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A Global Social Media Survey of Attitudes to Human Genome Editing

Tristan McCaughey,[1,2,9] Paul G. Sanfilippo,[1,9] George E.C. Gooden,[3,9] David M. Budden,[4,9] Li Fan,[5,6] Eva Fenwick,[1] Gwyneth Rees,[1] Casimir MacGregor,[7] Lei Si,[5] Christine Chen,[1,2] Helena Hai Liang,[1] Timothy Baldwin,[8] Alice Pébay,[1,3,10] and Alex W. Hewitt[1,3,5,10,*]
[1]Centre for Eye Research Australia, University of Melbourne, Melbourne, VIC 3002, Australia
[2]Department of Surgery, Monash University, Melbourne, VIC 3800, Australia
[3]Lions Eye Institute, University of Western Australia, Perth, WA 6150, Australia
[4]Systems Biology Laboratory, University of Melbourne, Melbourne, VIC 3010, Australia
[5]Menzies Institute for Medical Research, University of Tasmania, Hobart, TAS 7000, Australia
[6]State Key Laboratory of Ophthalmology, Zhongshan Ophthalmic Centre, Sun Yat-sen University, Guangzhou, Guangdong 510060, China
[7]School of Social Science, Monash University, Melbourne, VIC 3800, Australia
[8]Department of Computing and Information Systems, University of Melbourne, Melbourne, VIC 3010, Australia
[9]Co-first author
[10]Co-senior author
*Correspondence: hewitt.alex@gmail.com
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Ongoing breakthroughs with CRISPR/Cas-based editing could potentially revolutionize modern medicine, but there are many questions to resolve about the ethical implications for its therapeutic application. We conducted a worldwide online survey of over 12,000 people recruited via social media to gauge attitudes toward this technology and discuss our findings here.

CRISPR/Cas (clustered regularly interspaced short palindromic repeats/CRISPR-associated protein) provides an accurate and efficient means to edit the mammalian genome, and ongoing advances appear set to cause a paradigm shift in the medical care of inherited diseases. The technology has already shown promise for developing treatments and potentially curing some inherited genetic conditions (Hockemeyer and Jaenisch, 2016). Moreover, genome editing could be applied to non-health-related traits, such as physical appearance, and germline or embryonic alterations would have transgenerational consequences. In addition to greater technical proficiency, wider societal acceptance and understanding are required before CRISPR/Cas-based technology should transition into clinical practice (Lander, 2015). The scientific community has proposed a pause on human germline editing (Baltimore et al., 2015; Lander, 2015; Lanphier et al., 2015) and, although this call is not universally supported (Miller, 2015), there is general consensus that safety is paramount and further research is required prior to clinical use (Bosley et al., 2015). Furthermore, given the significant ethical issues, it is well accepted that the wider public must be engaged in discussions regarding the appropriate application of this technology.

As part of that process, we sought to investigate global perceptions of human genome editing applications and explore the factors associated with these views. We developed an online survey about attitudes to the application of genome engineering in different contexts (see Supplemental Information), translated it into a range of international languages, and recruited study respondents via social media (Facebook, Twitter, Google, and WeChat). We designed the survey to capture pertinent demographic details and gauge agreement for specific applications of gene editing using a five-point Likert scale. Specifically, we investigated whether there was greater support for gene editing in life-threatening diseases when compared to debilitating diseases; whether the acceptance of this technology varied between its use on human embryos or on terminally differentiated somatic cells; and whether it should be applied to non-health-related traits such as intelligence, strength, or physical appearance. Perspectives on using gene editing technology were also explored in the context of genetically modified (GM) food, a technology of which the public generally has a greater awareness, and where attitudes have previously been explored.

We analyzed responses from 12,562 people across 185 countries. 10,067 respondents provided complete demographic data, with attrition between survey items ranging from 0.6%–6.9%. 3,512/12,097 (29.0%) people were from the United States of America (USA) or the United Kingdom (UK), and 2,658/12,097 (22.0%) were from Japan or China (Figure 1). The median age of participants was 24 years (range 11–90) and 4,739/12,543 (37.9%) were female (Figure 1). This relatively young demographic compared to society overall seems consistent with the social-media-based recruitment mechanism that we used. 653/10,933 (6.0%) people reported being affected by or having a relative with a Mendelian-inherited disorder, while 5,107/11,678 (43.7%) people reported having a religious affiliation.

Overall, there was support among our survey respondents for the use of gene editing in children and adults to cure life-threatening diseases, with 59.0% (5,941/10,067) of people "agreeing" to this application of the technology and only 9.6% (963/10,067) "disagreeing" (Figure 2). Similarly, when questioned about the use of genetic editing to cure debilitating diseases, 59.4% (5,795/9,750) of people agreed. These findings are in contrast to a previous online survey restricted to the USA and Canada that showed greater public support for lifesaving applications

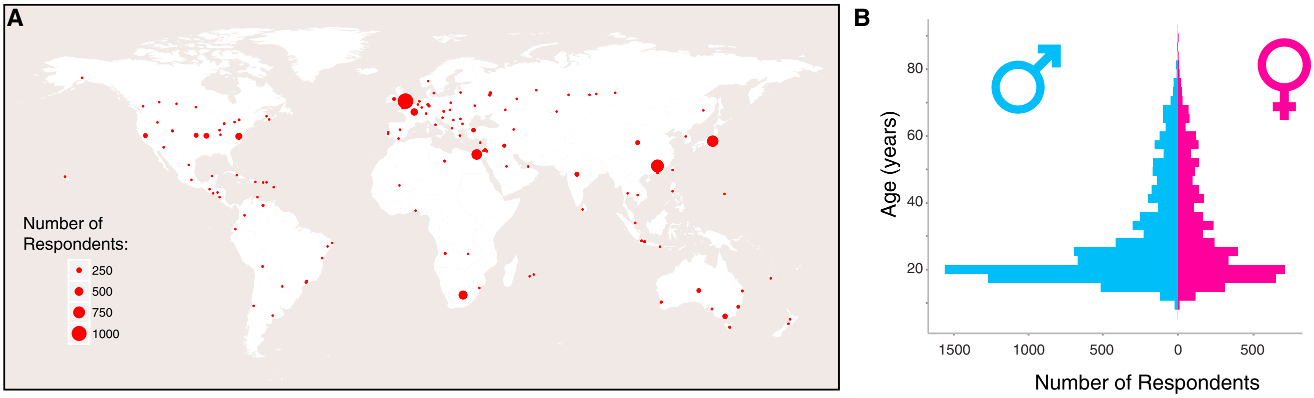

Figure 1. Demographic Profile of Survey Participants
(A) Worldwide distribution of study participants, based on their IP address details and geolocate details. Geolocate data for a total of 1,362 participants were not available.
(B) Distribution of age and sex across study respondents. The number of males (blue) and females (pink) for each age group is displayed.

of genetic modification but a decrease in acceptance as the severity of the disease decreases (Robillard et al., 2014). Furthermore, we found that there were similar levels of support among our respondents for embryonic editing as there was for gene editing in children or adults (Figure 2). As such, it would appear that despite many in the scientific community condemning embryonic editing and supporting somatic cell editing, our respondents view both applications as comparable (Baltimore et al., 2015; Bosley et al., 2015; Lander, 2015; Lanphier et al., 2015; Miller, 2015).

There was substantially less support among our respondents for the use of gene editing technology for non-health-related purposes (Figure 2), with 43.3% (3,884/8,961) of people stating they disagreed with this application. Participants who agreed with it (2,402/8,961, 26.8%) were questioned about the specific non-health-related traits they would modify with gene editing. Intelligence had the highest acceptance at 68.0%, followed by strength or sporting ability (58.4%) and appearance (51.3%). The reduced support for this technology for non-health-related purposes when compared to medical purposes is consistent with other findings (Robillard et al., 2014); however, with less than half of respondents disagreeing, this resistance appears far from universal, contrasting with the strong opposition from some researchers (Bosley et al., 2015; Pollack, 2015). This may reflect our recruitment bias, with participants possibly being more open to new technologies, given their use of social media, or more likely to be engaged in issues related to genetic modification.

We then applied multiple logistic regression analysis to assess the impact of demographic factors on respondents' perceptions (see Supplemental Experimental Procedures). We found that males were more likely to agree with all applications of gene editing compared to females (Figure 2, Table S1), with the strongest differences in non-health-related uses and GM food. Similarly, older age groups showed greater concerns with all applications of the technology, and this finding was most marked for non-health-related purposes as well as use on GM food, where a 9.3% and 33.9% increase in odds of disagreeing with each decade increase in age was found. This differential suggests that the relatively young demographic spread of our respondent pool may have skewed our survey results relative to the views of the overall general population.

We did not find an association between self-reported wealth and support or resistance to gene editing in humans, but participants from countries with high Gross Domestic Product (GDP) per capita were generally more supportive of all health-related applications of gene editing as well as its use in GM food (Table S1). When considering editing of somatic cells for life-threatening purposes, each 1,000 USD increase in GDP per capita of a country was associated with a small (1.32%) increase in the odds of respondents from that country agreeing with this application of gene editing. Participants from advanced economies with higher GDP per capita, such as the USA, were approximately 80% more likely to disagree with non-health-related uses than participants from developing countries with lower GDP per capita.

Respondents who reported a religious affiliation, particularly Christians, were notably more likely than those who did not to reject any application of genetic editing (Figure 2, Table S1). Given the traditional resistance of Christian groups to reproductive medicine and human embryonic stem cell research, these results are perhaps not surprising. Respondents who reported a Muslim affiliation did not show as strong a tendency in terms of health-related applications, but they did have a greater tendency than those without a reported religious affiliation to disagree with non-health-related applications and use on GM food.

We found a strong association between level of education and an increased acceptance of gene editing to treat diseases. Specifically, respondents who had completed tertiary education were 65% more likely to agree with gene editing for health-related purposes, compared to respondents who received no formal education (Figure 2, Table S1). Being affected by or having a family history of a monogenic or Mendelian disease was not associated with support for or against any application of gene editing.

The widespread application of gene editing technology requires greater public engagement and an open discourse between experts in the field and the general community (Baltimore et al., 2015). While

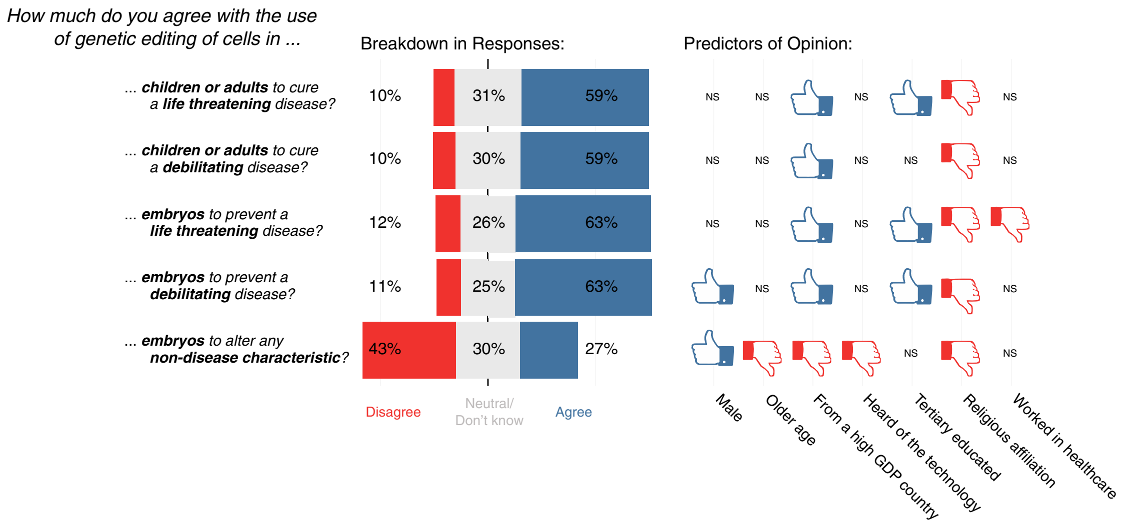

Figure 2. Breakdown of Responses for Survey Items Used to Gauge Participant's Agreement for Various Applications of Human Gene Editing
Putative predictors for support (blue thumbs up) or opposition (red thumbs down) to these applications were explored using multiple regression. Variables at the $p < 0.001$ level are displayed. See Supplemental Information for full model details. GDP, Gross Domestic Product; NS, non-significant.

the scientific community appears unified regarding the merits of somatic cell editing, the issue of germline editing is more divisive, demanding greater public discussion. Some have voiced concern that public backlash regarding germline editing will hinder somatic cell research (Lanphier et al., 2015), and the recent international summit on human gene editing concluded, "It would be irresponsible to proceed with any clinical use of germline editing unless… there is broad societal consensus about the appropriateness of the proposed application." Interestingly, our study participants generally supported the application of embryonic editing for life-threatening or debilitating diseases. Nonetheless, the varying views we identified across different demographic groups highlight the need for greater global engagement.

Online surveys present a unique opportunity for rapid collation of opinions on a large scale; however, this type of approach also has inherent limitations and recruitment biases (Eysenbach and Wyatt, 2002). Clearly many people are not exposed to social-media advertising, and surveys such as ours generally fail to recruit specific groups in the community, in particular older individuals or those without Internet access. To some extent this bias can be reduced by targeted campaigns and as such we sought responses from people across diverse demographic backgrounds, incorporating multiple languages; however, translation may have introduced additional biases. Finally, each individual was not examined for his or her understanding of the concepts involved and it is possible that not all respondents fully comprehended the questions. This issue could have affected data quality and our results should therefore be interpreted with some caution. In the future, population-based study design could enable the opinions of a specific population to be explored with fewer recruitment and selection biases, thus increasing the generalizability of the results within this population. Moreover, qualitative work such as focus-group discussions and semi-structured interviews could allow more in-depth investigation of the attitudes of under-represented demographic groups. It would also be important to look at attitudes toward other controversial applications of CRISPR/Cas such as gene drives, which introduce the prospect of large-scale ecological change (Esvelt et al., 2014).

Public sentiment has considerable influence over allocation of resources, political policy, and participation rates in studies, all of which affect the course of research. The rapid uptake of CRISPR/Cas-based gene editing is forcing the scientific community to confront complex ethical issues quickly, and in our view it is imperative that public opinion is considered to ensure that ongoing progress is supported and well received by broader society. In this exploratory study using a global online survey approach, we found that within our respondent group there was general acceptance of the health-related applications of gene editing but resistance toward non-health-related applications. Furthermore, it seemed as though a desire for better understanding of the technology, rather than an overall resistance to gene editing, may have underpinned caution in respondents' opinions. We hope that our study will stimulate further dialog and investigation. We would like to emphasize that it is very difficult to draw any generalizable inferences about attitudes and understandings of "public" opinion from highly heterogeneous populations using decontextualized quantitative survey instruments such as ours. Future research using a range of study designs will be needed to understand individual and societal perspectives on the application of CRISPR/Cas-mediated genome editing in medicine and elsewhere.

SUPPLEMENTAL INFORMATION

Supplemental Information for this article includes Supplemental Experimental Procedures and one table and can be found with this article online at http://dx.doi.org/10.1016/j.stem.2016.04.011.

AUTHOR CONTRIBUTIONS

Conceptualization, T.M., E.F., G.R., C.M., and A.W.H.; Methodology, T.M., L.F., L.S., H.H.L, and A.W.H.; Software, G.E.C.G., D.M.B., and T.B.; Formal Analysis, P.G.S., D.M.B., T.B., and

A.W.H.; Resources, C.C., H.H.L., and A.P.; Writing – Original Draft, T.M., G.E.C.G, P.G.S., and D.M.B.; Writing – Review & Editing, L.F., E.F., G.R., C.M., L.S., C.C., H.H.L., T.B., A.P., and A.W.H.; Visualization, P.G.S., G.E.C.G, D.M.B., and T.B.; Supervision, A.P. and A.W.H.; Funding Acquisition, C.C., A.P., and A.W.H.

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