



The Psychological Process Underlying Attitudes Toward Human-Animal Chimeric Brain Research: An Empirical Investigation

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Abstract This study adopted an empirical method to investigate lay people's attitudes toward the bioethical issues of human-animal chimeric brains. The results of online surveys showed that (1) people did not entirely reject chimeric brain research, but showed slightly more negative responses than ordinary animal testing; and that (2) their ethical concerns arose in connection with the perception that chimerism in the brain would humanize the animal. This means that people's psychology was consistent with the ethical argument that crossing the human-animal boundary would bring moral confusion to our society. Meanwhile, it was not in line with another argument that moral status

depended on having high capacities, and that chimerism would cause a problem if it enhanced animals' capacities. Furthermore, this study analyzed additional psychological factors related to people's moral judgment and the relationship among those factors. Several psychological factors, such as the perception that chimeric brain research is unnatural, were identified as mediating the relationship between perception of animal humanization and ethical concerns about creating and using chimeric brains. Introducing an empirical approach to the ethics of human-animal chimeric brains brought two findings: (1) this study informed us of socially shared intuition regarding this novel technology; and (2) it unveiled the psychological processes behind people's ethical concerns in more detail than they spontaneously mentioned. These findings will help to build normative arguments and future policies that are understandable and acceptable to society.

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Introduction

Recent developments in neuroscience have enabled the creation of a human-animal chimeric brain, an animal brain partially composed of human-derived neural tissue. Researchers have successfully transplanted human cerebral organoids (three-dimensional

neural tissue cultured in vitro from pluripotent stem cells) into the mouse cortex [1].

A human-animal chimera is an animal that is partially composed of human cells and is created by grafting human-derived cells into an animal embryo, fetus, or postnatal individual. This technique has made it possible to create various human organs, such as the pancreas, in an animal's body [2, 3]. A human-animal chimeric brain is produced by applying this chimeric technology.

Although this research is expected to contribute to the further development of medical and neuroscience research, some argue that there are moral concerns about creating and using human-animal chimeras, especially human-animal chimeric brains. However, the reasons why chimeric brains raise moral concerns are still under debate, and more importantly, it still needs to be determined how much of people's moral concerns they actually raise. To address this issue, the present study used empirical methods to determine people's attitudes toward creating and using chimeric brains, and the psychological processes that underlie those attitudes.

Ethics About Human-Animal Chimeric Brains

This section reviews the literature on the ethics of creating and using human-animal chimeras and, more specifically, human-animal chimeric brains.

The ethical debate on chimeric animals was initiated by Robert and Baylis [4], who argued that creating beings that are partly human and partly nonhuman would introduce "moral confusion." According to their argument, fixed species boundaries cannot be defined in a biological sense; nevertheless, boundaries are real in a moral sense for many people. In other words, people draw a clear line of demarcation between humans and nonhumans, granting full moral status only to the former. Robert and Baylis did not articulate their position on the pros and cons of chimeric animal creation, but they argued that breaching the moral demarcation line by creating novel beings that are partly human and partly nonhuman is threatening to the social order, and that this can be a reason to prohibit the creation of those beings [4].

Since then, there have been many arguments as to why the creation and use of chimeric animals is ethically problematic. While researchers have argued from various perspectives, these arguments fall into

two categories: anthropocentric and capacity-based. The former emphasizes the biological demarcation line between humans and nonhumans, whereas the latter emphasizes the functional properties of chimeric animals.

Anthropocentric Approach to the Ethics of Human-Animal Chimeras

On the one hand, the anthropocentric approach, including that of Robert and Baylis, rests on the premise that human species have privileged moral status. For example, Robert and Baylis state that society makes a moral distinction between humans and nonhumans, and that any attempt to cross that line can be problematic because it will create confusion within the morality currently accepted [4]. A similar argument is made by Hübner [5], which we refer to in the general discussion in detail.

A somewhat more nuanced argument of this type by Karpowicz et al. [6, 7] focuses on the concept of "human dignity". They state that human beings are worthy or respected because they possess certain kinds of psychological capacities, and that if a chimeric animal acquires these capacities, using it as an experimental material may be equivalent to a human experiment and thus undermines human dignity [6] (p. 333). They seem to refer to sophisticated abilities such as communication, developing a world view, sympathy, and so forth through the word "psychological capacities" [7] (p. 120). They claim that having certain capacities is important for human dignity, but they also state that all human beings, including infants or individuals with severe disabilities, have human dignity [7] (p. 121). Thus, they seem to focus on the distinctiveness of human beings rather than the specific capacities that humans possess.

Capacity-Based Approach to the Ethics of Human-Animal Chimeras

On the other hand, some ethicists claim that creating and using human-animal chimeras is morally problematic not because a chimera crosses the line between humans and nonhumans but because chimerism causes animals to have a higher level of capacity to be worthy of moral consideration than normal animals. These capacities include sentience, rationality, empathy, and self-awareness [8, 9]. In this line

of argument, humans are considered to have a privileged moral status today, not because of being human per se, but because of possessing a higher level of capacity relevant to moral status than other species. For example, Piotrowska argues that if a human-animal chimera acquires morally relevant capacities, it deserves moral consideration regardless of its species identity [8]. Although Piotrowska acknowledges that we should consider the origin of the cells that make up the chimeric animal when determining how to treat it, this is because the biological origin would help infer the chimera's capacity, not because the origin of the cells itself is morally relevant. Thus, if we could objectively identify the chimera's capacities, we need not consider what species the cells originate from. Similarly, Koplin proposed that a being's moral status depends on the value of conscious experience and pointed out that it does not matter whether the cognitive capacities underlying that experience are unique to humans [9].

Ethical Debate on Human-Animal Chimeric Brains

The previous two sections presented two views on ethical issues regarding the creation and use of human-animal chimeras. Although these arguments can be applied to the chimerism of all organs, including the liver, pancreas, and skin, the most prominent ethical debate is probably regarding human-animal chimeric brains, in which human neurons are incorporated into the brains of nonhuman animals. For instance, Karpowicz and colleagues, who take the anthropocentric approach, state that the notion of human dignity is grounded in some capacities generally found in human beings, such as reason, language, and empathy [7] (p. 120). These are clearly mental capacities, although they do not explicitly contrast mental and physical capacities. Thus, brain chimerism is considered a more serious issue than other organs, given that the biological basis of mental capacities lies in the brain. Similarly, advocates of a capacity-based approach regard mental capacity as morally relevant [8, 9]. Koplin focuses on human-animal chimeras with human neurons and highlights that questions about their moral status are particularly difficult [9] (p.23).

In addition, moral concern about animals with humanlike mental capacities may no longer be a mere thought experiment. It has been reported that mice

with human glial progenitor cells engrafted into their brains show higher learning ability than normal mice [10]. This suggests that the chimerism in the brain alters an animal's mental capacities. Although overly sensationalistic discussions should be avoided, as it remains to be seen whether such changes will occur in higher brain functions such as self-awareness and emotion, it will be beneficial to consider possible ethical issues in advance.

Therefore, the present study focuses on brain chimerism to discuss the ethics of human-animal chimera research.

Empirical Approach Toward Bioethical Issues

This section explains that an empirical approach can be helpful in discussing the ethics of human-animal chimeric brains. Recently, an interdisciplinary approach called experimental philosophy (x-phi) has attracted attention. X-phi is characterized by bringing together questions traditionally associated with philosophy and experimental methods traditionally associated with psychology and cognitive science [11]. The field of bioethics has also recently adopted methods from x-phi, causing the new field of experimental philosophical bioethics (bioxphi) to emerge [12, 13]. Here, we provide an overview of what information can be obtained by empirical methods, and then describe what implications can be drawn from those empirical findings.

Providing Information of People's Moral Judgments and the Psychological Processes Underlying Them

The methodology of bioxphi follows that of psychology and cognitive science to reveal people's judgment on bioethical issues through surveys and experiments. A typical method is to present study participants with hypothetical scenarios that reflect the bioethical debates and ask them about their perceptions and attitudes about the issues.

Bioxphi can provide us with two types of information. One is the quantitative data about what judgments about bioethical issues are supported by people. Some empirical studies have already investigated lay people's attitudes toward chimerism, not limited to chimeric brains [14–18]. These surveys are not always consistent about the extent to which respondents accepted chimerism, probably because they

varied in the countries where the data were collected and in the detailed information provided to respondents. However, these studies are worth noting as they inform us of the tendencies of people's judgments, including the possibility of cultural differences.

Another type of information is the psychological processes that underlie those attitudes, including those of which individuals are unaware. Examples of this type of research in the field of bioethics are provided by Rudski et al. [19] and Mihailov et al. [20]. Rudski et al. [19] surveyed lay people's choice of whether to maintain or withdraw life support for a patient in severe conditions and revealed that their choice was associated with their perception of the patient's mental capacities to plan and act. Likewise, Mihailov et al. [20] investigated lay people's judgments of the moral permissibility of cognitive enhancement. They presented participants with fictitious scenarios in which someone used a pill to enhance cognitive abilities and revealed that the permissibility of those enhancements varied depending on several situational factors, such as the purpose of the enhancement. These studies indicate that moral judgments are influenced by various psychological, contextual, or even seemingly irrelevant factors.

Building a Bridge Between Empirical Data and Normative Claims

This section describes the possible ways in which empirical investigations contribute to bioethical issues. While knowing people's judgments (i.e., whether people think it is morally permissible to create a chimeric brain) does not provide direct answers to normative questions (i.e., whether it is morally permissible to create a chimeric brain), it can provide useful information in the following ways.

One possible way is informing the evaluation of bioethical arguments. This possibility can be divided into two directions. On the one hand, collecting data of people's judgments can provide evidence to a certain ethical argument. As Earp et al. [13] state, if stakeholders consistently make a certain judgment, a moral claim encoded by the judgment has *prima facie* normative weight. While people's judgments do not provide a direct answer to normative questions, given that philosophers sometimes refer to intuitions as the basis for their argument, it seems reasonable to investigate what intuitions are shared by many people and

use them as a starting point for discussions. On the other hand, as Earp et al. also state, empirical findings can also contribute to debunking normative arguments. If empirical investigations reveal that people's intuitions are unreliable, a normative argument will lose its validity to the extent that it is associated with those unreliable intuitions.

Another possibility is that empirical data can inform policy making regarding bioethical issues. Scientific research is sometimes regulated by laws or by guidelines from the scientific community. Establishing appropriate regulations is important for realizing the benefits of scientific advancement while preserving society's trust in science. Examining lay people's moral judgments will help determine the appropriate regulations that are socially acceptable, especially when the subject of regulation is novel, like a human-animal chimeric brain, and thus it is unclear what perceptions people have about it. Furthermore, analyzing psychology underlying people's judgments can be helpful. Such analyses will tell us what principles people's judgments follow, including those that they cannot explicitly mention. Given that people are not always aware of the factors influencing their judgments, identifying those factors will help anticipate what future research will raise moral concerns and think about socially acceptable regulatory designs and the content of scientific communications.

Purposes and Hypotheses of the Present Study

This study adopted the methodology of bioethics to address three main questions and an additional exploratory question.

(A) The first question was whether creating and using human-animal chimeric brains are morally acceptable for participants. Given that research on chimeric brains is a form of animal experimentation, those opposing animal experimentation will certainly stand against chimeric brain research. Indeed, a previous survey showed that those opposed to animal research tended to oppose chimera research [17]. However, the present study focused on whether the creation and use of chimeric brains are considered particularly serious beyond the problems of animal experimentation in general. Therefore, we examined whether there are ethical concerns specific to chi-

merism by comparing people's attitudes toward ordinary animal experimentation with those toward chimeric brain research.

- (B) The second was the psychological process through which moral judgments about human-animal chimeric brains are formed. Specifically, this study examined whether the anthropocentric or capacity-based approach better explains people's moral judgments.¹ To this end, we measured the study participants' cognition of chimeras in two respects—the cognition that chimerism will humanize the animal and the cognition that chimerism will enhance the animal's capacities—and quantitatively analyzed the association between that cognition and the attitudes toward chimeric brain research. This analysis was aimed at testing which normative approach was consistent with the psychological process underlying people's moral judgments. On the one hand, if people form their attitudes in ways that align with the anthropocentric approach, the cognition of the humanization of chimeric animals should lead to the judgment that the chimera research is morally unacceptable. On the other hand, if the capacity-based approach fits with the psychology of people's judgments, the cognition of the enhancement of chimeric animals' capacities should lead to the judgment that the chimera research is morally unacceptable.
- (C) Third, we investigated the psychological factors related to moral judgments about chimera research other than those mentioned in the two approaches above, and the process by which those factors lead to the moral judgments. To this end, we conducted a pilot study and asked

our participants the reason for their moral judgments to know what factors they spontaneously mention. Subsequently, the main study analyzed the psychological processes of moral judgments using additional question items based on the responses gained in the pilot study.

- (D) In addition, we investigated an exploratory question without specific predictions: which mental function chimerism raises particularly strong ethical concerns. Regardless of whether one takes the anthropocentric or capacity-based approach, the type of mental function related to the transplanted nerve cells can influence moral judgments because some specific mental functions may be especially perceived as supporting the specialness of the human species or as having high moral value. Thus, we manipulated the information presented to our participants regarding the mental function associated with the transplanted brain region, and examined whether this manipulation leads to different moral judgments.

Overview of the Present Study

This paper reports two studies: pilot and main studies. The pilot study had two aims. First, we aimed to confirm the intelligibility of the description of chimeric brains and the questions presented to the participants for the main study. To address questions (A) and (D) mentioned in the previous section, we constructed a brief explanatory text on human-animal chimeric brains. Then, we asked the participants about the moral acceptability of chimeric brain research. We checked the intelligibility of the materials and improved them for the main study. Second, the pilot study addressed question (C) by collecting people's spontaneous responses regarding the reasons for moral judgments about chimeric brains. We asked their reasons in an open-ended format and determined which variables to measure in the main study. Question (B) was not addressed in the pilot study because we wanted to avoid explicitly asking about cognitions that could be related to moral judgments and influencing the participants' spontaneous responses.

The main study adjusted the methodology based on the pilot study's results. It addressed questions (A) and (D) using the revised materials. Also, it measured participants' cognition of the humanization and

¹ We mentioned existing empirical studies that surveyed public attitudes toward chimera research, but few of them investigated the psychological processes behind the attitudes. One exception was Sawai et al. [18], who asked respondents about their expectations and concerns about chimera research. The respondents were most likely to choose "humanization of animals" as their concern (39.2%), suggesting that they have moral concerns consistent with an anthropocentric view. However, the statistical relation between this concern and the acceptance of chimera research was not significant; thus, the support for the anthropocentric approach seems insufficient. Moreover, their survey did not measure people's concerns about enhancing animal function. Therefore, more research is needed to investigate the psychological processes underlying people's moral judgments regarding chimera research.

enhancement of chimeric animals to address question (B), whether the anthropocentric or the capacity-based approach was more consistent with people's psychology. Question (C) was also addressed, but by using a quantitative approach.

Pilot Study

Summary

The pilot study confirmed the intelligibility of the survey materials and collected participants' spontaneous responses about the reasons for their moral judgments. As a result, we extracted three categories of reasons for negative judgments and one category of reasons for positive judgments for chimeric brain research.

Method

Participants and Recruitment

We recruited participants through Prolific. In total, 659 individuals participated in this pilot study.² Of them, 49 were excluded from the following analyses because they failed to correctly respond to the comprehension check question. Thus, 610 participants (410 females, 192 males, and 8 individuals who answered nonbinary, other, or preferred not to indicate gender) were included in the analyses. Their age ranged from 18 to 79 years ($M=39.91$, $SD=13.79$). Most participants lived in the United Kingdom (81%) and were Christian (31%) or had no specific religious affiliation (61%). Of these, 56% had a Bachelor's degree or higher. All participants spoke English as their first language.

Both the pilot and main studies were approved by the ethics committee of Niigata University.

Procedure

We conducted an online survey to examine the participants' attitudes toward human-animal brain chimeras and the general use of animals in research. Questions about chimeras and ordinary animals were presented in random order. The details of the question items are presented in the supplementary material (Supplementary file 2).

Attitudes Toward Chimeras We presented participants with a description of the human-mouse brain chimera. The description stated that scientists had been developing a new technology to transplant cultured human nerve cells into the mouse brain and that the brain functions of mice were believed to change depending on which part of the brain was transplanted. Participants were then instructed to imagine that further research development would enable the transplantation of nerve cells related to a specific mental function. The functions related to the transplanted cells were manipulated in the description, and the participants were randomly assigned to one of the 13 conditions (sense of vision, sense of smell, sense of pain, basic emotions such as sadness, complex emotions such as regret, language comprehension, empathy, autonomous behaviour, intelligence, rationality, sense of morality, self-control, and self-awareness). A complete description can be found in the supplementary materials (Supplementary file 1, Appendix 1).

After reading the description, the participants were asked about their moral judgments. For each of four acts (CREATE: to transplant cultured nerve cells into the mouse's brain; USE: to use the mouse that underwent the transplantation for research purposes; STIMULI: to expose the mouse that underwent the transplantation to physically damaging stimuli, such as electric shock, without any research purpose; KILL: to kill the mouse that underwent the transplantation without any research purpose), the participants were asked to evaluate the degree to which the act was morally permissible (1 = "Strongly Disagree" to 7 = "Strongly Agree"). These four questions were asked in random order, and after each item, the participants were asked, in an open-ended format, why they chose that answer.

The assumption of the latter two questions (imposing stimuli or killing without any research purpose) is unlikely to be made in an actual chimera study.

² The pilot study did not conduct a power analysis because hypothesis testing was not its primary purpose. We determined the sample size of about 50 per condition based on the goal of collecting sufficiently diverse responses to the free-text questions and on a budget constraint.

However, the pilot study had participants assume an extreme situation because we could not predict the level of people's permissibility judgments in advance, and in the event of a ceiling effect, it would be difficult to tell whether the act itself was judged permissible or the appropriateness of the purposes was relevant.

We then checked the participants' comprehension of the presented description by asking about the capacity to which the transplanted nerve cells were related. The participants chose from three options (the capacity described in each condition, the sense of hunger, or remembering past experiences), and those who chose the incorrect ones were excluded from the analyses.

Attitudes Toward Ordinary Mice We asked the participants to evaluate the degree to which each of the three acts (USE, STIMULI, and KILL) was morally permissible (1 = "Strongly Disagree" to 7 = "Strongly Agree"). As with the questions about chimeras, these three items were asked in random order, and the participants provided the reason for their choice immediately after each item.

In addition to the above questions, we asked some questions for exploratory purposes, but these were not used in the analyses reported below.

Intelligibility After answering the abovementioned questions, participants rated the intelligibility of the description of chimeric brains they read in the survey on a 7-point scale (1 = "Very Easy" to 7 = "Very Difficult").

Results and discussion

Intelligibility of Survey Materials

The first aim of the pilot study was to confirm the intelligibility of survey materials. In total, 434 participants (71%) rated the description as easy to read (1–3 on a 7-point scale). The median was 2 and the mean was 2.81 ($SD=1.28$). The mean score was significantly lower than the midpoint of the scale ($t(609)=23.01$, $p<0.001$). This result shows that the description of chimeric brains was sufficiently intelligible.

Table 1 Mean values of moral permissibility in the pilot study

Target	CREATE	USE	STIMULI	KILL
Chimeric mouse	3.73 (1.85)	4.29 (1.93)	1.56 (1.07)	2.20 (1.63)
Ordinary mouse	-	4.22 (1.83)	1.57 (1.18)	2.24 (1.72)
<i>d</i>	-	0.03	0.01	0.03

Note. Numbers in parentheses indicate standard deviations

Moral Judgments Regarding Human-Animal Chimeras and Ordinary Animals

Table 1 shows the participants' moral permissibility judgments, disregarding the mental function manipulated in the description they read.

A three-way analysis of variance (ANOVA) was conducted to determine the factors affecting permissibility judgment. The independent variables were action type (USE, STIMULI, or KILL; a within-participant factor), target of evaluation (a chimera mouse or an ordinary mouse; a within-participant factor), and mental function (13 conditions, such as the sense of vision; a between-participant factor). The permissibility of creation was not included in the analysis because the variable regarding the ordinary mouse was not assessed. Results showed that the action type had a significant main effect ($F(2, 1194)=837.39$, $p<0.001$),³ but the main effects of the other factors and all first- and second-order interactions were insignificant ($F_s<1.1$, $ps>0.37$). This means that the permissibility judgments did not differ depending on whether the target was a chimera or an ordinary mouse. However, the mean score of STIMULI was lower than two, indicating a possible floor effect. Therefore, we modified the wording of the question items in the main study to examine the differences between the targets more accurately. In addition, the manipulation of mental function involved in the transplanted nerve cells did not affect permissibility judgment. Participants may have paid less attention to specific mental functions and thought about general problems with chimeric brains when responding to

³ Multiple comparisons of the action type with Shaffer's correction revealed that the three action types were judged differently from one another ($ts(597)>12.19$, $ps<.001$): USE was judged the most permissible, followed by KILL and STIMULI.

Table 2 Reasons for the judgments of the moral permissibility of chimera research

Attribution of moral rights to a mouse	<ul style="list-style-type: none"> • Because it's not morally right to play with other living creatures lives for no reason • I don't believe that it is morally permissible to kill anything • I think that this is probably causing unnecessary harm without real benefit • The mouse cannot give consent to this • It depends on the circumstances; however, no life is more important than another and if we would not transplant them into a human we should not make the decision to do this to a mouse
Unnaturalness	<ul style="list-style-type: none"> • Because it is tampering with nature • I think it is messing with nature • Because mice should behave like mice and not human beings • Possibly OK if only for functions natural to a mouse • It is not God's plan
Changes in fundamental features of a mouse	<ul style="list-style-type: none"> • It will have alien DNA that would probably not agree with its anatomy. It might have physical and psychological implications if it acted different and thought differently to its fellow mice • A mouse does not need potentially higher self-awareness with such a short lifespan • To introduce empathy into the brain of a mouse seems to undermine what a mouse is: its identity as a separate and possibly sentient species
Benefits of advancing science and medicine	<ul style="list-style-type: none"> • This can change humans lives for the better. Although sad for mice this could be groundbreaking • As long as the research is to prevent suffering in humans, I support the use of this procedure • In the advancement of science • It will advance our knowledge of the brain • Will help us understand how to fix human brains

questions. To test the effect of differences in mental function, we also modified the questions to emphasize mental function.

Reasons Against the Creation and Use of Chimeric Brains

We then explored the reasons for the moral judgment. First, we extracted negative responses (1–3 on a 7-point scale) regarding four types of acts against chimeric mice and identified the reasons for judgments that the respondents answered in free text. These reasons included the moral rights of a mouse (e.g., the right to be protected from harm and freedom of choice), unnaturalness, and changes in the fundamental features of a mouse. The same was done for respondents who showed positive responses to chimera research (5–7 on a 7-point scale). Most of the respondents cited the benefits of advancing science and medicine. Examples of the responses are presented in Table 2.

We were able to collect reasons beyond the two factors we had initially assumed, i.e., humanization and enhancement of animals. Based on these

responses, we created question items for the main study.

Main study

Summary

Following the pilot study procedure, the main study examined the participants' moral permissibility judgments of human-animal chimeric brain research. The results showed that chimeric brain research was judged less permissible than ordinary animal experimentation, though the difference was small. However, the participants' responses differed little by the transplanted brain region and the associated mental function.

Furthermore, the main study analyzed the cognitive processes behind moral judgments by adding questions about the determinants of moral judgments. The analysis showed that people's psychology was consistent with the anthropocentric approach: the cognition of humanization of a chimera animal was negatively correlated with the permissibility judgment of chimera brain research.

Method

Participants and Recruitment

We recruited participants through Prolific. Those who participated in the pilot study were excluded from recruitment. In total, 930 individuals participated in this study.⁴ Thirty-four individuals failed to correctly answer the comprehension check question and were excluded from the analyses. This exclusion left 896 participants (445 females, 444 males, and 7 individuals who answered nonbinary, other, or preferred not to indicate gender). Their age ranged from 18 to 82 years ($M=39.99$, $SD=13.93$). The participants mainly resided in the United Kingdom (84%), had a bachelor's degree or higher (56%), and did not have an affiliation with a specific religion (59%, followed by 34% Christians, 1.6% Muslims, and others).

Procedure

An online survey was conducted to investigate people's attitudes toward chimeras and ordinary animals. Unlike the pilot study, all participants read a description of the brain chimera first (the complete description can be found in the supplementary materials, Appendix 1) and then answered questions regarding the chimera and ordinary animals. The display order of the question sets for chimera and ordinary animals was randomized.

Question Items

The details of the question items can be found in the supplementary material (Supplementary file 3).

Moral Judgments The participants evaluated the degree to which each of the four acts (CREATE, USE, STIMULI, and KILL) regarding chimeras and mice

was morally permissible (e.g., “It is morally permissible to use [the mouse with human nerve cells related to XX/an ordinary mouse] for research purposes.”; XX was the mental capacity corresponding to each condition; 1 = “Strongly Disagree” to 7 = “Strongly Agree”). These four items were presented in random order.

We made changes to the pilot study questions in three respects: (1) the phrase “only when necessary for research purposes” was added to question items for STIMULI and KILL to soften the moral wrongness of these acts and avoid the floor effect; (2) in the questions about chimeras, the mental capacity that relates to the transplanted cells was included to remind the participants of the description presented in each condition; and (3) we added an item of CREATE for ordinary mice (“It is morally permissible to artificially breed an ordinary mouse for research purposes.”) to make the questions about chimeras and ordinary mice as equivalent as possible.

Cognition for Chimeras and Mice Following the moral judgments, we measured the participants' cognition of the chimeras and ordinary mice. Three questions were asked about both the chimeras and the mice: attribution of moral rights (“[The mouse with human nerve cells related to XX/An ordinary mouse] has equal moral rights as humans.”), perception of unnaturalness (“Using [the mouse with human nerve cells related to XX/an ordinary mouse] for research purposes goes against nature.”), and perception of scientific benefits of using the chimeras/mice (“Using [the mouse with human nerve cells related to XX/an ordinary mouse] will help in the advancement of science.”).

In addition, five questions were asked regarding the chimeric mouse. Two items measured the perception of humanization of the mouse (“The mouse with human nerve cells related to XX can be regarded as a human”, “The mouse with human nerve cells related to XX can still be regarded as a mouse”), and responses ($r=-0.47$, $p<0.001$) were reversed and averaged so that higher values indicated a higher perception of humanization. The next two items measured the perception of enhancement of the mouse's mental capacity related to the transplanted cells (“The mouse with human nerve cells will have a higher capacity for XX than an ordinary mouse”, “The mouse with human nerve cells will have a lower

⁴ A sample of 64 participants per group would be required to detect a medium effect size ($d=0.5$) in comparing mean values at a significance level of 0.05 and a power of 0.8. We considered that we needed 1.1 times more participants based on the number of participants excluded from the analysis in the pilot study and thus recruited about 70 participants per condition. However, some analyses ignored the condition, and the power may have been too high. Therefore, it is necessary to pay attention to effect size as well as the statistical significance when interpreting the results.

capacity for XX than an ordinary mouse”). Responses to these two items ($r = -0.48$, $p < 0.001$) were reversed and averaged so that higher values indicated a higher perception of enhancement. Finally, one item was asked to measure the perception of the change in the fundamental features of the mouse (“Transplanting human nerve cells related to XX will change the fundamental features of the mouse”).

The questions about cognition of chimera/ordinary mice were presented in a fixed order for ease of response.

Comprehension Check At the end of the questions about the chimeric mouse, the participants’ comprehension of the description was checked in the same way as in the pilot study. Those who failed to respond correctly were excluded from the analysis.

Results and Discussion

Determinants of Moral Judgments About Creating/Using Chimeras

A three-way ANOVA was conducted to examine the determinants of moral judgments. The independent variables were mental function related to the transplanted nerve cells in the description (13 conditions), target of evaluation (chimera/ordinary mouse), and action type (CREATE, USE, STIMULI, or KILL). The dependent variable included judgment of the moral permissibility of each act.

As this ANOVA revealed a significant interaction between mental function and the target ($F(12, 883) = 2.46$, $p = 0.004$), we examined the simple main effects of mental function. The effect was significant when the target was a chimeric mouse ($F(12, 883) = 2.33$, $p = 0.006$), but multiple comparisons with Shaffer’s correction showed significant differences in only two pairs (rationality was judged as more permissible than basic emotions, $t(883) = 3.57$, $p = 0.030$, and the sense of pain, $t(883) = 3.43$, $p = 0.041$). The effect of the mental function was insignificant when the target was an ordinary mouse ($F(12, 883) = 0.94$, $p = 0.509$). Although the main study modified question items to emphasize the mental function, this factor showed little effect again, suggesting that the differences of mental function was not important when forming attitudes toward chimeric brains.

Table 3 Mean values of moral permissibility in the main study

Target	CREATE	USE	STIMULI	KILL
Chimeric mouse	3.82 (1.88)	3.93 (1.87)	3.26 (1.85)	3.53 (1.90)
Ordinary mouse	4.32 (1.86)	4.34 (1.83)	3.35 (1.87)	3.73 (1.92)
<i>d</i>	0.27	0.22	0.05	0.10

Note. Numbers in parentheses indicate standard deviations

But at the same time, the result that the simple main effect of mental function was significant only toward a chimeric mouse may be noteworthy, which we discuss in the general discussion.

Next, as the interaction between the target and action type was significant ($F(3, 2649) = 37.27$, $p < 0.001$), we tested the simple main effects of the target. The act toward the chimera was judged to be significantly impermissible regardless of the action type ($F_s(1, 883) > 7.74$, $p_s < 0.006$; Table 3).⁵ The mean scores shown in Table 3 indicate that the ceiling effect was avoided, and thus this result would indicate the differences across the targets more accurately than the pilot study. The results suggest that brain chimerism intensifies people’s ethical concerns, but the effect sizes were small. In particular, the differences across the target were especially small for killing and imposing stimuli on a mouse. These acts were clearly harmful to whatever the subject was and, therefore, may have been judged impermissible regardless of whether or not it had human cells.

⁵ Apart from the purposes of the present paper, we also examined the simple main effects of the action type. The effects were significant for both chimeric ($F(3, 2649) = 123.06$, $p < .001$) and ordinary mice ($F(3, 2649) = 261.84$, $p < .001$). When the target was a chimeric mouse, USE was judged to be the most permissible, followed by CREATE, KILL, and STIMULI. Multiple comparisons with Shaffer’s correction showed that these mean values were significantly different from one another ($t_s(883) > 4.43$, $p_s < .001$). When the target was an ordinary mouse, the pattern of the result was almost the same, except for the difference between USE and CREATE ($t(883) = 0.59$, $p = .552$; the other comparisons were significant, $t_s(883) > 9.32$, $p_s < .001$).

Table 4 Regression analysis to explain moral permissibility judgment

	Step 1	Step 2
Humanization	-.231***	-.002
Enhancement	-.016	-.041†
Moral rights		-.262***
Unnaturalness		-.293***
Changes in fundamental features		-.089***
Benefits		.404***
R^2	.054***	.564***
Adjusted R^2	.052	.561
ΔR^2		.510***

Note. The numbers represent the standardized partial regression coefficients. *** $p < .001$, † $p < .10$

Psychological Process of Moral Permissibility Judgments

Next, we analyzed the psychological processes underlying moral judgments in more detail.⁶ The analyses in this section were aimed at (1) comparing the effects of perceived humanization and enhancement, and (2) exploring the mediating processes between these two perceptions and the moral judgment. For simplicity, four variables regarding moral judgments, which were strongly correlated with one another (Cronbach's $\alpha = 0.94$), were averaged to construct a single index of moral permissibility.

Hierarchical multiple regression analysis was used to investigate the factors predicting moral judgment (Table 4). The analysis was conducted in two steps. The first step aimed to test the two hypotheses derived from the anthropocentric and capacity-based approaches and determine which approach better fit people's psychology. Thus, moral judgment was predicted by the perception of humanization and enhancement. In the second step, four variables based on free descriptions were added to the regression model to test whether the reasons people spontaneously mentioned were actually associated with their judgment.

The results showed that both models significantly explained the variance in moral judgment (step 1:

$R^2 = 0.054$, $F(2, 893) = 25.41$, $p < 0.001$; step 2: $R^2 = 0.564$, $F(6, 889) = 191.71$, $p < 0.001$), and the second model had larger explanatory power than the first ($\Delta R^2 = 0.510$, $F(4, 889) = 260.11$, $p < 0.001$). This implies that adding the variables derived from the free descriptions improved the model. In the first step, the perception of humanization predicted less permissible judgment ($\beta = -0.231$, $p < 0.001$), while the perception of enhancement did not have a significant effect ($\beta = -0.016$, $p = 0.620$), supporting the hypothesis from the anthropocentric approach that people's moral concerns are directed against animals that cross the boundary between humans and animals. However, the effect of the perception of humanization diminished in the second step ($\beta = -0.002$, $p = 0.926$). Instead, all the added variables had significant effects on moral judgment ($|\beta| > 0.088$, $ps < 0.001$). These results suggest that the factors that people spontaneously mentioned in the pilot study were more direct determinants of their moral judgments than the perception of humanization in their psychological processes. These factors might mediate the effect of perception of humanization, the effect of which diminished in the second step.

Given that the regression analysis suggested the existence of a mediation process, we decided to perform additional analysis to test this mediation effect. Structural equation modeling (SEM) examined a model wherein the perception of humanization influenced moral permissibility judgment. A model was created in which the effect of the perception of humanization and enhancement on moral judgment were mediated by the other variables of cognition for chimeras (Fig. 1). The model revealed sufficient goodness of fit (RMSEA = 0.026, CFI = 0.999, GFI = 0.999, AGFI = 0.986). The SEM results showed that, on the one hand, perception of humanization was positively related to the factors that led to harsh moral judgments (attribution of moral rights, unnaturalness, and changes in fundamental features), and negatively related to the factor that led to permissive judgments (benefits). The indirect effects of these mediating factors were all negative (Table 5), suggesting that the perception of humanization led to the judgment that creating and using chimeric brains were impermissible through their relationship to the more proximate determinants of the judgment. On the other hand, perception of enhancement was associated with only two

⁶ See supplementary materials (Supplementary file1, Appendix 2) for the basic statistics of the relevant variables.

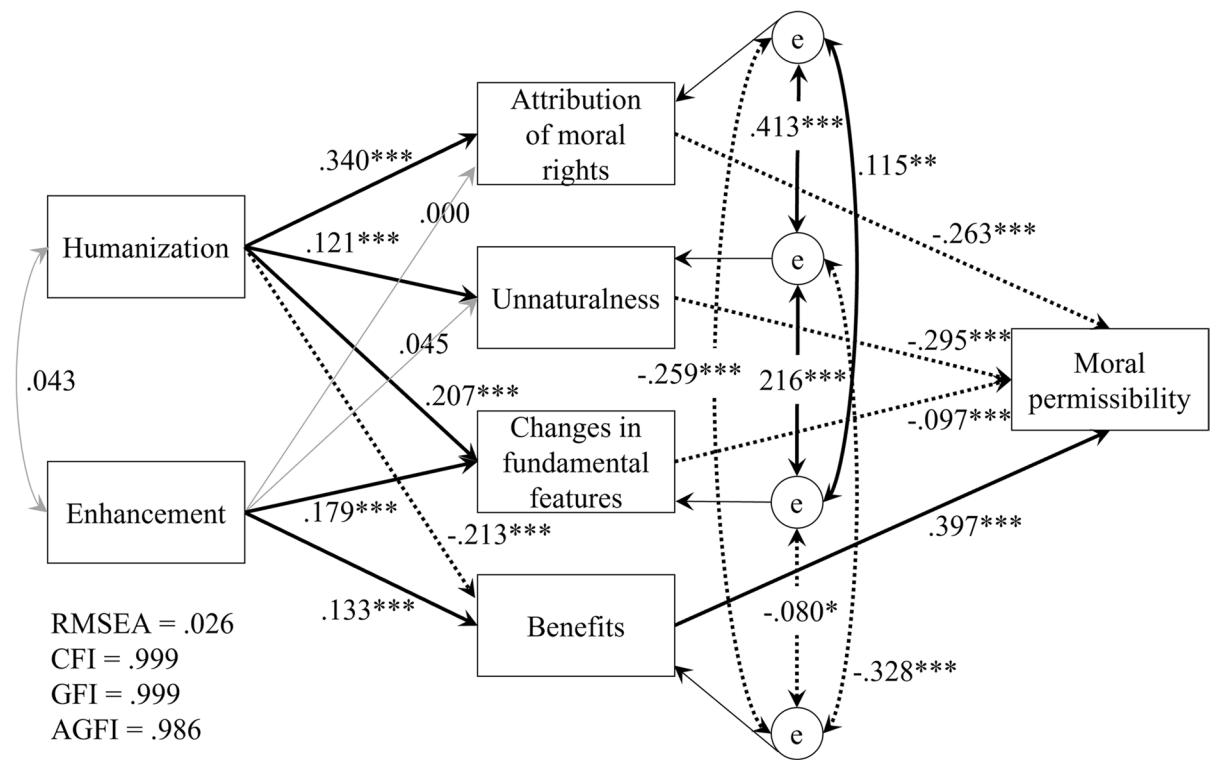


Fig. 1 Structural equation modeling of the psychological process of the moral permissibility judgment. *Note.* Black lines indicate statistically significant paths and correlations

(*** $p < .001$, ** $p < .01$, * $p < .05$). Solid lines indicate positive relationships and dotted lines indicate negative relationships. The coefficients are standardized

Table 5 Estimation of indirect effects on the moral permissibility judgment

	Estimated value	Standard error	p-value	95% CI	Standardized estimation
Humanization → Moral rights → Permissibility	-0.152	0.022	< .001	[-0.196, -0.113]	-0.089
Humanization → Unnaturalness → Permissibility	-0.061	0.018	.001	[-0.096, -0.026]	-0.036
Humanization → Changes → Permissibility	-0.034	0.010	.001	[-0.055, -0.016]	-0.020
Humanization → Benefits → Permissibility	-0.144	0.026	< .001	[-0.199, -0.094]	-0.084
Enhancement → Moral rights → Permissibility	0.000	0.015	.995	[-0.029, 0.029]	0.000
Enhancement → Unnaturalness → Permissibility	-0.022	0.018	.213	[-0.058, 0.011]	-0.013
Enhancement → Changes → Permissibility	-0.029	0.009	.002	[-0.048, -0.012]	-0.017
Enhancement → Benefits → Permissibility	0.088	0.023	< .001	[0.043, 0.134]	0.053

Note. Standard errors and 95% confidence intervals were estimated using the bootstrapping method (5,000 samples)

of the four mediating variables. Moreover, the two significant indirect effects were in opposite directions and these effects canceled each other out. This may explain why we could not find a significant association between perception of enhancement and moral judgments.

General Discussion

In this final section, we first summarize the present study’s empirical findings and then discuss their normative implications. Specifically, we illustrate the potential ways to embody normative discussions in

three forms mentioned in the introduction: confirmation, debunking, and policymaking. Finally, we conclude with the limitations of the present study.

Psychological Processes Behind the Moral Judgments Regarding Brain Chimerism

Moral Concerns for Creating/Using a Brain Chimera

In this paper, we examined people's judgments regarding moral (im)permissibility of human-animal brain chimera research through two studies. The comparison of moral judgment about chimeric and ordinary mice showed that creating and using chimeric mice were judged to be less permissible than ordinary animal use in research. This means that people believe that transplanting human nerve cells makes a mouse more worthy of moral consideration. However, the result must be interpreted with caution because the effect size was small. Participants were only given a written description of a human-animal chimeric brain, and it is not clear how realistically they could imagine creating or using such an animal. Further research is needed to determine whether people do not find morally significant differences between chimeric brain research and ordinary animal experiments, or whether the present study failed to properly detect the differences.

At the same time, the mean scores of permissibility judgments were around the mid-point of the scale, suggesting that our participants did not entirely reject the chimerism. Although we should not draw too strong of a conclusion from these mean scores since the study was not based on a random sample, it will be important that the results demonstrated that people's attitudes can be more nuanced rather than complete rejection or acceptance.

In addition, we explored the possibility that the moral judgment was affected by the region to which the human nerve cells were transplanted. The result showed that this factor had little effect even though the wording of questions was modified to emphasize the difference in the main study. This suggests that people do not pay much attention to this factor when they make moral judgments. This interpretation is consistent with the result that moral judgments did not correlate with the perception of enhancement of mental function. However, it may be too early to assume that differences in mental function

are irrelevant to moral judgments. The factor had a simple effect only when the target of the acts was the chimeric mouse. This suggests that the participants responded to the presented information in a reasonable manner since this factor was obviously irrelevant when they thought about the ordinary mouse. Having said that, as significant differences in moral judgments were found in only a few comparison pairs, and these differences were small, the robustness of this effect requires further investigation.

Psychological Processes Behind the Moral Judgment

The present study not only examined the extent to which people accept brain chimerism but also investigated how those attitudes were determined. We tested two hypotheses that derived from the anthropocentric and capacity-based approaches. The result supported the former: the more participants perceived the humanization of an animal, the less they judged human-animal chimeric brain research to be permissible.

Furthermore, free-text responses in the pilot study revealed a range of reasons other than animal humanization and enhancement, and the main study confirmed their quantitative relationship with the judgment. The analysis showed that the effect of perceived humanization was mediated by the factors that participants spontaneously mentioned. These results suggest that, on the one hand, people can be aware of the factors that affect their own moral judgments; on the other hand, there is a more fundamental determinant underlying them, which people are less likely to mention spontaneously. Analyses of this kind can shed light on the implicit values people hold when forming their attitudes toward human-animal chimeric brains. People are not always aware of the factors that influence their own attitudes. Thus, analyzing the correlations between variables can reveal the psychological processes behind people's moral judgments in more detail.

Implications of Empirical Investigations on Bioethics

Our results do not simply tell us whether people generally find human-animal brain chimerism morally permissible or not. They also reveal the psychological background of the moral (im)permissibility judgment. This can be significant because

mere information of the moral judgment does not imply the values that people hold in thinking about human-animal brain chimerism. Our findings suggest rather how the moral judgment is driven by the implicit values.

As mentioned in the introduction, several suggestions have been made as to how empirical evidence can be used to draw implications for bioethical issues. We follow these suggestions to consider how our findings can inform normative discussions concerning human-animal brain chimerism. The following subsections discuss our findings' implications from three perspectives.

These discussions will have two types of contributions. On the one hand, the discussions regarding confirmation and debunking can contribute to bioethics by examining the basis of existing arguments when they refer to some kind of intuitions. These discussions may contradict each other since the former says that empirical evidence contributes to normative discussions by providing *prima facie* validity to a certain argument, and the latter says that empirical evidence can debunk normative arguments by revealing that they are associated with morally irrelevant factors and thus unjustified. Therefore, the present paper does not commit to either perspective. Rather, this paper provides possible and concrete examples of how we can draw normative implications from empirical results when we adopt each perspective, and it will contribute to the future discussions about how we should bridge between empirical data and normative arguments about bioethical issues.

On the other hand, the discussion of policymaking has applicational implications regarding regulations of scientific research. Although it must be noted that people's attitudes do not determine the validity of ethical claims, the viability of those claims is also important in view of the practical nature of bioethical issues. Any rules that are not understood and accepted by the public will undermine trust in social institutions and hinder their effective operation. As Fitz et al. [21] state, "we should craft regulation so that it reasonably aligns with public attitudes" (p.185). The data on the average acceptance level and the processes determining it will allow policymakers to design appropriate regulations that are socially acceptable and that also promote scientific advancement.

Confirmation

The first possible contribution is confirmation, the idea that people's judgment can be used as a clue that a certain normative claim has *prima facie* weight. In other words, we can choose a normative claim that is consistent with people's judgment as the starting point for the discussion, unless there are other arguments that it is invalid. Although this does not mean that a normative claim's validity is proven by empirical data, it makes sense to refer to people's judgments given that philosophers sometimes make arguments with reference to intuitions.

An example of the normative argument that refers to intuitions can be found in the seminal paper regarding the ethics of human-animal chimerism. Robert and Baylis proposed that "moral confusion" could be led by obscuring the boundary between humans and nonhuman animals. In their analysis, they note "notwithstanding the claim that biologically species are fluid, *people believe* that species identities and boundaries are indeed fixed and in fact make everyday moral decisions on the basis of this belief" [4] (p.6, italics added). Notice that they carefully refrain from committing themselves to the existence of the "moral confusion," nor they do not endorse that such confusion determines the moral impermissibility of human-animal chimerism. Nevertheless, given that "the plausible objection to the creation of novel interspecies creatures rests on the notion of moral confusion" [4] (p.11), it is interesting to empirically determine whether there is any psychological fact that has a potential to develop into moral confusion.

We think the present study is illuminating in terms of this empirical inquiry. We found that people's moral judgment was driven by perceived humanization. This result appears to show that people hold anthropocentrism implicitly in their minds. Furthermore, given that the perception of enhancement did not relate to the moral judgment and that there was no correlation between the perceptions of humanization and enhancement (see Fig. 1), people's ethical concerns regarding the species boundaries appears to be distinct from the issues of capacity. Possibly, this manifests the content of "(folk) essentialism about species identities" [4] (p.10).

Our results appear more illuminating when we consider the analysis of moral confusion provided by Hübner [5], who points out that two different

prescriptions are derived from the anthropocentric view. One is that we have to provide special protection to partly human beings because they belong to the human species. Consequently, unless we cannot assure the protection, we should not create such beings (see also [22] for a similar discussion). The other prescription is that we should avoid creating chimeric beings because they make the species boundary, which is morally significant by itself, obscure. This implies that we should destroy a chimeric being if it is created because its existence raises a moral problem. Both arguments are anthropocentric in that they assume that species boundaries are morally significant. However, they seem to impose conflicting demands on us: protecting a chimeric being on the one hand and eliminating it on the other. Therefore, the creation of a human-animal chimera will cause a situation that can certainly be called “confusion,” in which we cannot follow two moral obligations. Although Hübner argues how this conflict *logically* derives from the anthropocentric view, we are rather interested in Hübner’s assumption that this conflict can be also manifested *psychologically*: there may be “contradicting intuitions within the same person at the same time” [5] (p.201), and this dilemma may be “the deeper foundation of ‘inexorable moral confusion’ [...] within *human thinking and action*” (p.207, italics added).

The present study’s results seem to confirm the existence of such anthropocentric thinking. First, the negative correlation between the perception of humanization and the moral permissibility judgment toward chimeric brain research seems to reflect the psychological fact corresponding to anthropocentrism. Second, more interestingly, this correlation was partly mediated by the attribution of moral rights and the perceived unnaturalness. These factors seem to match the two views that Hübner [5] identified within the anthropocentric view: the mediation via the attribution of moral rights seems to reflect the protection of a human-animal chimera, and the mediation of the perceived unnaturalness seems to reflect the prohibition of obscuring the boundary between humans and animals. It is also noteworthy that these two mediators were not correlated with the perception of enhancement, suggesting that they exclusively reflect the anthropocentric view. Therefore, our results seem to give an empirical ground to Hübner’s analysis of moral confusion; people’s attitudes against

human-animal chimerism are driven by the folk anthropocentric view, which tracks the two routes conflicting with each other.

Perhaps we can go further toward the case against human-animal chimerism. While Hübner [5], similarly with Robert and Baylis [4], emphasizes that his discussion is “analytical” rather than “normative” (p.206), he hints at how to argue from the former to the latter. The reasoning is such that creating a human-animal chimera generates an inevitable moral dilemma between two prescriptions, i.e. protection and elimination, and this dilemma constitutes an argument against its creation (p.203). Therefore, our findings could provide an empirical ground for the normative argument since they suggest that the conflicting intuitions related to the anthropocentric view actually occur in people’s mind.

Debunking

Moral judgments can turn out to be unjustified if they are produced via unreliable psychological processes. For example, deontological judgments about whether an action is permissible or not in moral dilemmas might be driven by whether the action is conducted with force that is manually mediated or automated (e.g., whether pushing a man off a footbridge with a pole or with a button-operated trapdoor) [23]. Such a finding can lead to the conclusion that deontological judgments are unjustified given that the driving factor (a pole or a trapdoor) is morally irrelevant. Similarly, Earp et al. [13] suggest that the explication of unreliable psychological processes, which involve morally irrelevant factors, can contribute to the debunking of bioethical theses.

Furthermore, people can be unaware of such morally irrelevant factors in producing their moral judgments, leading to post-hoc rationalization of those judgments. This may be even the case with philosophers; for example, the Kantian principle that prohibits the instrumental use of person or the Doctrine of Double Effect that distinguishes intended and foreseen harms might have been proposed by philosophers in their attempts to rationalize the inclination toward deontological judgments, which are nevertheless actually driven by the morally irrelevant factors. In this case, those philosophical theses can be arguably unjustified [24]. Thus, debunking can reach not

only people's judgments but also, possibly, philosophical theorization related to those judgments.

One could use our present study's results to debunk a specific sort of judgments concerning human-animal chimeric brains. Here we sketch a couple of possibilities, illustrating how the explication of the psychological processes can be informative.

One possibility is the debunking of psychology behind the anthropocentric approach. The anthropocentric approach emphasizes the distinction between human and nonhuman animals; and indeed, our results showed that people connected the humanization of an animal with moral impermissibility. However, more detailed analyses of the psychological processes pose a question regarding how sound the reasoning behind those judgments is as we have found that the effect of perceived humanization was mediated by the perception of unnaturalness. It has been well recognized that whether something is natural or not is morally irrelevant or insufficient for any substantial normative claims. If this is the case, the anthropocentric approach will be unjustified to the extent that its perceived truth is partly mediated by an irrelevant factor, that is, unnaturalness.

Another possibility is the debunking of the validity of benefits evaluation. Benefits derived from scientific research appear to give a relatively clear reason for conducting it. Human-animal chimeric brain research can provide a variety of benefits, such as the intrinsically valuable knowledge of the brain or the future advancement of medical treatment of human neuronal diseases. Although it is another matter whether such a reason can outweigh reasons against the research, it works as a *pro tanto* reason favoring it. The present study has found that the perception of benefits has an impact on the moral permissibility judgment of brain chimerism, which perhaps reflects this reasonable connection. However, we have also found that the perception of benefits is negatively correlated with the perception of humanization. As far as we know, there is no reasonable connection between chimerism possibly humanizing the target animal and chimerism having less scientific or medical benefits. Thus, although we conducted SEM with the assumption that the perception of benefits leads to permissibility judgment, perhaps there might be a backward psychological process: the judgment that chimerism is impermissible arises first, and the benefits are underestimated to be consistent with the judgment. If

this is the case, the anthropocentric approach is unjustified to the extent that the approach may be found persuasive partly in virtue of the biased psychological process.

Policymaking

Bioxphi can be important not only for philosophical debates but also for practical considerations, such as policymaking related to bioethical issues. This character is inherited from the discipline of bioethics, which has a more practical character than other philosophical areas [13]. In the following, we consider several possible contributions from the present study.

First, knowing people's acceptance level can help discuss how stringent the regulations on chimeric brain research should be. Almost every bioethical issue is related to the question of how to design social institutions, and especially in the case of novel technological issues, it has been argued that we cannot dismiss the public trust toward the technological advancement in question. It is because regulations over technologies must be in accord with the value held by the public as well as estimated costs and benefits [21, 25]. In this regard, our results do not indicate that people entirely reject creating and using human-animal brain chimeras, as the mean scores of moral permissibility were 3–4 on a 7-point scale, though we must be cautious in interpreting the mean scores in a non-random sample. Although the pilot and main studies differed in the wording of the question items, the main study assumed a situation more similar to actual research, and permissibility was higher.

However, their acceptance level was lower for chimeric brain research than for ordinary animal experiments, though the difference was small. Therefore, chimeric brain research may raise unique ethical concerns that other animal experiments do not, and thus it will be important to inform the public about the research.

Second, our analyses of psychological process behind moral judgment suggest an interesting possibility. Given the customary debate in bioethics between the anthropocentric and capacity-based approaches, it is as if we have to make a choice between what they prescribe in embodying the regulation related to human-animal chimeric brains. In a simple form, the results of the present study could

be taken to suggest that there is *pro tanto* reason to favor the regulation implied by the anthropocentric approach, because people's moral judgment was found to be correlated with the perception of humanization instead of enhancement of animals. However, we think more nuanced implications should be drawn. Remember that while the perception of enhancement was not correlated with moral judgment, this occurred because the effect was mediated by the perception of fundamental change and the benefits of research, and these effects canceled each other out. Thus, it is not correct to say that people's negative attitude toward chimeric brain research (if any) is driven exclusively by the intuition that matches the anthropocentric approach; rather it should be said that their negative attitude is partly driven by perceived change in the animal's fundamental features, which would be emphasized in both of anthropocentric and capacity-based approaches. This reasoning suggests that it is misleading to consider the regulation over human-animal chimeric brains in terms of the choice between the two approaches. Rather, it should be considered in terms of the possible fundamental change in animals, whether we think of ways to prevent such change or make it clear whether such change is morally problematic.

Objections might include statements that there will be no fundamental changes made via chimerism, at least in the near future, and therefore people's concerns could be dismissed in policymaking. However, even if this were to be true, it remains useful to understand this psychological process because it would prompt policymakers and scientists to explain well to the public that chimeras will not acquire any fundamental changes in the near future. This is no trivial issue, because without such an explanation, there will emerge distrust and dubious discourses, which can lead to the prevention of scientific advancement.

Third, we note the importance of the finding that there are multiple backgrounds that affect people's attitudes because they manifest a form of value plurality. In policymaking, we cannot avoid navigating between plural, potentially conflicting reasons [13]. The word "plurality" or "pluralism" may conjure up images of a situation in which there are multiple stakeholder groups with different values, but the present study suggests a possibility of *psychological plurality*, where the set of distinct values may coexist implicitly within even each person's mind. This

reminds us that, even when we do not have to be concerned with conflict between stakeholders, there is still the need of navigation between multiple pros and cons, which we think is just the case of human-animal brain chimerism.

Limitations

We have to acknowledge the limitations of the present study. First, owing to the study's correlational nature, we could not establish a causal relationship in which the perception of humanization led to negative attitudes toward chimeric brain research. In particular, the present study examined the psychological process through SEM. We must note that this is an analysis in which the analyst assumes causal connections between variables to build a model, not an analysis to discover causal connections.

It could be argued that those who opposed chimeric brain research tended to perceive humanization to justify their negative attitude toward chimeric brain research, and that the opposition was formed by some other factor [cf. 26]. If so, however, it would still be interesting to note that people appealed to the anthropocentric rather than the capacity-based approach to justify their intuition. The psychology of such justification can be a target of further empirical research.

Second, our participants judged moral permissibility shortly after reading a concise text; thus, their responses were not necessarily well-informed and well-considered judgments. Although this method was effective in identifying lay people's intuitive moral judgments, their judgments may have been different if they had taken a longer time to deliberate. Moreover, opportunities to communicate with others and encounter different views may have altered their attitudes. Such judgments might have been a better research subject given the actual process of designing social systems. Further research is needed to elucidate how people form attitudes and build social consensus when they face an ethical issue.

A third limitation was the low representativeness of the sample. Since the present study was not based on random sampling, it might not reflect the average response of the general public. In particular, most of the sample comprised college graduates, and highly educated people might have a more favorable attitude toward scientific research than others. Additionally, it is necessary to examine the responses of

non-English-speaking people and consider whether moral judgments are shared across cultures.

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Declarations

Competing Interests The authors declare no conflict of interest.

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