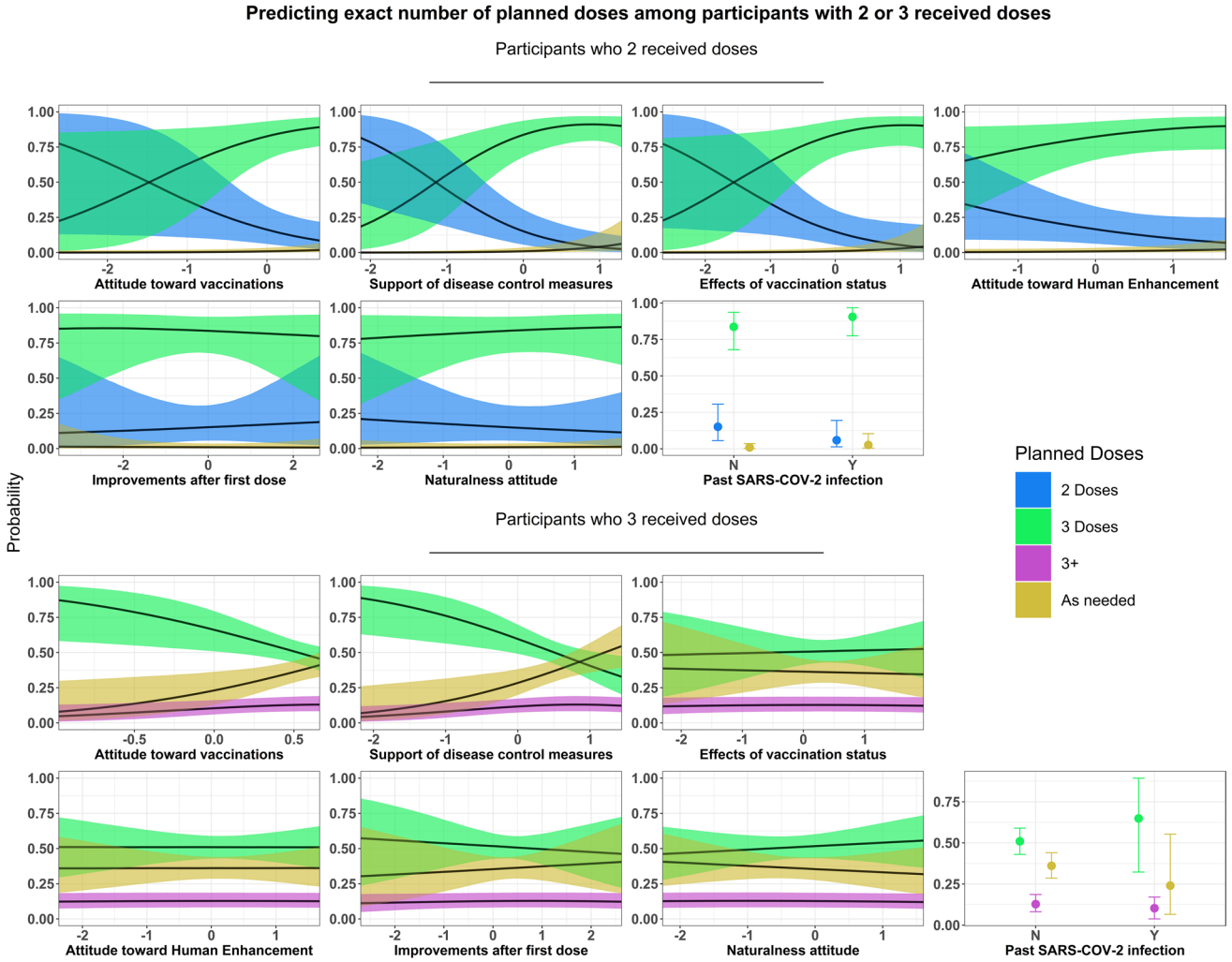

Fig. 7 Results from the respective models, that included attitude toward vaccination. The shaded areas represent 95% credible intervals. Curves correspond to the draws from the expected value of the posterior predictive distribution. Values are scaled and centered. When conditioning on one predictor, the others are by default set to their mean/reference category by *brms*. Since the models do not used data of unvaccinated participants, the complete effect of vaccination status scale was used. Prior for predictors = *N* (0,1). Attitude toward vaccination was retained as predictor we were interested if there are meaningful differences among groups

to reject vaccination. We furthermore wanted to validate the final willingness to use the model (parallel frequencies) by predicting data it had never seen before.

5.1 Methods

5.1.1 Participants

Participants were again recruited from the same sources as in the first study, including Facebook groups hosting a critical discourse on vaccination. An apriori power analysis for an independent t-test determined sample size. Following the differences in the magnitude of the perception of invasiveness in our first study, we set the expected effect size to $d = 0.50$, the desired power to 0.80, and alpha to 0.05. We furthermore accounted for the uneven distribution of unvaccinated

and vaccinated participants in the German population in May of 2023 (13/87% [10]) and set the allocation ratio to 6.7. This yielded a required sample size of at least $N = 222$ (29 unvaccinated, 193 vaccinated).

The survey was completed by $N = 301$. We overpowered the study to mitigate eventual data loss due to dishonest answers. This was done primarily for unvaccinated participants, as members of the Facebook groups often expressed hostile attitudes regarding our call for participation. Furthermore, members of the two groups did not participate at even rates, so an imbalance on the side of the vaccinated participants resulted in the necessity to recruit more unvaccinated.[7]

One person was excluded because they indicated they were seven years old while also having no educational degree. No other exclusions were made. The complete dataset comprised $N = 300$ persons (*Male* = 129, *Female* = 163, *Other* = 2, *NA* = 6; $M_{Age} = 33.9$ [Range: 18–81] years). One participant's age was coded *NA* due to the initial statement of being over 8461 years old. Other responses of this participant were not overly suspicious. Vaccination status against SARS-CoV-2 was distributed as follows: *Unvaccinated* ($n = 43$, 14.33%) and *Vaccinated* ($n = 257$, 85.67%).

5.1.2 Measures

If not stated otherwise, items used a 7-point Likert scale on which the maximum represented the highest affirmation. A complete list of items is provided in the Supplementary.

Willingness to use. Participants were introduced to the same scenario and measurements as in the first study. However, we only used examples with parallel frequencies (Table 1).

Vaccination status. "Have you ever received a vaccination against SARS-CoV-2?" (Y/N).

Vaccine features: Participants were asked to rate how much the following features apply to the vaccination against SARS-CoV-2: naturalness, invasiveness, effectivity, and safety. Additional categories were introduced to compare ratings on the former two with general concerns about vaccination and Human Enhancement. Considering the initial study's findings, which revealed a correlation between the refusal of the specific SARS-CoV-2 vaccine and general resistance to vaccination, we again chose vaccination against SARS-CoV-2 as context. Despite the diminished prominence of COVID-19 discussions in the German public in May 2023, it was the most recent, prevalent and extensive discourse surrounding vaccinations.

Vaccine features importance: The participants were questioned regarding the importance they attributed to their perception of the aforementioned features when deciding about (not) getting vaccinated against SARS-CoV-2.

Attitude. People were again introduced to the notion of Human Enhancement and stated their attitude toward this phenomenon and vaccination in general.

Naturalness attitude. Same scale as in the first study.

5.1.3 Procedure

To test our hypotheses, we conducted an online study using *LimeSurvey* [74] that was in full accordance with the ethical guidelines of the University of Bamberg. The link was distributed by the sources mentioned in the Participants section. It was approved by an umbrella evaluation for psychophysical testing of the University of Bamberg ethics committee (Ethikrat der Universität Bamberg) on August 18, 2017.

After consenting to the use of their data, participants filled out sociodemographic information and completed the measures as stated above. University students and participants from online survey distributors could apply for course credit or other benefits from the particular website. The survey language was German. Data sampling occurred from May 12th, 2023, to May 22nd, 2023. Data analysis occurred after having recruited $N = 301$ participants.

5.2 Results

When equality of variance was not present, degrees of freedom were corrected using the Welch approximation. All p-values are two-sided.

[7] The supplementary features repeated analysis that combined random samples from both groups to a total sample of 222 with the original proportions. Results of these analysis support the analysis done with the sample of $N = 300$. So even under the original estimation, we would have most certainly found similar effects as reported here.

5.2.1 Overview and rationale of analysis

To gain insight into the suitability of our measures, we start our analysis by examining the internal consistency of the naturalness attitude scale and compare its sum score and attitudes toward vaccination and Human Enhancement along the line of vaccination status. We also analyze if participants rate the means for cognitive enhancement differently regarding invasiveness and naturalness (*Scales and comparison between vaccinated and unvaccinated*).

We then evaluate how vaccinated and unvaccinated perceive the vaccination against SARS-CoV-2 and how much the perceived qualities of the vaccine contributed to the decision whether to receive it. This was done to test for the assumptions that unvaccinated participants deem the vaccine as more unnatural and more invasive and, due to the hypothesized special emphasis, attach particular importance to their perception (*Perception of vaccination against SARS-Cov-2*).

To ensure model robustness, we integrated novel data regarding people's willingness to utilize cognitive enhancement methods. This additional dataset was employed to validate the final model constructed in the initial study (*Model evaluation*).

5.2.2 Scales and comparison between vaccinated and unvaccinated

Internal consistency of the naturalness attitude scale was $\alpha = 0.77$, credible interval—CI95% [0.74, 0.81].[8] Unvaccinated participants held a less affirming attitude toward Human Enhancement: $t_{(298)} = -8.27$, $p < 0.001$; $d = -1.36$ [– 1.70, – 1.02] and vaccination in general $t_{(48.82)} = -9.50$, $p < 0.001$; $d = -2.04$ [– 2.40, – 1.67] while scoring higher in naturalness attitude compared to their vaccinated counterparts: $t_{(298)} = 8.49$, $p < 0.001$; $d = 1.40$ [1.06, 1.74]. Credible interval of posterior differences did not include 0.

Our first study found that unvaccinated participants rated some means for cognitive enhancement higher in invasiveness than vaccinated participants. In the second study, these differences were either not as strong or not significant: one-time administration of a drug in the form of pills ($t_{(298)} = 1.95$, $p = 0.052$, $d = 0.32$ [0.00, 0.64]), one-time injection of a drug into the arm ($t_{(298)} = 2.64$, $p = 0.009$, $d = 0.43$ [0.11, 0.76], credible interval of posterior differences did not include 0), one-time administration of a plant-based drug ($t_{(298)} = 0.43$, $p = 0.66$, $d = 0.07$ [– 0.49, 0.77]), daily administration of a drug in the form of pills ($t_{(298)} = 2.07$, $p = 0.04$, $d = 0.34$ [0.16, 0.67], credible interval of posterior differences contained just 0), the daily injection of a drug into the arm ($t_{(48.7)} = 0.19$, $p = 0.85$, $d = 0.04$ [– 0.28, 0.37]) and daily administration of a plant-based drug ($t_{(298)} = 1.25$, $p = 0.21$, $d = 0.21$ [– 0.11, 0.53]).

Similar to our first study, unvaccinated participants rated the one-time administration of a drug in the form of pills ($t_{(298)} = -3.16$, $p = 0.002$, $d = -0.52$ [– 0.85, – 0.19]), one-time injection of a drug into the arm ($t_{(298)} = -3.59$, $p < 0.001$, $d = -0.59$ [– 0.92, – 0.26]), daily administration of a drug in the form of pills ($t_{(68.93)} = -5.34$, $p < 0.001$, $d = -0.72$ [– 1.05, – 0.40]), the daily injection of a drug into the arm ($t_{(298)} = -2.31$, $p = 0.02$, $d = -0.38$ [– 0.70, – 0.06]) as less natural than vaccinated participants. Credible interval of posterior differences did not include 0 (other *p's* > 0.20).

5.2.3 Perception of vaccination against SARS-Cov-2

Figure 8 displays how participants perceive the vaccination against SARS-CoV-2 regarding certain features and how important the perceived features were for their decision to accept or reject the vaccination. Analysis and figures were done with *ggstatsplot* for R (0.10.0) [79].

A repeated measure ANOVA revealed significant differences in the importance among the unvaccinated $F_{(2.51, 105.44)} = 3.33$, $p = 0.03$, $\widehat{\omega_p^2} = 0.001$. But post hoc pairwise *t*-tests failed to reach significance after correcting the alpha level (*p*'s > 0.07—Supplementary). Here, the importance of perceived naturalness was the lowest among all features.

Noticing that some vaccinated participants deemed the perceived invasiveness as somewhat meaningful for their decision to get vaccinated, we explored correlations between the measures and across group lines (Supplementary). We expected that vaccinated people who reported higher importance of perceived invasiveness do so because they deem the vaccine less invasive. However, the analysis revealed a positive yet non-significant correlation between perceived invasiveness and the importance of this feature, $r = 0.16$, $p > 0.05$. Within this group, the importance of perceived invasiveness

[8] We reversed one item (Humans are the crown of creation) in accordance with the findings of the first study. However, in this sample this item was not negatively correlated with the PCA's component. To ensure comparability and due to theoretical consideration about the scales purpose, we nevertheless decided for reversing it. If employed in future research, this item should be critically examined.

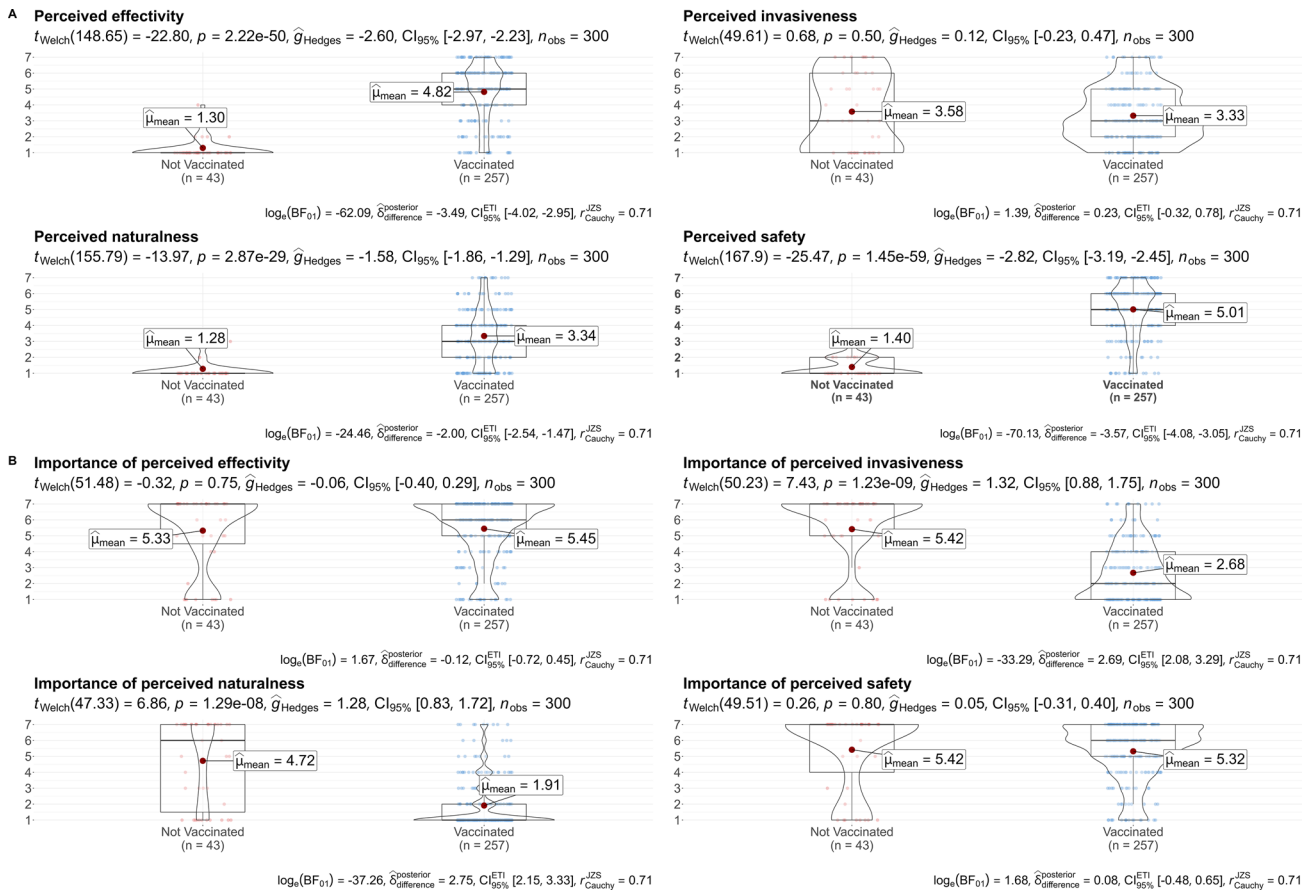

Fig. 8 Perception how vaccination against SARS-CoV-2 possesses a certain feature (**A**) and the importance of this perception for the decision whether to get vaccinated or not (**B**)

only correlated significantly with the importance of perceived naturalness $r = 0.40$, and the importance of perceived safety $r = 0.24$, p's < 0.05. This brief analysis cannot resolve the role of perceived invasiveness within vaccinated participants. We found a similar pattern of correlations within the vaccinated participants ($r_{\text{perceived invasiveness – invasiveness importance}} = 0.17$, $p > 0.05$ and $r_{\text{importance naturalness – invasiveness importance}} = 0.67$, $_{\text{importance safety – invasiveness importance}} = 0.76$, p's < 0.05.

5.2.4 Model evaluation

Figure 9 shows the prediction of Model 10 (Table 4) for the data of our studies.

6 General discussion

We conducted two online studies ($N = 314$ and $N = 300$) to contextualize the relationship between vaccination behavior/intention and the rejection of Human Enhancement. Our findings indicate that individuals who reject vaccination against SARS-CoV-2 hold stronger beliefs in favor of naturalness and value this feature more than those vaccinated. Unvaccinated participants also seemed to devalue invasiveness more than their vaccinated counterparts. To our knowledge, this is the first link between concrete vaccination behavior (in Germany) amidst a global pandemic and the Human Enhancement debate. Besides replicating other findings from the empirical research on Human Enhancement, our data also shows that attitudes toward vaccination and Human Enhancement are likely to be influenced negatively by a more affirmative attitude toward naturalness. An effect that seems stronger for unvaccinated

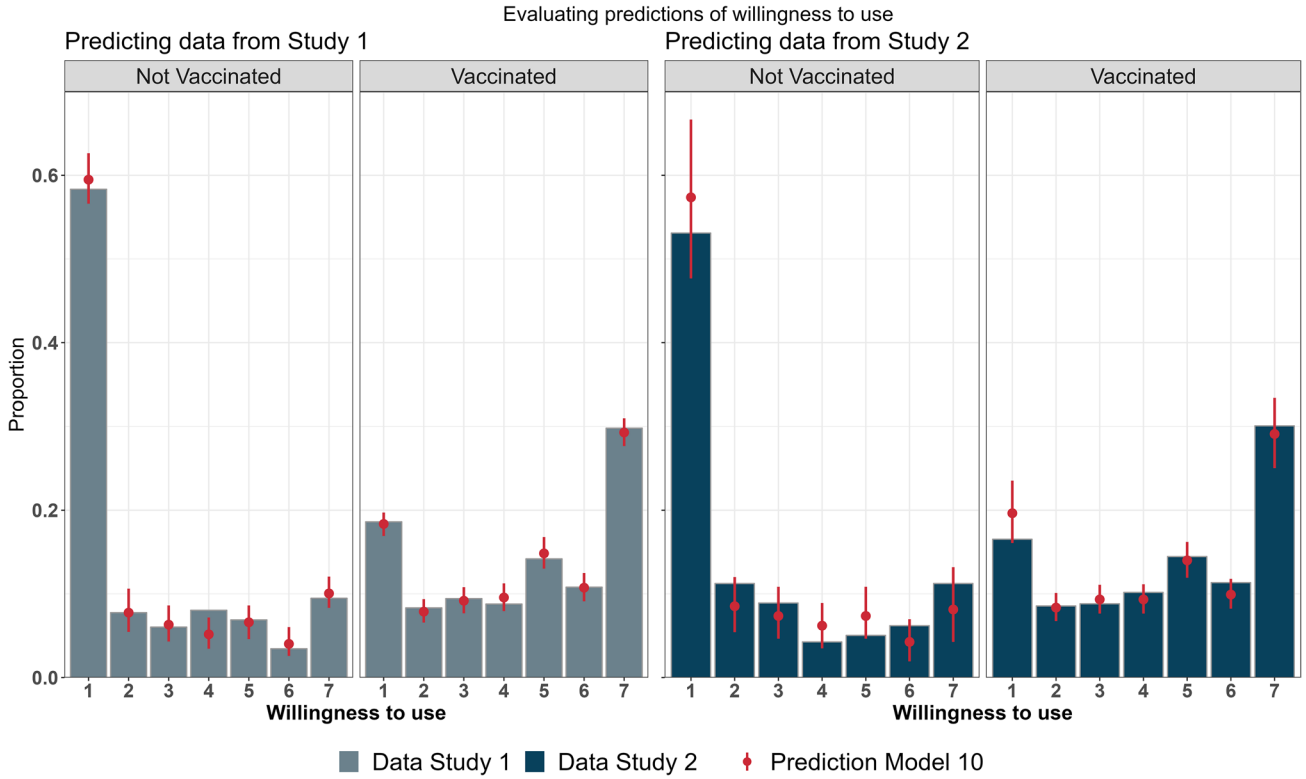

Fig. 9 Predictions were generated by the pp_check method of *brms*. Random levels for participants were generated by allowing new levels, sampled from a Gaussian distribution with [0, *SD* (Random factor participants)]. Lines represent the 95% credible interval and dots the median

participants. Rejecting vaccination appears to be indicative of a set of beliefs that reaches beyond the engagement with this particular enhancement and may explain the rejection of other examples and the general phenomenon.

Reported attitudes revealed that those not vaccinated favored phenomena commonly associated with alternative medicine and disfavored those that imply human interference with nature of various kinds. This hints toward a stable set of naturalness-related and affirming beliefs associated with rejecting vaccination against SARS-CoV-2.

This can be linked to a recent study by Fasce et al. [20]. Employing thematic analysis, they identified 11 "attitude roots," i.e., psychological predispositions that may explain why people reject vaccination. Within their framework, the appeal to naturalness can fall under the theme "Natural is best," which is grouped with other themes such as "Science denial" and "Alternative medicine" under the root "Unwarrented beliefs." If supplied by religious motives, the same appeal may be characterized as being determined by the root "Religious concerns" and the themes of "Impurity," respectively, "Appeal to natural order." The issue of invasiveness may be fueled by the root "Fear and phobias" and its related themes of "Safety concerns." Comparing the general differences between unvaccinated and vaccinated in our samples, we can also spot traces of other attitude roots, such as "Distorted risk perception." This fits well with recent findings revealing substantial positive correlations between psychological constructs associated with attitude roots and the general endorsement of anti-vaccination arguments, including those unassigned to the specific root [80]. How the different anti-vaccination attitudes roots translate to attitudes toward Human Enhancement, in general, remains unclear. Yet, the results of our study point toward a possible association with at least one root.

Findings substantiate the impression that Human Enhancement is commonly understood and defined in terms of invasiveness and the material presence of the technology in question. The lack of the latter may explain why vaccinations were not seen as prime examples of Human Enhancement, similar to a previous study [1]. Interestingly, enhancement ratings of unvaccinated participants differed from vaccinated only in two cases that are extensively covered by the literature as prime examples of Human Enhancement: Drugs to increase life expectancy and drugs to enhance cognitive functioning [4].

A more positive attitude toward Human Enhancement, higher perceived naturalness of means, lower invasiveness, low application frequency, and a lower affirmative attitude toward naturalness predicted a higher willingness to use means

of cognitive enhancement across several models with sufficient certainty. Among individuals not vaccinated against SARS-CoV-2, perceived naturalness was reliably more influential than among vaccinated participants. Our models also yielded evidence for interaction effects between vaccination status and naturalness attitude (Parallel frequencies model only), respectively, perceived invasiveness. Although estimates of the latter were somewhat uncertain, visual analysis of the models' coefficients suggested that being unvaccinated amplified the detrimental impact of attitudes towards naturalness and perceived invasiveness on willingness to use. Still, findings indicate that, in a context with supplementary background information, the perceived naturalness of the intervention appears to carry greater weight than the more general attitude towards naturalness. The interaction effect of vaccination status and perceived invasiveness was reliably present when all interventions were included in the model. However, this effect was less certain in the sub-models that comprised only a portion of the interventions. Models with all interventions included highly invasive procedures, such as electronic device implantation and brain surgery, while the sub-models excluded these interventions. Yet, the sub-models featured more "classical" examples of Human Enhancement, while the former models included interventions not regularly discussed in the debate.

The negative impact of perceived invasiveness when contemplating means to enhance cognitive functions is concurrent with other studies [18, 51, 61, 62]. Considering the somewhat inconsistent findings regarding the positive effects of naturalness on adopting cognitive enhancement [18, 47], our research further clarifies this relation. It suggests a positive link between the perceived naturalness of means and the willingness to adopt them. Additionally, it elucidates the role of affirmative attitudes towards naturalness, which partially reaches beyond a specific enhancement's features.

The addition of interaction terms led to improvements in model fit but rendered the effect of vaccination status highly uncertain. This may suggest that it is not the vaccination status per se that matters but rather the individual valuation of intervention properties that also manifests in vaccination behavior. This was further supported by the finding of the first and partially second study that unvaccinated participants rated the administration of drugs as pills or injections as more invasive and less natural. Although the invasiveness results were less robust, this suggests a differing perception and emphasis on variables consistently predicting the general willingness to use different cognitive enhancement methods. Feature properties are important, yet perception and evaluation of these properties seem linked to a broader belief system.

The fact that perceived naturalness, invasiveness, and affirmative attitude toward naturalness were very likely to impact the willingness to use cognitive enhancement, especially for the unvaccinated, may be explained by a close association of these features with purity concerns. It has been shown that this moral foundation, concerned with whether something violates the purity of something, influences both attitudes toward vaccination [12, 65] and cognitive enhancement [50, 51]. Most recently, Chen et al. [65] revealed the close association between the perception that vaccination against SARS-CoV-2 is impure and that the human body is sacred. Importantly the items used in this study contained a direct reference to the eligibility of moral statements based on alleged unnaturalness [81]. Chen et al. [65] point out that the body-membrane-breaking application of vaccination may trigger purity-related concerns. They also found that perceiving the vaccination as impure fully mediated the link between purity moral foundation and vaccination status. Thus, the aversion to technological interventions deemed unnatural and invasive and the strong affirmation of naturalness, in general, may hint toward a strong moral foundation of purity that deserves further investigation.

General willingness to use the interventions appeared relatively low, especially for the unvaccinated participants (Fig. 9). Effects at the group level showed a considerable variation across intervention types and participants. Credible intervals of the ratings often overlapped, hindering a clear distinction between predicted ratings. However, we could identify a trend for the probability of the lowest rating. This may result from a general reluctance to use cognitive enhancement means [62, 70] and a moderate to strong negative attitude toward various phenomena related to Human Enhancement in general [41]. Moreover, unlike other studies [e.g., 51, 82, 83], we evaluated if participants would use the enhancement on themselves. There is evidence that people are reluctant to use enhancement for themselves while being more permissive to the use by others [47].

The final model employing interventions with parallel frequencies exhibited respectable predictive capabilities, albeit with some shortcomings observed specifically among unvaccinated individuals and concerning extreme ratings.

Interactions between vaccination status and naturalness attitude predicted attitudes toward Human Enhancement and vaccination across several models. Explained variance was consistently higher for attitude toward vaccination, probably due to the close association with vaccination status. The interaction effects further support our hypothesis that a stronger emphasis on naturalness is one link between the rejection of vaccinations and attitude toward Human Enhancement. However, this association was not as certain when predicting attitudes toward Human Enhancement.

The predictive power of ratings of vaccination, as an example of Human Enhancement, on attitude toward vaccination and Human Enhancement was inconsistent or relatively weak (See Supplementary). Given the possibilities of interferences due to contemplating vaccination as an instance of Human Enhancement, we have no conclusive evidence for the claim that participants reject/accept vaccination due to classifying it as Human Enhancement. Having a particular attitude toward vaccination and contemplating whether it is Human Enhancement directly intertwines the two assessments. There may be some association, but overall, vaccination was not classified as a prime example of Human Enhancement. Affirmation or rejection of the two phenomena must not necessarily stem from explicit conceptualization. One can reject vaccination without knowing about Human Enhancement or be affirmative to the prospect of cognitive enhancement without acknowledging that vaccination is Human Enhancement. Still, what may link the evaluation of vaccination and Human Enhancement may be a set of underlying, fundamental beliefs. This is consistent with the observation that one general factor can explain over half of the variance in the willingness to use various Human Enhancement associated means [33] and the idea of anti-vaccination attitude roots [20].

Given the cross-sectional nature of our studies, inferring effects are possible. We can not rule out that vaccinated participants' attitudes toward vaccination changed after receiving the vaccine. Suggesting some form of post-hoc reasoning, an alternative model predicting the attitude toward vaccination suggests that among vaccinated participants, attitude toward Human Enhancement was less important than naturalness attitude, the positive effects of vaccination status, and identification with vaccination status. Especially those who endorse vaccination the highest may have experienced strengthened confidence in vaccination throughout the pandemic [84]

Vaccinations seemingly modulate the relationship toward oneself and the environment. Vaccinated participants reported that their feeling of safety improved after receiving the vaccine. Seemingly trivial, these findings exemplify that Human Enhancement can transform risk perception [2] and can yield an adaptation to a hazardous environment [5]. Interestingly, vaccinated people, although better protected against the disease [85, 86], reported no differing feelings of vulnerability compared to unvaccinated people. In addition, unvaccinated participants reported being more relaxed. Reports of decreasing immune protection combined with the back-then dominance of virus variant B.1.1.529 ("Omicron") in Germany may have fostered increased concerns among vaccinated people. Our data suggest that receiving a vaccination does not render the virus perception-wise harmless. A decrease is not an elimination but must first be understood relative to an individual baseline, which may differ between vaccinated and unvaccinated and may be hard to decrease due to general carelessness.

Discriminatory disease containment measures may have contributed to increased feelings of being left out reported by unvaccinated participants. In that case, getting not enhanced modulates the relation to the social environment. Possible social influence, coercion, and division are prevalent topics in the Human Enhancement debate [26, 27, 40, 70, 71, 87, 88]. Any so-experienced coercion to enhance, regardless of origin, can directly interfere with the subjective notion of autonomy and bodily integrity. The sometimes violent and aggressive civic protest of opponents of disease control measures and vaccination can be interpreted as the counter-reaction to a social and political environment to which the unvaccinated do not want to adapt with the help of Human Enhancement [see 5].

Models predicting vaccination intention suggested a negative effect of naturalness attitude for unvaccinated participants. However, the limited number of unvaccinated participants intending to receive the vaccine rendered the generalizability of this effect unclear. Visual inspection also suggests the universal effect of attitude toward vaccinations and the support of disease control measures when predicting vaccine intention and the exact number of desired doses. In the latter case, the naturalness attitude had no effect. Probably because these analyses only featured individuals that were already vaccinated. Logically, those most concerned about their safety engage in the most protective behavior and higher adherence to health measures [89]. Therefore, the positive effect of supporting disease control measures in predicting vaccination intention may reflect one's perception of the virus's severity.

The design of the first study could not reveal if participants rejected the SARS-CoV-2 vaccine *because* they deemed it unnatural and invasive. Our second study aimed at addressing this gap and revealed that unvaccinated participants evaluated the vaccine against SARS-CoV-2 as less natural, safe, and efficient but similarly invasive as vaccinated participants. Nevertheless, perceived unnaturalness and moderate invasiveness were cited as somewhat equally influential in the decision not to be vaccinated as the perceived lack of safety and efficacy. Although individual vaccine hesitancy is a multifactorial phenomenon [14, 21, 90], the acceptance of SARS-CoV-2 vaccination appears to be closely tied to confidence in the vaccine's safety and effectiveness. Conversely, vaccine rejection also seems linked to the belief that the vaccine is unnatural, with a particular emphasis on this perception and concerns regarding invasiveness. We present meaningful associations of individual vaccine hesitancy that align with previous theoretical and empirical insights.

Affirmative attitudes toward naturalness do not simply change because one gets vaccinated, but they seem to play an important gatekeeping role in the decision per se. This effect seems to transpire to other instances of Humen Enhancement and hinges on the technological intervention's perceived features.

6.1 Limitations and directions for future research

The unvaccinated participants in our studies were also targeted through Facebook groups deemed critical to disease control measures. It is unclear if the members of the respective groups are representative of other unvaccinated participants, but also how many were redirected from the groups. Ubiquitous advertisements to receive the vaccination, a discourse that put heavy pressure on everybody to get vaccinated, and the fact that at the time of the first study, 85% of the German population above 18 years were vaccinated at least once [69] suggests that the remaining ~ 15% unvaccinated persons are likely to represent an ideological hard kernel. Still, the applicability of our results to vaccine hesitancy beyond a global pandemic, especially during the early stages of a vaccination campaign against another disease, is restricted. Comparison between unvaccinated persons who are and are not engaged in the public anti-vaccination movement remains an interesting topic for future research. Future research should also investigate the relation between conspiracy theories and a certain appeal to natural immunity [56, 80].

We do not know if the attitude toward vaccination was already low before the pandemic or if the ubiquitous discussion of this issue has polarized vaccinated and unvaccinated. Data sampling for the second study occurred in May 2023, when COVID-19 had practically disappeared from the German public discourse. This may have influenced the assessment of reasons for vaccination behavior.

Overall, the evidence for our hypotheses is weakened by the correlative and cross-sectional operationalization of the study that allows for no causal inference. Moreover, some participants may not be vaccinated for medical reasons or have just recovered from the disease.

There might be a cultural bias to our findings, especially when assessing the attitude toward phenomena like anthroposophy and alternate healing practitioners that has an influential tradition in Germany (Supplementary). Given the relatively small sample size, including the low prevalence of people who have received only one dose, and the possible bias, it is recommended that future studies employ larger cross-cultural samples.

Employed items were not part of a preexisting psychometric instrument and should be tested for validity. This especially concerns measurements of naturalness attitude. Within the first study, items directly referring to the vaccination's effect are of limited use when answered by unvaccinated participants. Future studies should make sure to attune item formulation to unvaccinated participants better. The drop in internal consistency when excluding logically inconsistent items of the vaccination status scale further urges psychometric inquiry.

Besides the adoption of vaccination, our fictional scenarios only assessed willingness to use methods for cognitive enhancement, which is just one subfraction of Human Enhancement. Linking our findings to factual engagement with cognitive enhancement or other enhancement types other than vaccination seems promising. When assessing the willingness to use a method for cognitive enhancement, interventions should be more balanced and presented more realistically. A scenario in which side effects of the administration of plant-based drugs are communicated to have the same potential side effects as brain surgery demands improvement.

Perceptions of vaccines' invasiveness and naturalness require further investigation. This may be done by experimentally manipulating the administration method in hypothetical scenarios or comparing historical vaccine uptake data concerning the administration method (nasal vs. injection vs. oral). Studies should also examine if there is any difference in the perception depending on the vaccination mechanism. Still, concrete vaccination behavior is a problem difficult to study in a laboratory and experimental context. Quantitative measures should be enriched by qualitative accounts that elaborate more deeply on the individual motives and conceptual understandings [e.g., 15, 91].

7 Conclusion

As deadly viruses like SARS-CoV-2 continue to exist and will develop in the future, humanity's environment poses threats we are not fully adapted to. Rather than relying solely on external disease control measures, people have been adapting to potentially dangerous environments through vaccination for about three centuries. The reluctance to adopt this adaptive enhancement strategy, executed rapidly with innovative technology, appears to correlate with a heightened repugnance to accept interventions viewed as invasive and unnatural. This suggests that skepticism of the particular can transpire to rejection of the general. Rejecting vaccination can have fatal consequences, as the struggle against

pandemics demands collaborative action and compliance with disease control measures [92]. Our studies provided initial evidence of aspects worth exploring further when planning future vaccination campaigns and other efforts to mass distribute Human Enhancement.

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Author contributions NAD constructed the surveys, formulated items, analyzed the data, wrote the original draft, and revised the manuscript. CCC provided supervision over all processes. All authors read and approved the final manuscript.

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Code availability Not applicable.

Declarations

Ethics approval and consent to participate The study was in full accordance with the ethical guidelines of the University of Bamberg. It was approved by an umbrella evaluation for psychophysical testing of the University of Bamberg ethics committee (Ethikrat der Universität Bamberg) on August 18, 2017. All participants were informed about their data protection rights and approved the usage of their data prior to the questionnaire. Written informed consent was obtained from all participants.

Consent for publication Not applicable.

Competing interests The authors declare that they have no competing interests.

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