

SCIENCE AND SOCIETY

U.S. attitudes on human genome editing

Although views on human genome editing differ, all want public engagement

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The emergence of CRISPR-Cas9 gene editing has given new urgency to calls from social scientists, bench scientists, and scientific associations for broad public dialogue about human genome editing and its applications. Most recently, these calls were formalized in a consensus report on the science, ethics, and governance of human genome editing released by the U.S. National Academy of Sciences (NAS) and the National Academy of Medicine (NAM) that argued for public engagement to be incorporated into the policy-making process for human genome editing (1). So, where does the public stand on the issue of human genome editing? And how do those attitudes translate into the desire for more public input on human genome editing as new applications emerge in the policy arena?

The NAS/NAM report classifies applications of human genome editing on the basis of purpose and heritability. The purpose of human genome editing can be therapeutic (to treat or prevent disease) or focused on enhancement (purposes unrelated to treating or preventing disease). As for heritability, edits to the human genome can be to somatic (nonreproductive) cells, or to heritable germline cells. Although the report draws clear lines in terms of permissibility



among these different types of applications, given the current state of the science, regulatory frameworks, and public engagement, we know little about how the report's conclusions map onto public attitudes.

Initial insights emerged from a 2016 STAT-Harvard survey (2), which suggested that only 35% of U.S. citizens would support therapeutic treatment of unborn babies (although the wording was ambiguous as to those edits being somatic or to the germ line). Similarly, a Pew Research Center poll in the same year indicates that only 31% of Americans surveyed were not worried by the prospect of therapy that changed a baby's genetic makeup and

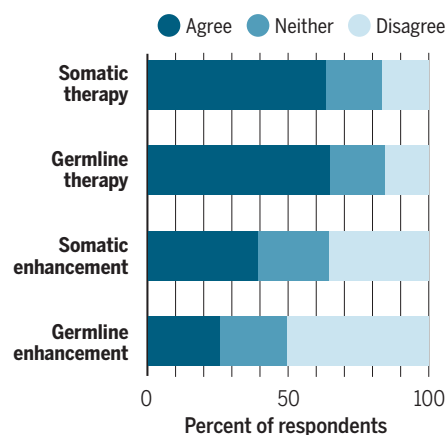
could be passed on to future generations (3). Nearly half of adults (49%) indicated that gene editing would be less acceptable to them if the effects "changed the genetic makeup of the whole population." The Pew survey, however, did not allow for an assessment of whether there is a distinction in how people perceive somatic and germline edits when the application is related to therapy versus enhancement. Those nuances are particularly relevant when it comes to measuring reactions to the likely types and uses of human genome editing as identified by experts in the bench sciences and bioethics (1).

To more systematically examine public attitudes, we relied on national survey data from 1600 U.S. adults that YouGov collected in December 2016 and January 2017 (for complete wording on all questions, see table S1). The influences we describe held after controlling for potential confounds in multivariate models (tables S2 and S3).

In contrast to previous surveys, two-thirds of our respondents saw both somatic therapy (64%) and germline therapy (65%) as acceptable (see the first figure). We did, however, observe lower levels of acceptance for germline enhancement applications (26%; with 51% finding it unacceptable) than we did for somatic enhancement applications (39%; with 35% finding it unacceptable). Our data suggest that among members of the public, the distinction between treatment- and enhancement-oriented applications of human genome editing currently carries substantially more weight in support judgments than does the somatic/germline distinction.

Acceptance of gene editing

A majority finds use of human genome editing for therapeutic purposes acceptable, including somatic and germline edits. Public opposition increases for applications aimed at enhancement.



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Consistent with other recent studies, we found that 59% of respondents expressed at least some support for human genome editing to treat human medical conditions or restore health, whereas only 33% expressed at least some support for using these techniques to enhance or improve human abilities.

What drives attitudes? Previous research, including some of the existing survey data on human genome editing, suggests that attitudes toward embryonic research (4) and genome editing (3) are at least partly related to respondents' religiosity. Our survey data supported those findings. Among those reporting low religious guidance, a

large majority (75%) express at least some support for treatment applications, and a substantial proportion (45%) do so for enhancement applications. By contrast, for those reporting a relatively high level of religious guidance in their daily lives, corresponding levels of support are markedly lower (50% express support for treatment; 28% express support for enhancement).

Most previous surveys of emerging technologies have measured only self-assessed familiarity with new technologies. When we looked at the number of factual questions about genome editing that respondents could answer correctly (questions are listed in the supplementary materials), greater command of facts related to genome editing was positively associated with support. For those unable to correctly answer any of our nine factual questions,

32% expressed support for treatment and 19% did so for enhancement. At the other end of the knowledge scale, those able to correctly answer six or more factual questions expressed much higher levels of support, with 76% indicating at least some support for treatment and 41% indicating support for enhancement. Individuals in the middle and high factual knowledge groups were evenly split between support and opposition to enhancement, whereas

individuals in the low knowledge group were much more likely to indicate that they neither support nor oppose gene editing (50%). Knowledge, then, does not necessarily relate to more

support for enhancement-related edits but does appear to relate to more extreme views on enhancement overall (5).

What does this mean for public engagement? This past year, U.S. National Academies reports related to genetically modified crops (6), gene drives (7), and human genome editing (1) have called for societal debates that progress well beyond the technical aspects of genome editing and additionally focus discussions on its political, regulatory, ethical, and moral implications. Our data show relatively broad consensus among all groups in support of the idea that the scientific community "should consult with the public before applying gene editing to humans." How much the public embraces the views of public engagement expressed in these reports, however, also depended on respondents' levels

of religiosity and information. Despite opposite levels of support for human gene editing, both the highly religious and highly knowledgeable respondents have the highest (and statistically indistinguishable) levels of support for public engagement. Close to three-quarters of the most knowledgeable respondents and the most religious respondents in our sample embraced the idea of consulting the public.

We also asked about the public's view on the role of scientists themselves in guiding the development of new technologies. Our data show that highly religious and less knowledgeable respondents were much more doubtful about the ability of the scientific community to provide enough oversight by themselves than were those with low religious guidance or high knowledge (see the second figure).

In sum, our findings show a broad mandate for public engagement, even across groups who otherwise differ in their evaluation of potential applications of human genome editing and in their assessment of the scientific community's ability to navigate emerging science independently of public input. ■

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5. Higher factual knowledge was significantly related to support for gene editing for therapy uses but not for enhancement uses, where those in the higher-knowledge group had higher levels of support than those in the lower-knowledge groups, but not to a significant level. This could be owing to respondents overall being less supportive of enhancement-related edits or to higher factual knowledge levels leading to more split opinions on enhancement. These effects are reflected in the lower levels of variance in the models predicting support for enhancement-related edits compared to the models predicting support for therapy-related edits (see tables S2 and S3).
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ACKNOWLEDGMENTS

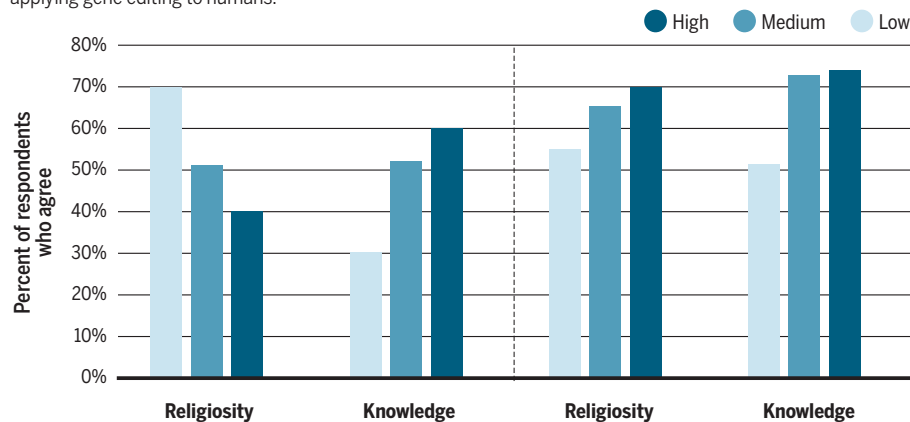
The authors acknowledge the Office of the Vice Chancellor for Research and Graduate Education at the University of Wisconsin–Madison (with funding from the Wisconsin Alumni Research Foundation) for its support of this research.

SUPPLEMENTARY MATERIALS

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Influence of religiosity and knowledge

More religious and more knowledgeable respondents agree on the need for public engagement. Highly religious respondents differ from highly knowledgeable ones in how capable they think the scientific community is of guiding the development of new technologies, but both groups agree that scientists should consult with the public before applying gene editing to humans.



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Science **357** (6351), 553-554.
DOI: 10.1126/science.aan3708

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