Human Germline Engineering: A Study of Attitudes among Canadian University Students and the American Public

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Abstract

Attitudes toward human germline engineering were assessed across four studies. Studies 1 and 2 used participant ratings to develop a coherent set of germline engineering targets. Study 3 showed that in a sample of Canadian students, approval was higher for therapeutic modifications than for enhancing modifications, and higher for modifications targeting physical traits than for those targeting psychological traits. A regression analysis showed that approval related positively to knowledge and Agreeableness, and negatively to perceived risk and female gender. Study 4 replicated the same pattern of approval based on goal and trait type with a sample of American adults, and showed that overall approval correlated positively with level of education and Agreeableness, and negatively with perceived risk, female gender, and Extraversion. These findings provide empirical support for our proposed structure of attitudes toward germline engineering and show that overall approval can be predicted from stable individual differences.

Keywords: attitudes, biotechnology, genetic engineering

1. Introduction

The completion of the human genome project in 2003, just 50 years after Watson and Crick discovered the sequence of DNA, has been deemed a landmark event in the history of science (Venter et al., 2001; International Human Genome Sequencing Consortium, 2004). The culmination of a lengthy international research effort, the complete sequence of the human genome was hailed as a means of understanding our fundamental physical and functional composition in a first step toward identifying and preventing genetic diseases (White House Press Release, 2000 June 5). With over 1,000 clinical trials of gene therapy completed or in progress (Edelstein, Abedi, & Wixon, 2007), it is clear that global interest in human genetic engineering is strong.

Recent accomplishments in genome sequencing have shown that 80% of the genome is related to biochemical functions, providing new insights into gene expression (ENCODE Project Consortium, 2012). These developments pave the way for various forms of human genetic engineering, including human germline engineering, a new medical technology that modifies the cells of sperm, ova, and very early embryos to treat diseases or enhance desirable characteristics (Stock & Campbell, 2004). Because such procedures target germinal cells, any changes made are genetically heritable. Once realized, the ability to sculpt the human genome will have significant social and personal consequences, raising important questions like those raised by cloning and eugenics (Fukuyama, 2002; McKibben, 2004). Are therapeutic applications aimed at disease prevention more acceptable than cosmetic or enhancement applications? Does approval differ according to whether the targeted trait is seen as physical or psychological in nature? How do individual differences affect such attitudes? The goal of this study is to address such questions by developing a valid measure of attitudes toward human germline engineering and analyzing the responses of two different sample groups.

1.1. Attitudes toward Germline Engineering – Types of Procedures

The explosion in media coverage of genetic engineering and genomics during the mid-1990s spurred a wave of related attitude research (Pin & Gutteling, 2009).

However, there has been precious little, if any, research focusing specifically on attitudes toward germline engineering. Consequently, our perspective was informed by several areas of related research. The first major theme that emerged from the literature is that attitudes toward basic genetic engineering vary according to the type of target. Support declines as the target of modification moves from microorganisms, to plants, to animals, and finally to humans (Chen & Raffan, 1999; Dawson & Schibeci, 2003; Surmeli & Sahin, 2010). This shows that approval for genetic engineering is context-dependent, and thus suggests that approval for human germline engineering will also vary according to the type of characteristic targeted, with lower approval for procedures targeting traits considered to be more fundamentally human and higher approval for less central traits.

This idea receives additional support from another line of related research focused on the attitudes of young, healthy individuals toward the use of psychopharmacological drugs intended to improve cognitive or emotional functioning. Drugs used as enhancements include selective serotonin reuptake inhibitors (Kramer, 1993), beta-blockers (Jefferson, 1996), stimulants (McCabe, Knight, Teter & Wechsler, 2005) and drugs affecting memory and cognition (Yesavage et al., 2002). In a study of attitudes toward using pharmaceuticals as enhancements, Riis, Simmons, and Goodwin (2008) found that people are more reluctant to target personality traits than cognitive traits because personality traits are typically considered more fundamental than cognitive abilities. These authors did not examine physical traits, but given society's obsession with body modification via dieting, exercise, and cosmetic surgery, we expect relatively positive attitudes toward modifications targeting the physical body, compared to those targeting personality or cognitive traits. We therefore hypothesize that approval will be highest for modifications targeting physical traits, lower for cognitive traits, and lowest for personality traits.

1.3. Attitudes toward Germline Engineering – Goals of Modification

The second theme to emerge from the related literature is that approval varies according to the goal of the modification (Walters & Palmer, 1997; Wilson & Haslam, 2009). Most authors assign the goal of modification to one of two distinct categories: therapeutic modifications and enhancement modifications. Therapeutic modifications aim to eliminate disadvantages by screening out diseases and predispositions to unwanted medical conditions. Enhancement modifications aim to improve physical and mental characteristics beyond "normal" levels. Although there is no attitudinal research focused on the goals of germline engineering, research on attitudes toward genetic engineering has shown that people favour therapies over enhancements (Chen & Raffan, 1999; Hampel, Pfenning, & Peters, 2000; Meisenberg, 2009; Meister, Finck, Stobel-Richter, Schmutzer, & Brahler, 2005). For targets ranging from food crops and livestock to human medical applications, modifications aimed at disease prevention or resistance elicit higher approval than those aimed at enhanced growth or trait selection. Therefore we expect greater approval for applications of germline engineering seen as therapeutic compared to those seen as enhancing.

1.4. Individual Differences Correlates

There is ample evidence that certain demographic and psychological variables may relate to approval for human germline engineering. The first consistent finding to emerge from the related literature is that women express lower approval for various applications of genetic engineering than men, as well as more negativity and ambivalence (Chen & Raffan, 1999; Hampel, Pfenning, & Peters, 2000; Prokop, Leskova, Kubiatko, & Diran, 2007). This is consistent with the fact that women are typically more invested in their offspring than are men (Buss, 1999). Any change to the child would have profound and direct implications for its mother. We thus expect that gender will be a key determinant of attitudes toward germline engineering, with women showing lower average levels of approval than men.

A second notable trend is that favourable attitudes toward genetic engineering can be predicted from different forms of related knowledge such as general knowledge of science (Sturgis, Cooper, & Fife-Schaw, 2005), specific knowledge of biology (Chen & Raffan, 1999; Surmeli & Sahin, 2010), biology and genetics (Bal, Samanci, & Bozkurt, 2007), or biotechnology and genetic engineering (Klop & Severiens, 2007). We hypothesize that scientific knowledge will predict attitudes toward human germline engineering.

Perceived risk is another likely predictor of attitudes toward germline engineering. Several studies report that most participants associate at least some degree of risk with genetic engineering (Chen & Raffan, 1999; Bal, Samanci, & Bozkurt, 2007; Urban & Pfenning, 2000).

The only study to investigate the role of risk perception as a determinant of attitudes toward genetic engineering found it was the single strongest predictor, compared to religiosity, moral orientation, environmental awareness, and political orientation (Urban & Pfenning, 2000). This indicates that attitudes towards germline engineering will be partly determined by the perceived degree of risk.

Another variable that may predict attitudes toward human germline engineering is psychological essentialism, the tendency to construe classes of entities as having underlying essences (Medin & Ortony, 1989) that are natural, universal, discrete, and temporally stable (Haslam, Rothschild, & Ernst, 2000). In an examination of arguments used by the most prominent advocates and opponents of biotechnology, Wilson and Haslam (2009) found that conceptions of human nature hinge on essentialist assumptions. Advocates of genetic engineering believe that there is no fixed human essence and that our species is malleable and dynamic. They repudiate the "natural" as an ethical norm, they emphasize human qualities that place us "beyond nature" such as our rationality, and they view our characteristics as modular and separate. These views contrast starkly with opponents of genetic engineering, who believe to varying degrees in a fixed human essence and protection of the "natural" as a guide to what is good and right. They emphasize qualities that place humans "in nature" such as emotion, and they focus on the indivisible wholeness of human nature. If expert scientists and bioethicists are sharply divided in their belief in the essentialism of the human species itself, it follows that a measure of human essentialism will differentiate laypeople's attitudes toward genetic engineering. Moreover, research shows that people who essentialize human social categories have reduced motivation to change essentialized groups or their members, including one's self (Prentice & Miller, 2007). This reinforces the idea that belief in an essential human nature will predict lower support for human germline engineering.

Finally, it may be instructive to consider the relative impact of stable personality traits. Although few, if any, studies of attitudes toward broader genetic engineering have looked at the influence of personality, research suggests that the Big Five factor of Openness might affect attitudes toward germline engineering. Openness involves intellectual curiosity, a preference for novelty and nontraditional values (Ashton, Lee, Vernon, & Jang, 2000), as well as independence and nonconformity (De Raad, Hendriks, & Hofstee, 1992). Such perspectives dominate the arguments put forth by advocates of germline engineering, outlined earlier (Wilson & Haslam, 2009). These aspects of Openness may thus underlie a relationship between Openness and attitudes toward germline engineering in laypeople.

The present research will be conducted in two phases. In Studies One and Two, we will use participant ratings to develop a coherent set of potential targets of germline engineering. Studies Three and Four will test the hypotheses that approval for potential targets of germline engineering will vary according to the goal of modification and the type of characteristic being targeted. We expect to find greater approval for modifications classified as therapies versus enhancements, and declining levels of approval as we move from physical traits to cognitive traits to personality traits. In terms of individual differences, we hypothesize that overall approval will relate negatively to female gender, perceived risk, and psychological essentialism, and positively to related knowledge and Big Five Openness.

2. Study 1

2.1. Objective and Study Population

The goal of Study 1 was to screen unfamiliar items from a pool of potential targets of germline engineering in order to ensure that future ratings would be based on targets of an acceptable level of familiarity. Participants were 33 students (6 male, 27 female) recruited from the introductory psychology participant pool at Queen's University in Kingston, Ontario, Canada. They participated for course credit. Ages ranged from 17 to 23 years (M=18.18, *SD* = 1.18). We recruited via email and collected all ratings online using SurveyMonkey.

2.2. Methods

Participants provided consent and demographic information, and then read a brief overview of germline engineering. They then provided familiarity ratings for 170 potential targets of modification, generated by the authors and six other members of the Personality Assessment Laboratory at Queen's University. All 170 items were validated as being at least partly genetically determined using a thorough Google Scholar search for published research on the genetic basis of each trait, disease, ability or characteristic.

Participants indicated their familiarity for each item using a 7-point Likert scale where a score of one was designated "completely unfamiliar" and a score of seven as "completely familiar."

2.3. Results

To begin the screening process, all items were grouped into one of six categories based on their purported goal (therapeutic or enhancing) and targeted trait (physical, cognitive, or personality). Mean familiarity ratings and standard deviations were calculated for each of these six categories. Any items that were one or more standard deviations below the mean familiarity rating for their category were dropped, leading to the elimination of 27 items. We continued by screening the next three to five items with the lowest mean familiarity score in each category, leading to the deletion of 27 more items. We thus deleted 54 items, approximately one third of our initial pool, leaving 116 potential targets of germline engineering.

3. Study 2

3.1. Objective and Study Population

The goal of Study 2 was to validate our grouping of items into goal and type categories by deleting any potential targets of modification that were seen as unrepresentative of specific goals and trait types. This ensured that statistical comparisons of approval between categories based on goal and trait type would be internally valid. Participants were 40 students (5 male, 35 female) recruited from the Queen's University introductory psychology participant pool. They participated for course credit, and ages ranged from 17 to 21 years (M=18.21, *SD* = 0.92). We recruited via email and used SurveyMonkey for data collection.

3.2. Methods

After providing consent and demographic information, participants provided representativeness ratings for 116 potential targets of germline engineering. A 7-point Likert scale was used to rate the degree to which each item was representative of therapeutic and enhancement goals, and of physical, cognitive, and personality traits. The use of five representativeness ratings ensured that participants were free to categorize as they saw fit, and were not led to associate a given target with a specific goal or type by being forced to make either-or categorizations.

3.3. Results

The aim of data analysis was to keep only 15 items in each goal and type category, leaving 90 items spread across 6 categories for use in Studies Three and Four. We retained items that had a higher mean score for the goal and trait category to which they were allotted in Study 1, relative to the one other goal and two other type categories. Results indicated that participants saw a clear distinction between procedures with a therapeutic goal and those with an enhancing goal. Ratings of trait type indicated a distinct difference between physical and non-physical targets, but our participants' category ratings did not reflect the same distinction between cognitive and personality traits found by Riis et al. (2008) in their participants' approval ratings. Mean ratings showed that participants generally saw little difference between traits typically associated with cognition and traits typically associated with personality. We therefore collapsed across these two categories to create a broader category encompassing psychological traits and modified our hypothesis concerning trait types such that we expected to find greater approval for modifications of physical traits than of psychological traits. Our hypotheses concerning goals of modification and the relationship between attitudes and individual differences remained unchanged. Our screening procedure thus retained 60 potential targets of germline engineering divided into 4 groups of 15 items representing physical therapies, psychological therapies, physical enhancements, and psychological enhancements. These items are presented in Table 1.

Table 1. Targets of germline engineering retained in study 2 screening procedure to measure attitudes in studies 3 and 4, grouped by goal and trait type.

		Trait Type	
		Physical	Psychological
Goal	Therapeutic	Multiple sclerosis, asthma, diabetes, leukemia, cancer, thyroid disease, Parkinson's disease, hemophilia, genetic fertility problems, osteoporosis, heart disease, autoimmune disorders, cystic fibrosis, genetic sleep disorders	Schizophrenia, mental retardation, developmental delays, ADD / ADHD, Alzheimer's, autism, homosexuality, communication disorders, down syndrome, learning disabilities associated with memory, agoraphobia, genetic predisposition for eating disorders, bipolar disorder, depression, extreme moodiness
	Enhancement	Body type / build, height, facial symmetry, physical reflexes, hand-eye co-ordination, hair thickness, athleticism, muscles, physical energy, ageing, sense of hearing, agility, weight, resistance to sunburn / tanning	Analytical thinking, IQ, memory, concentration, musical ability, agreeableness, ability to learn languages, mental alertness, conscientiousness, mathematical ability, artistic creativity, extraversion, optimism, determination, emotional intelligence

4. Study 3

4.1. Objective and Study Population

The purpose of Study 3 was to compare approval for possible targets of germline engineering according to the goal (therapeutic or enhancing) and type (physical or psychological) of modification, and to examine the role of several individual difference variables as predictors of attitudes. Participants were 190 students (32 male, 158 female) recruited from the Queen's University introductory psychology participant pool. We originally recruited 200 participants, but were forced to drop 10 individuals from all analyses due to incomplete data; these participants completed an average of less than 10% of the total questions. They participated for course credit, and ages ranged from 18 to 27 years (M=18.32, *SD* = 1.03). We recruited via email and conducted the study online using SurveyMonkey.

4.2. Methods

After providing consent and demographic information, participants were presented with questionnaires in the following order: the attitude questionnaire for 60 targets of germline engineering, measures of related knowledge, psychological essentialism, perceived risk, and the NEO-FFI personality inventory.

4.3. Questionnaires

Attitudes Toward Germline Engineering Questionnaire. Written instructions asked participants to imagine that they, along with a partner, were in the very early stages of pregnancy. Using a 7-point Likert scale, participants indicated how likely they would be to use germline engineering to modify each of 60 potential targets in their unborn child. The items were randomized in terms of type and goal associations, and were presented in the same order to all participants.

Knowledge. Related knowledge was measured with three self-report items asking participants to use a 7-point Likert scale to report their knowledge of general scientific concepts, biology, and genetic engineering. These items were averaged to create a composite score. Because our samples are composed of non-specialists, our measure of related knowledge avoided assessment of specialized knowledge of germline engineering. A fourth item asked participants to indicate the number of credits they had attained in biology, physics, chemistry, and other sciences in high school and university.

Essentialism of Human Nature. Our essentialism index was adapted from Haslam, Rothschild & Ernst's nine-item measure of essentialist beliefs about social categories (2000) to measure the degree to which participants believe that humans share a fixed, biologically-based, intrinsic essence.

Example items include "Being human is unchangeable; humans cannot become nonhumans," and "There are specific features or characteristics that are necessary to be human." Participants responded using a 7-point Likert scale with responses ranging from "strongly disagree" to "neither agree nor disagree," to "strongly agree."

Perceived Risk. Risk was measured using three self-report items asking participants to estimate how much risk they imagined germline engineering poses for their child, for their future grandchildren, and for future generations in general. These items used a 7-point Likert scale with responses ranging from "little or no risk" to "average risk" to "a great deal of risk."

Personality (NEO-FFI). Personality was measured using the NEO-Five Factor Inventory (NEO-FFI) (Costa & McCrae, 1989), an abbreviated 60-item version of the 240-item Revised NEO Personality Inventory (Costa & McCrae, 1985).

4.4. Results

Knowledge. Analysis of our knowledge measures revealed significant missing data for credits earned studying science, forcing us to drop this measure. Across our 8-part credit measure, data was missing for an average of 42.25 participants per part, or 22.2% of the total sample. There were no issues with missing data for the three self-reported ratings of scientific understanding, which had a mean intercorrelation of .77 and a Cronbach's alpha score of .91, indicating strong internal consistency. We aggregated these three ratings to create a single-item index of related knowledge with a mean score of 3.93 (*SD* = .50).

Essentialism of Human Nature. Following Haslam et al. (2000), we used a total score on essentialism, which had a mean value of 4.68 for the nine items (*SD* = .90) and Cronbach's alpha was .73 (N=186). As a check on our adaptation, we conducted a varimax rotated principal components analysis, which returned two factors with eigenvalues over 1, accounting for 46.3% of the total variance. While this is less explanatory power than the two factors found by Haslam et al. (2000), the pattern of loadings was nearly identical to what they found, supporting our conclusion to use the overall essentialism score.

Risk. The mean intercorrelation for the three items assessing risk was .67, and Cronbach's alpha was .87 (N=190). We combined the three items to create an index of overall perceived risk, with an average score of 4.81 (*SD* = 1.34).

Personality. Internal consistencies for the NEO-FFI scales, calculated using coefficient alpha, were .86, .83, .73, .82, and .84 for Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness, respectively. These values are consistent with Costa and McCrae's data (1989) and data for Canadian university students (Holden & Fekken, 1994).

Attitudes Toward Germline Engineering. Mean ratings of approval for all potential targets of germline engineering sorted by goal and type are presented in Table 2. We conducted a 2x2 analysis of variance to test the hypotheses that approval ratings would be higher for therapeutic versus enhancement goals and for physical versus psychological types. Our ANOVA found a main effect of goal, $F(1, 189) = 425.77$, $p < .001$, and a main effect of type, $F(1, 189) = 147.91$, $p < .001$. These were qualified by an interaction between goal and type, $F(1, 189) = 224.68$, $p < .001$, indicating that the main effect of type was driven by the difference in approval scores between physical and psychological therapies, and not enhancement procedures. Pairwise comparisons showed that approval for applications with therapeutic goals was higher than approval for applications with enhancement goals, $p < .001$, and that approval was higher for applications targeting physical traits versus applications targeting psychological traits, $p < .001$. These results confirmed our hypotheses concerning both the goal of modification and the type of trait targeted.

Table 2. Mean ratings of approval for using germline engineering to modify one's child, sorted by goal and type.

	Mean	SD	N	Cronbach's α	Items
Physical Therapies	5.25	1.50	190	.97	15
Psychological Therapies	4.46	1.46	190	.96	15
Physical Enhancements	2.86	1.48	190	.96	15
Psychological Enhancements	2.92	1.57	190	.97	15

Individual Differences. We conducted a multiple linear regression analysis using the enter method to test the hypothesis that approval would have predictable relationships to individual difference variables. The overall model proved significant, $F(9, 173) = 6.10$, $p < .001$, $R^2 = .24$. Detailed results are presented in Table 3. As hypothesized, overall approval was predicted by male gender, having greater related knowledge, and perceiving less risk. Contrary to our predictions, psychological essentialism and Big Five Openness were non-significant. Unexpectedly, Agreeableness was a significant predictor of overall approval.

Table 3. Regression of approval for human germline engineering on individual difference variables.

	Standardized β	t
Gender	.18*	2.48
Knowledge	.15*	2.15
Perceived Risk	-.32***	-4.59
Essentialism	.11	1.56
Neuroticism	-.14	-1.78
Extraversion	-.13	-1.66
Openness	-.05	-.72
Agreeableness	.17*	2.11
Conscientiousness	-.03	-.34

* $p < .05$, *** $p < .001$

5. Study 4

5.1. Objective and Study Population

The purpose of Study 4 was to determine whether the results obtained with a Canadian university student sample in Study 3 would replicate with a new sample of American adults. We recruited 205 participants (120 female, 85 male) using Amazon Mechanical Turk and collected data using SurveyMonkey. From an original sample of 206, only one participant was dropped because of missing data. Participants received as compensation a $1 credit for Amazon. Our participants ranged in age from 18 to 74 ($M = 37.26$, $SD = 12.41$).

5.2. Methods and Questionnaires

Mechanical Turk users with sufficiently high approval rates (i.e. over 95%) were directed to SurveyMonkey, where they provided consent and demographic information. They then completed the same questionnaires presented in Study 3, with two related exceptions. To our demographic questions we added a one-item measure of level of education, with eight response options ranging from grade 8 or less to attaining a post-graduate degree. This was intended to replace our objective measure of knowledge, represented by credits earned studying science, which we chose not to include with the three self-report measures of related knowledge because of the difficulties experienced by our student sample with this item. The content and order of the other questionnaires remained the same as in Study 3.

5.3. Results

Knowledge. The average intercorrelation for the three knowledge measures was .72, and Cronbach's alpha was .88 (N=205). We averaged the three items to create a single-item index of related knowledge, which had a mean of 4.33 ($SD = 1.24$)

Essentialism of Human Nature. We again used the overall score for essentialism, which had a mean score of 5.51 ($SD = .88$) and a Cronbach's alpha of .77 (N=205). As before, two factors accounted for approximately half of the variance, that is 51.5%.

Risk. Our three risk perception items were strongly correlated, with a mean intercorrelation of .82, and highly internally consistent, with a Cronbach's alpha score of .93 (N-205). We therefore aggregated the three items to get a single item risk perception score, with a mean value of 4.56 ($SD = 1.66$).

Personality. Internal consistencies for the NEO-FFI scales, calculated using coefficient alpha, were .90, .86, .70, .81, and .87 for Neuroticism, Extraversion, Openness to Experience, Agreeableness, and Conscientiousness, respectively. These values are consistent with past norms (Costa & McCrae, 1989).

Attitudes Toward Germline Engineering. Mean ratings of approval for all potential targets of germline engineering sorted by goal and type are presented in Table 4. We again ran a 2x2 analysis of variance to examine the structure of attitudes in our sample of American adults. We found a main effect of goal, $F(1, 204) = 317.65$, $p < .001$, and a main effect of type, $F(1, 204) = 78.30$, $p < .001$. As in Study 3, these were qualified by an interaction between goal and type, $F(1, 204) = 78.98$, $p < .001$. This showed that the main effect of type was driven by the difference in approval scores for physical and psychological therapies, and not by the difference between the two types of enhancements. Pairwise comparisons showed that approval for procedures with therapeutic goals was higher than approval for those with enhancement goals, $p < .001$, and that approval was higher for procedures targeting physical traits versus those targeting psychological traits, $p < .001$. These results replicated our findings from Study 3 and confirmed our goal and type hypotheses.

Table 4. Mean ratings of approval for using germline engineering to modify one's child, sorted by goal and type.

	Mean	SD	N	Cronbach's α	Items
Physical Therapies	5.26	1.88	205	.98	15
Psychological Therapies	4.73	1.74	205	.96	15
Physical Enhancements	3.15	1.72	205	.97	15
Psychological Enhancements	3.12	1.77	205	.98	15

Individual Differences. We again conducted a multiple linear regression analysis, using the enter method of variable selection, to determine whether overall approval could be determined from certain well-established individual difference variables. The overall model proved significant, $F(9, 195) = 6.45$, $p < .001$, $R^2 = .23$. Detailed results are shown in Table 5. As hypothesized, higher approval was predicted by being male and perceiving little related risk. Unlike in Study 3, related knowledge was not a significant predictor. We conducted a second analysis of variance with level of education in place of related knowledge, and found that level of education was significantly positively related to overall approval. Essentialism and Openness were unrelated to overall approval, but Agreeableness was again found to predict approval and Extraversion emerged as a negative predictor.

Table 5. Regression of approval for human germline engineering on individual difference variables.

	Standardized β	t
Gender	.20**	2.97
Education	.15*	2.42
Perceived Risk	-.33***	-5.22
Essentialism	.06	9.53
Neuroticism	-.02	.76
Extraversion	-.18*	-2.37
Openness	-.10	-1.57
Agreeableness	.15*	2.02
Conscientiousness	.05	.66

* $p < .05$, ** $p < .01$, *** $p < .001$

6. General Discussion

The main goals of this research were to investigate the structure of attitudes toward human germline engineering and to relate overall approval for such procedures to individual differences. We hypothesized that approval for modifications of traits, diseases, and abilities, would depend on the goal and type of trait targeted, with greater approval for modifications with therapeutic goals versus enhancement goals, and greater approval for modifications targeting physical traits than those targeting psychological traits.

The results of two studies conducted separately with a sample of Canadian university students and a sample of American adults confirmed our goal and type hypotheses and provided partial confirmation for our individual differences hypotheses. We will discuss each of these areas in turn. The finding that our participants approved more of therapeutic procedures than enhancing procedures confirms our hypothesis about the goal of the change and parallels the findings of research on basic genetic engineering in agriculture and medicine (Chen & Raffan, 1999; Hampel, et al., 2000; Meisenberg, 2009; Meister, et al., 2005), which showed lower support for genetic enhancements to crops and livestock relative to preventive applications. This may reflect the belief that, for humans, removing genetic diseases and disadvantages creates a fair and level playing field, whereas adding desirable characteristics is unfair because it provides unique advantages over others. Another possibility is that genetic enhancements are seen as a degradation of our human nature, an interpretation that follows from critics who argue that modification represents a loss of humanity (Wilson & Haslam, 2009). Additional research would be necessary to show this, as our regression analysis found no relationship between overall approval and our particular measure of essentialist thinking about human nature.

Looking at the effect of the trait type on attitudes, we found that both of our samples approved more of modifications targeting the body than those targeting the mind, a pattern of approval that echoes a broader trend in genetic engineering wherein approval declines as the target of modification moves up the chain of life from micro-organisms to humans (Chen & Raffan, 1999; Dawson & Shibeci, 2003; Surmeli & Sahin, 2010). This attitude may be motivated by the same thinking that drove the participants in Riis et al.'s study of enhancement pharmaceuticals (2008) to favour cognitive modifications over personality modifications, namely that some aspects of the self are more fundamental to self-identity than others. Future research could address this issue by relating approval to the perceived importance of a trait to one's self-identity.

It is key to note that the interaction effect we observed in both samples indicated that differences in approval based on trait type were largely limited to therapeutic procedures, with approval ratings for physical and psychological enhancements being nearly identical within each sample. This suggests that that the prime concern for most people who would personally consider using germline engineering is the ethical judgment of whether a given procedure is a therapy or an enhancement, with the relative impact of trait type confined to therapeutic procedures. We interpret this as evidence that basic physical and psychological traits are relatively equal in terms of their centrality and our desire to alter them via germline engineering, but in the domain of disadvantages and diseases, the body is less central than the mind and we are more willing to consider changing it via germline engineering. This interpretation fits with the current cultural expectation that persons with disabilities be labeled as such, rather than as "disabled persons."

The results concerning individual difference variables offer potential insight into motivations for accepting germline engineering. As hypothesized, women in both samples gave lower approval ratings than men toward germline engineering, replicating a consistent pattern of findings in the genetic engineering literature (Chen & Raffan, 1999; Hampel, et al., 2000; Prokop et al., 2007). Lower approval could be caused by women's higher skepticism that genetic engineering would work (Hampel et al., 2000), or their greater number of negative concerns about the technology (Prokop et al., 2007). Moreover, women's traditional roles as caregivers may necessitate greater caution in matters related to nurturing a family. This may extend from being wary of genetically engineered food (Hill, Stanisstreet, Boyes, O'Sullivan, 1998; Moerbeek & Casimir, 2005) to being more wary of germline engineering than men because of their greater investment in producing and parenting children (Buss, 1999).

We also found support for the hypothesis that attitudes would clearly relate to risk perception, with stronger support related to lower perceived risk. Data analysis showed that, for both samples, perceived risk had the strongest weighting of any predictor and the strongest degree of significance, which extends Urban and Pfenning's conclusions (2000) regarding the importance of risk perception. This also offers validation to many detractors in the bioethics community who emphasize that germline engineering poses unforeseen risks, not only to one's child and descendants, but also to society in general (Fukuyama, 2002; McKibben, 2004; Sandel, 2007). Even with a preamble to the approval rating task that purposely avoided emphasizing possible risks of germline engineering, risk perception was still the dominant predictor. Of additional interest is the finding that risk was a stronger predictor of attitudes toward physical and psychological enhancements than toward physical and psychological enhancements.

This is notable because it shows that the categorical distinction between necessary therapies and cosmetic enhancements, and the consistent differences in approval for these goal-based groupings, is fundamentally tied to risk perception. There appears to be less tolerance for risk when germline modifications attempt to confer genetic advantages that enhance or improve an individual beyond the norm. Perhaps the risk of negative consequences is more acceptable when a child's genetic makeup indicates that he or she is likely to experience significant disadvantages anyway.

Overall approval was also predicted from related knowledge in Study 3, which replicates the results of studies that have found a relationship between attitudes toward genetic engineering and knowledge of general science or biology (Chen & Raffan, 1999; Sturgis, et al., 2005; Surmeli & Sahin, 2010), and knowledge of genetics or biotechnology (Allum, et al., 2008; Bal, et al., 2007; Hampel, Pfenning, & Peters, 2000; Klop & Severiens, 2007). Related knowledge was not significant for our sample of American adults in Study 4, so we conducted a second analysis of variance with education replacing related knowledge and found that education was a significant positive predictor. It is likely that scientific knowledge is much more salient for student participants who are currently enrolled in a program of higher education than for a general sample of participants. We conclude that the relationship between approval for human germline engineering and related knowledge is dependent on the way that related knowledge is measured for a given group. Additional research efforts could clarify this relationship with an objective measure of knowledge asking participants to answer content-specific questions about human germline engineering. Future research could also investigate whether this relationship is mediated by certainty about what germline engineering is likely to accomplish or not accomplish.

Despite our success in replicating the internal structure of Haslam et al.'s (2000) measure of essentialism, we found no connection between attitudes toward germline engineering and essentialist conceptions of human nature. It is possible that our adaptation of the measure undermined its validity. Haslam et al. (2000) had participants rate two examples of 20 social categories on each of the nine facets of essentialism; our procedure asked participants rate only one target, humans, according to the nine facets. Alternatively, one's views on the degree to which human nature is fixed, natural, and whole might not necessarily relate to one's attitudes toward altering the human body and mind. The philosophical debate raging in the bioethics literature concerning the essence of human nature may not resonate with people in general. Future research may need to ask people more simply and directly about the importance of ensuring that future persons are physically and psychologically equable with people living now.

Examining the relationship between personality and attitudes toward germline engineering provided some interesting results. Big Five Openness was not a significant predictor of attitudes toward germline engineering. Openness is by definition multifaceted and perhaps facets of Openness that might relate to new medical technologies, like an appreciation for unusual ideas, are negated by unrelated facets like having wide-ranging interests and an appreciation for art (McCrae & John, 1992). Future research could investigate this hypothesis by expanding on specific facets of openness. Unexpectedly, Agreeableness was clearly the most potent personality variable: it predicted higher levels of overall approval and approval for all four subsets of modifications sorted by type and goal. Perhaps the cooperativeness and trust facets of Agreeableness drive approval. Likewise, Agreeable people may be more optimistic (McCrae & John, 1992), and optimism may make them more hopeful and confident about the possible benefits of germline engineering while downplaying negative aspects like perceived risk and moral uncertainty. Future research could examine the interplay of risk aversion and optimism in accepting new medical technologies.

We also found that other personality factors emerged as significant predictors for the two subsets of modification with the lowest levels of approval. Approval for physical enhancement was higher among those with lower Neuroticism and lower Extraversion, and approval for psychological enhancement was higher among those with lower Neuroticism. We interpret this pattern as evidence that procedures aiming to correct impairments of function are both more acceptable on average and generally favourable regardless of one's personality, while less favourable procedures that aim to enhance one's body or mind are more likely to find favour among those who are less anxious and more social.

This is the first formal study targeted of attitudes toward human germline engineering and their relationship to individual differences.

Future research can address some of the limitations. One area of concern is the breakdown in differentiation between targets of modification associated with cognition and personality as indicated by participants' representativeness ratings in Study 2. This could reflect a lack of clarity in our distinctions, a lack of understanding on the part of our raters, or a real lack of distinction between these categories. Future research can address this by validating item groupings with more sophisticated populations or better conceptual definitions. Although our studies have the advantage of examining populations that are comparable to those used in the general literature on attitudes toward genetic engineering, it stands for future research to show whether the observed stability in the pattern of attitudes and individual differences is replicable among samples for which the technology of germline engineering may be more salient, such as expectant parents.

The results of the present work have important implications. Earlier research on related medical technologies has led some to conclude that the popularity of genetic screening will be limited by low customer demand (Meisenberg, 2009). Our findings show that attitudes toward a wide range of applications of human germline engineering are generally positive for both students and adults, in terms of personal interest. These results contradict the assumption that scientific approaches to permanently modifying the genotype would generally be met with ethical or intuitive opposition. However, certain forms of human germline engineering were less popular than others: both student and adult samples were more approving of therapeutic procedures relative to enhancing procedures, and both favoured modifications targeting the body over those targeting the mind. This structure parallels the pattern of attitudes in research on genetic engineering and enhancement pharmaceuticals, and suggests that personal interest in this technology will be quite high in the case of certain applications. These findings expand upon a small but important area of research by showing that attitudes toward the use of medical technologies to sculpt the genetic makeup of our future children are psychologically multifaceted but relatively consistent and predictable.

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