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The Influence of Trust and Perceptions of Risks and Benefits on the Acceptance of Gene Technology

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A causal model explaining acceptance of gene technology was tested. It was hypothesized that trust in institutions using gene technology or using modified products has a positive impact on perceived benefit and a negative influence on perceived risk of this technology. Furthermore, perceived benefit and perceived risk determine acceptance of biotechnology. In other words, trust has an indirect influence on the acceptance of the technology. The postulated model was tested using structural equation modeling procedures and data from a random quota sample of 1001 Swiss citizens between 18 and 74 years old. Results indicated that the proposed model fits the data very well. The same causal model explains females' and males' acceptance of gene technology. Gender differences were found for the latent variables trust, perceived benefit, and acceptance of gene technology. Females indicated more trust, perceived less benefit, and demonstrated less acceptance than did males. No significant difference was observed for perceived risk. The implications of the results are discussed.

KEY WORDS: Acceptance of biotechnology; gene technology; risk perception; trust; gender differences

1. INTRODUCTION

The future development of gene technology depends heavily on public acceptance. Genetic engineers and scientists are aware that attitudes of the public will have a strong impact on the progress of the field.(1) Consumer's shopping behavior and political regulations will determine how gene technology will be used in the future. To understand reactions of the public it is important to know which factors have an influence upon risk perception and acceptance of this new technology.

1.1. Perception of Gene Technology

Psychometric studies have identified factors which determine public perception of different hazards.(2) In these studies, participants assessed various characteristics of a broad range of potential hazards, and principal components analysis was used to identify the factors that determine the perception of these hazards. According to these studies, hazards like DNA technology and nuclear power tend to be judged relatively high on catastrophic potential and are judged to be unknown, associated with new and possibly harmful delayed effects. Sparks and Shepherd(3) investigated public perceptions of hazards associated with food. Compared with other food hazards, genetically engineered food was perceived as a moderately severe risk and as a very unknown risk.

Even when people assume that gene technology is associated with relatively high risks and rather unknown consequences, they do not reject biotechnology altogether.(4) Acceptance of gene technology varies according to the type of application. Generally, applications involving plants are viewed as more acceptable than those involving animals. Furthermore, consumers assess genetically modified food more negatively than genetically altered drugs. Factors that shape pub-

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lic perceptions of different applications of biotechnology have been investigated.[5,6] However, results of these two studies were rather mixed. Frewer, Howard, and Shepherd[5] found that participants were more concerned about applications involving the use of animals than plants or micro-organisms. Less important was the kind of application (food/drugs). In the study conducted by Siegrist and Bühlmann[6] participants rated the similarity of all possible pairs among 15 scenarios involving different applications of gene technology drawn from agricultural, food-related, and medical applications. Data were analyzed using the method of multidimensional scaling. Results indicated that two dimensions are relevant for the perception of gene technology: (1) Nature of the application (food-related, agricultural applications/medical applications), and (2) involved organisms (animals, plants/micro-organisms). In this study, aggregated data were used to show the different perceptions of various applications of gene technology. On the individual level, however, there were rather strong correlations among the different applications. Therefore, the same model may explain acceptance of gene technology to alter food as well as to produce new drugs.

1.2. Trust and Knowledge

Most people do not have detailed knowledge of gene technology. A majority of the Swiss people, for example, were unable to correctly answer basic true/false questions about gene technology (e.g., "It is impossible to transfer animal genes into plants").[7] One way people cope with this lack of knowledge is to rely on social trust to reduce the complexity of risk management decisions.[8,9] That is why confidence in laws controlling gene technology and trust in companies as well as scientists doing genetic modification research are so important. Trust in these institutions may result in a positive evaluation of biotechnology. As a consequence, gene technology is assessed as beneficial and not laden with dangers to our society.[10] A study by Hoban, Woodrum, and Czaja[11] yielded similar results on the negative side. Lack of faith in the information given by institutions involved in gene technology was a significant predictor of opposition toward genetic engineering.

Although there is broad consensus on the importance of social trust, there is no agreement among social scientists on how to conceptualize social trust.[12] One of the open questions relevant to the present article pertains to the dimensionality of trust. Frewer *et al.*[13] have claimed that trust is a multidimensional construct; however, in their study they investigated factors which have an influence on trust in a variety of information sources. Metlay[14] found that two dimensions which he labeled as affective components and competence components had an influence on public trust and confidence in the U.S. Department of Energy as a whole. It may be that, depending on the situation, more or less unrelated factors influence the level of trust a person has. These results are not contrary to our perspective that trust should be viewed as a unidimensional construct ranging from trust to distrust.

The importance of trust for the explanation of risk perception has been demonstrated in several domains. Freudenburg[15] found that people who placed trust in current scientific and technical abilities to build safe nuclear waste disposal sites were less concerned about a hypothetical nuclear waste repository in their county than people with no trust in the relevant institutions. In another study investigating factors which determine opposition to a radioactive waste repository, it was shown that trust in management had a strong influence on perceived risk.[16] A negative association among perceived risk and trust in experts, government, and industry was also observed in several other studies.[17,18]

1.3. Model Description and Rationale

Based on a review of the relevant literature, Siegrist[10] proposed a causal model of acceptance of gene technology. This model is shown in Fig. 1. Survey data from students were used to test the structural model. The proposed model explained the data very well. Trust in companies and scientists performing gene manipulations had a strong effect on the benefits and risks perceived. Acceptance of the new technology was determined by perceived benefits and risks. In other words, trust had a strong indirect influence on acceptance. However, no significant relationship was found among perceived benefits and risks. This result was rather interesting and surprising because significant correlations among perceived benefits and perceived risks had been found in past studies.[19–22] The bivariate correlation between risks and benefits was significant,[10] as expected based on past results. However, the causal model revealed that the relationship vanished when the variable trust was held constant.

In Switzerland, gene technology has been on the political agenda for a long time. The public discourse has determined which dimensions have become salient. As with previous emerging technologies, the discussion has focused on possible benefits and risks.

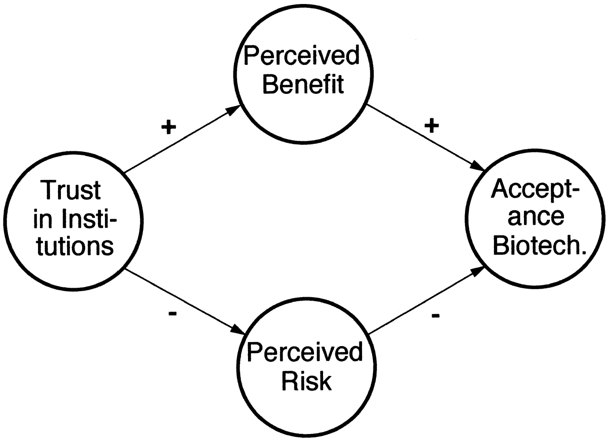

Fig. 1. Hypothesized model of acceptance of gene technology.

A content analysis of a Zürich newspaper, the *Neue Zürcher Zeitung*, revealed that a majority of the articles dealing with gene technology mentioned risks or benefits.[23] This is in accord with our view that perceived benefits and perceived risks are crucial for the acceptance of gene technology, and that trust does not directly influence acceptance.

The results of the study conducted by Siegrist[10] are somewhat limited in that attitudes of students were investigated. Therefore, it still needs to be determined whether the model holds true for a more general public. One aim of the present study was to replicate the results using data from a survey of the general population of Switzerland.

1.4. Gender Differences

Several studies have observed risk perception gender differences. Women have proved to show more concern about the risks associated with technologies than men.[24–31] Noteworthy are the results of a survey study conducted by Flynn, Slovic, and Mertz[17] that found that the perceived risks of White women were higher than the perceived risks of White men. No difference, however, was found between non-White women and men, whose perceptions of risk were quite similar to White women. These results suggest that factors such as power, status, alienation, and trust determine people's perception and acceptance of risk.

Davidson and Freudenburg[32] reviewed the literature investigating the gender differences in environmental risk concerns. The findings are clear: In most studies, women expressed higher levels of concern about potential environmental and technological risks than men. Numerous studies have focused on nuclear energy and nuclear waste; fewer studies have focused on other technologies (e.g., gene technology). Based on the reviewed literature, Davidson and Freudenburg[32] concluded that two hypotheses have been supported. First, men tend to have more trust in institutions, particularly those involving science, technology, and government. Furthermore, trust is negatively related to environmental concern. In other words, a difference in the initial level of trust produces the gender gap in concerns about environmental risks. Second, women are more concerned about health and safety than men because women often play the role of nurturer and care provider of the family. As a consequence, women are more concerned about environmental risks. It should be noted that in most studies reviewed by Davidson and Freudenburg,[32] white people were investigated. To date it is undetermined whether Flynn, Slovic, and Mertz's[17] finding of the gender differences between non-White women and men can be replicated. Such a replication would be a serious challenge to the nurturer explanation.

The gender gap was also observed in studies investigating perception of gene technology.[11,28] Males were more in favor of this technology than females. One possible explanation is that women have less trust in institutions doing genetic modification research than men do, and that they therefore show less acceptance. This explanation, however, has not been tested empirically.

In most studies reporting gender differences, mean differences or simple correlations were investigated. It has not been determined whether the same relationships among trust, perceived benefit, perceived risk, and acceptance of a technology hold true for both women and men. Not having a representative sample, this hypothesis was not tested by Siegrist.[10] Therefore, a second aim of the present study was to test whether identical causal models can be used to explain perception of gene technology across gender. It was hypothesized that the same model would explain males' and females' perception of gene technology. Additionally, tests were conducted for mean differences across gender for the latent variables depicted in Fig. 1. The hypothesis was that males would show a higher level of trust than females. That difference in the initial level of trust would be the reason for observed differences among the other latent variables. Therefore, when trust is controlled, no mean differences for perceived risk, perceived benefit, and acceptance of gene technology would be expected.

2. METHOD

2.1. Participants

The data for the present study come from a survey conducted in Switzerland. A random quota sample of 1001 persons between 18 and 74 years of age was interviewed by telephone. The quota variables were region (German- or French-speaking region of Switzerland) as well as age and sex of participants. Interviews were conducted during the fall of 1997. The response rate was about 27%.

Fifty-one percent (n = 511) of the participants were female and 49% (n = 490) were male. The mean age was 42.39 (SD = 15.06). Twenty-one percent of the participants were between 18 and 29 years old, 38% were between 30 and 44 years old, 17% were between 45 and 54 years old, and 24% were 55 or older. Seventy-six percent (n = 757) of the participants lived in the German-speaking region, and 24% (n = 244) lived in the French-speaking region of Switzerland.

2.2. Questionnaire

The questionnaire was designed to measure a broad range of constructs relating to biotechnology. For the present study, variables measuring the four constructs of the causal model shown in Fig. 1 were used. Table I shows the 19 variables used for measuring "perceived benefits of gene technology," "perceived risks of gene technology," "trust in the institutions responsible for regulating biotechnology or using genetic engineered products," and "acceptance

Table I. Indicator Variables Used for Testing the Causal Model

F1	Perceived benefit[a]
	Gene technology is or will be used in different areas. How do you assess the benefits associated with the following applications?
V1	Using gene technology for altering plants, with the aim that less fertilizer or plant-protective agents are used.
V2	Using gene technology for altering plants in such a way that yields are increased.
V3	Using gene technology for altering cattle to increase the milk- or meat-production.
V4	Using gene technology for the production of drugs and vaccines against diseases.
V5	Using gene technology for early diagnosis (before people have any symptoms) of diseases.
F2	Perceived risk[b]
	How do you assess the risks associated with the following applications?
V6	Using gene technology for altering plants, with the aim that less fertilizer or plant-protective agents are used.
V7	Using gene technology for altering plants in such a way that yields are increased.
V8	Using gene technology for altering cattle to increase the milk- or meat-production.
V9	Using gene technology for the production of drugs and vaccines against diseases.
V10	Using gene technology for early diagnosis (before people have any symptoms) of diseases.
F3	Trust[c]
	How much trust do you have in the following institutions or persons that they are conscious of their responsibilities in doing genetic engineering or handling the modified products?
V11	Scientists and researchers at universities.
V12	Pharmaceutical companies.
V13	Agricultural companies.
V14	Food companies.
F4	Acceptance[d]
V15	Rennet is used for the production of cheese. Usually, rennet is produced from calf stomachs. Using gene technology, it is possible to produce a rennet that has a more constant quality. Would you buy cheese which has been produced with this genetically modified rennet?
V16	Would you buy genetically modified tomatoes, which have the advantage of lasting longer?
V17	Would you buy meat from animals which were fed with genetically modified corn?
V18	Would you buy any food from which substances were eliminated using gene technology, so that allergic people are not faced with problems?
V19	Would you buy chocolate containing genetically modified lecithin?

[a] Four possible answers were given: very high benefit, rather high benefit, rather low benefit, and no benefit at all.
[b] Four possible answers were given: very high risk, rather high risk, rather low risk, and no risk at all.
[c] Respondents were asked to express their trust using a value between 1 (indicating no trust at all) and 5 (very high trust).
[d] Four possible answers were given: certain, probably, probably not, and not at all.

of gene technology." Variables were assigned to each construct based on theoretical considerations. The indicator variables used in this study were different from those used in the study conducted by Siegrist.[10] Personal and demographic characteristics of the respondents were also measured.

2.3. Data Analysis

Structural equation modeling procedures were used to test the plausibility of the postulated causal model. The program EQS[33] was used for estimating parameters. Analysis was based on the raw data, and the maximum likelihood (ML) method was employed. Assessment of model fit was based on the Comparative Fit Index (CFI),[34] the residual values, and the meaningfulness of the model. The CFI ranges from zero to 1.00, where a greater value indicates a better fit of the model to the data. It is rather difficult to set a cutoff criterion; however, the CFI should exceed 0.90.[34]

Analyses were conducted in four stages. First, confirmatory factor analyses were performed for each latent variable to test whether the postulated measurement model was appropriate. Second, once the measurement model was established, the observed data were fitted to the hypothesized model. In other words, measurement components (confirmatory factor analysis) and structural components (relations among latent variables) were combined in a comprehensive statistical model. The Lagrange-Multiplier Test (L-M Test) was used to identify additional parameters which would contribute to a significantly better-fitting model. Third, the model was tested for males and females separately. The invariance of all causal paths across the two samples was tested. Finally, mean differences of latent variables across gender were investigated.

Only the responses of participants who answered all 19 questions were used for testing the model. Data of respondents who answered at least once with "don't know" were deleted. Therefore, data analyses were based on the answers of 693 respondents. Due to the rather large sample size and the number of tests conducted, the critical value for p was set to 0.01.

3. RESULTS

Preliminary analyses showed that the data were univariately normal. Therefore, the maximum likelihood algorithm was appropriate for estimating parameters. The initial model depicted in Fig. 1 did not yield a good fit to the data (CFI = 0.83). However, the L-M Test indicated that three additional correlations among error terms should be incorporated into the model. Post-hoc modifications regarding correlated errors of indicator variables are somewhat problematic.[35] However, relaxing the three parameters seems to be justified due to the content of the items. Items V4 and V5 as well as items V9 and V10 are related to medical applications, which are viewed a bit differently than other applications of gene technology.[6] For the latent variable trust, the error terms of the observed variables V13 and V14 are also correlated. Both items are related to institutions producing food, whereas the other two items are related to institutions doing genetic modification research. Since the initial and the revised model are nested, the difference in χ^2 between the two models could be used for assessing the improvement in fit of the new model. Table II shows that for the revised model the χ^2 has dropped significantly ($\Delta\chi^2_{(3)} = 548.99, p < 0.001$), and the revised model yielded a good fit to the data (CFI = 0.93). However, the L-M Test indicated that the causal path from perceived benefit to perceived risk should be incorporated into the model. As shown in Table II, estimation of this new model yielded a significantly improved ($\Delta\chi^2_{(1)} = 15.71, p < 0.001$) and well-fitting model (CFI = 0.93). For this model the average absolute standardized residual was 0.037 and the largest value was 0.161. The residuals were scattered more or less symmetrical around zero, with most residuals in the middle. According to Jöreskog,[36] this

Table II. Test Statistics for Hypothesized Model

Model	χ^2	df	CFI[a]	$\Delta\chi^2$	Δdf
1. Initial	1082.49	148	0.83		
2. Addition of 3 correlations among error terms[b]	533.50	145	0.93	548.99	3
3. Addition of causal path Benefit → Risk	517.79	144	0.93	15.71	1

[a] Comparative Fit Index.
[b] E4 ↔ E5; E9 ↔ E10; E13 ↔ E14.

pattern indicates a good model. Furthermore, all signs associated with causal paths were in the predicted direction.

The data clearly support the hypothesized model. The final model is presented schematically in Fig. 2. Estimates along each path represent standardized coefficients. The coefficients associated with the residual variable are presented in the small circles. In EQS all model variables including error and disturbance terms are standardized.[33]

A second aim of the present study was to investigate gender differences in perceiving gene technology. Therefore, the equivalence of causal paths across men and women were tested. Data from 327 women and 366 men were used.

For the initial model no constraints were imposed. The analysis indicated that the same model is appropriate for both men and women. In a second model, factor loadings were constrained to be equal in both groups. Table III shows that the increase in the χ^2 was not significant ($\Delta\chi^2_{(15)} = 22.95, p > 0.05$). We can conclude, therefore, that the meanings of the latent variables are equivalent among the two groups. For the next model, in addition to the factor loadings, regression coefficients were constrained to be equal in both groups. The χ^2 did not change significantly ($\Delta\chi^2_{(5)} = 12.58, p > 0.02$). These results strongly demonstrate that the same causal model explains perception of gene technology for both males and females.

Finally, differences across gender in the latent means of trust, perceived benefit, perceived risk, and acceptance of gene technology were tested. The procedure proposed by Byrne[37] was used. All factor loadings and coefficients among latent variables were

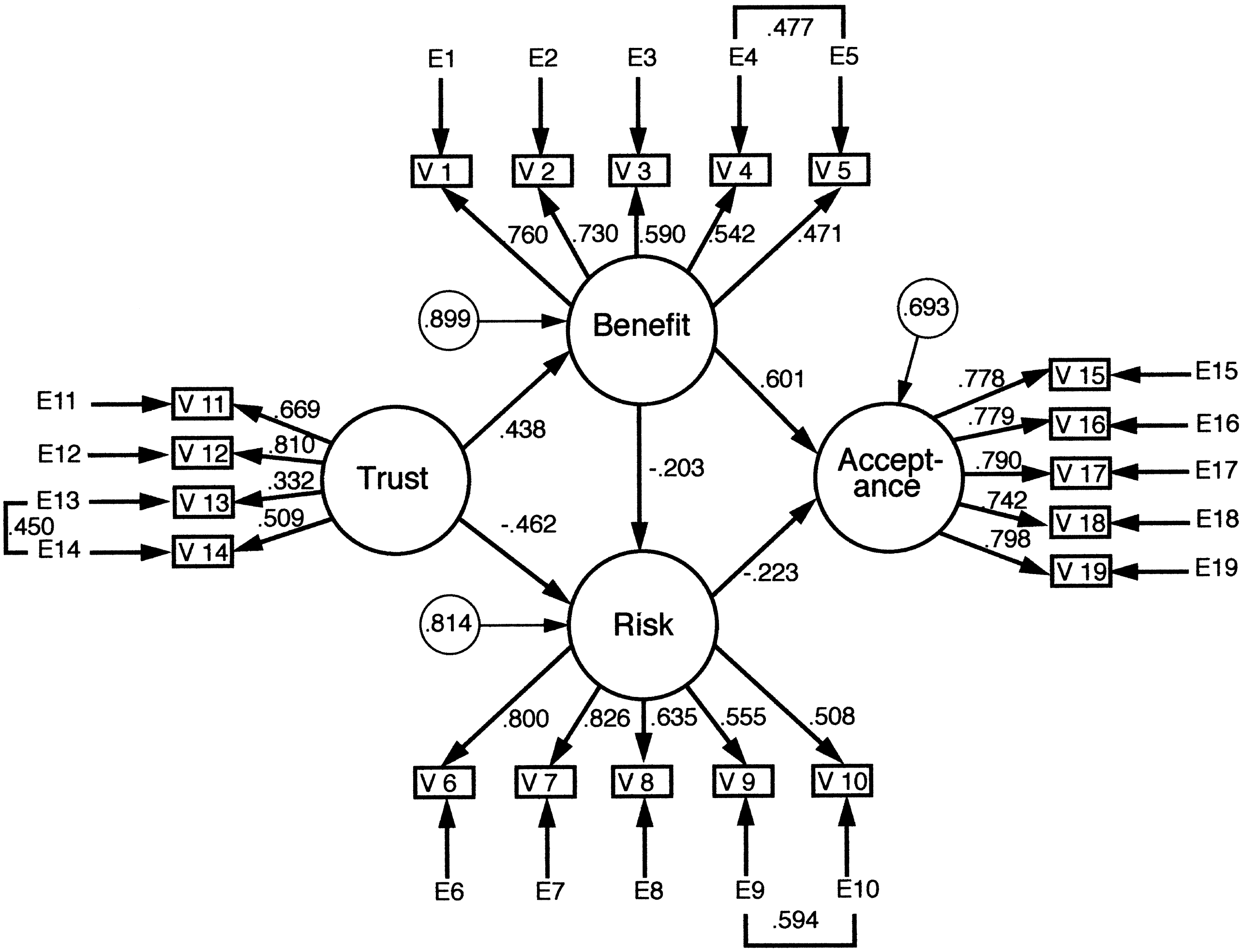

Fig. 2. Final model of acceptance of gene technology. Values represent standardized estimates, $N = 693$. All coefficients are significant ($p < 0.001$).

Table III. Tests for Equality across Gender

Model	χ^2	*df*	CFI[a]	$\Delta\chi^2$	Δdf
1. Initial model without constraints	713.13	288	0.92		
2. Equality constraints on factor loadings	736.08	303	0.92	22.95	15
3. Equality constraints on regression coefficients	748.66	308	0.92	12.58	5

[a] Comparative Fit Index.

constrained to be equal across groups. Intercepts for the observed indicator variables were constrained in the same way. The intercepts of the latent variables were freely estimated in one group (females) and constrained equal to zero in the other group (males). Males, therefore, served as a reference group, and intercepts were interpretable only in a relative sense. The model fit well ($\chi^2_{(323)} = 779.17$, CFI $= 0.92$). The L-M Test revealed that two constraints related to the equivalence of an indicator variable intercept yielded a significant χ^2 increase. Reestimation with these two constraints deleted from the model specification yielded virtually the same results. Therefore, results of the analysis with all constraints imposed are reported here.

As shown in Table IV, females had a significantly lower level of trust than males. Controlling for trust, significant differences were also found for perceived benefits and acceptance of genetically modified products, with females making lower judgments than males. The indirect effects were not significant. This means that the significant gender difference for trust was not the cause for the differences for benefits and acceptance. Controlling for trust and benefit, no significant difference for perceived risk was found across gender. However, indirect effects for perceived risk were almost significant ($p < 0.05$).

Table IV. Tests for Differences in Latent Means across Gender. Estimations for Females are Presented, Males Serving as Reference Group

Latent variables	Direct effects	Indirect effects
Trust	−0.137 (0.052)**	
Benefit	−0.169 (0.062)**	−0.074 (0.085)
Risk	−0.005 (0.055)	0.129 (0.060)*
Acceptance	−0.261 (0.058)**	−0.200 (0.109)

Standard errors are in parentheses; latent mean parameters were fixed to zero for men.
* $p < 0.05$; ** $p < 0.01$.

4. DISCUSSION

In the past, a number of studies dealing with the perception and acceptance of nuclear power and radioactive waste have been conducted.[(e.g.,38,39)] Far fewer studies of the perception and acceptance of gene technology exist. Scientists are convinced that this technology will increase in significance in the near future. Therefore, more knowledge about risk perception and acceptance of gene technology is needed.

Siegrist[(10)] has proposed a causal model that explains the acceptance of gene technology. The test of the model was somewhat limited in that study, however, because data from students were used. Therefore, one aim of the present study was to test whether the model depicted in Fig. 1 explains acceptance of gene technology by the general population as well. Results confirmed this hypothesis: It was possible to replicate the earlier findings, using a large representative sample and different indicator variables. One difference between the two studies is noteworthy. In Siegrist's study, perceived benefit did not significantly influence perceived risk. In the present study, however, perceived benefit had a significant, though weak, impact on perceived risk. Based on theoretical considerations, we believe that the proposed causal model is the most meaningful model. However, the possibility that alternative models exist which also fit the data very well cannot be ruled out.

The results of the present study support the hypothesis that trust in institutions or persons doing genetic modification research or using modified products is the most important factor influencing perception of gene technology. Trust has an impact on perceived risk as well as on perceived benefit. Acceptance of the products is directly determined by the perceived risk and the perceived benefit. Trust therefore has an indirect impact on the acceptance of biotechnology.

In the present study, trust was operationalized as a unidimensional construct. However, the questions used for the measurement of trust were rather general, and allowed participants to focus on aspects that they perceived as relevant.

The demonstrated importance of trust for the perception and acceptance of gene technology raises the question of how trust is created. Earle and Cvetkovich[(8)] have argued that shared values constitute the foundations of trust. If an institution's behavior is judged to reflect a person's values, the institution will be seen to be trustworthy. People's knowledge of gene technology is rather limited. Therefore, the salient values in this case would be general and not very specific (e.g., a prosperous economy is important). According to this theory, general beliefs and values should have an important influence on trust. It has been shown that worldviews have a significant influence on trust in institutions responsible for or regulating gene technology,[10] and on the assessment of risks and benefits associated with different technologies.[40–42] Biotechnology companies, therefore, are faced with a difficult task, since it may not be possible to change people's worldviews.

The implications for companies involved in gene technology are clear-cut. An event with negative consequences could have a disastrous impact on trust and result in a decreased acceptance of biotechnology. Thus, the industry should be interested in strong regulations designed to prevent unwanted side-effects. Laypeople assess gene technology as an unknown technology, with new and potentially harmful delayed effects.[2] Even tiny incidents will be covered in the news media, and this attention could completely change the public perception of the technology. The accident at Three Mile Island in 1979 has shown what an enormous impact a "harmless" incident can have.

If the social trust model proposed by Earle and Cvetkovich[8] is correct, there is another way to increase trust in the gene technology industry. Trust can be increased if a technology is framed to reflect the public's salient values. For example, it has been shown that certain food applications of gene technology can be framed in such a way that they are perceived to be similar to medical applications.[6] Reframing to make different values salient may be a promising approach for some applications but not for others.

Frewer, Howard, and Shepherd[43] contend that public reactions to specific products of genetic engineering may not be closely related to attitudes toward the technology overall. Correlations among error variances for perceived risks (and benefits) of medical applications indicate that they are viewed somewhat differently than food applications. This result is in line with other studies.[5,6] However, the factor loadings of the present study show that all applications are influenced by the same latent variables to some degree.

A number of studies have shown that women express higher concerns about environmental and technological risks than men.[32] Most of these studies have investigated nuclear power, and to our knowledge no test for invariant latent mean structures was performed. In the present study, the hypothesis that the same causal model explains the perceptions of men and women was confirmed. The analysis of the latent means revealed some interesting findings. Results of this study support the hypothesis that the different level of trust in institutions determines the different risk perceptions between males and females. The positive indirect effect for perceived risk indicates that risk perception for women is higher than for men. It should be noted, however, that it failed to reach the specified significance level. Nevertheless, when trust and benefits were controlled, no difference between genders was found for perceived risk. For perceived benefits and acceptance of gene technology, significant differences were found. Women perceive lower benefits and are less accepting of gene technology than are men. Only the direct effects were significant. This means that the initial difference in the level of trust does not explain the difference in perceived benefits. Further, the initial differences in the level of trust and level of benefits do not explain the observed mean difference in the acceptance of gene technology. The results of this study, therefore, only partially support the institutional trust hypothesis.[32] The expected results have been observed for trust and perceived risk, but not for the other latent variables.

Fox and Firebaugh[44] showed that women are more likely than men to question the utility of science. In their study, attitudes toward spending on space exploration were used as proxy for perceived utility of science. Using a more direct measure, the present study shows that when the level of trust is controlled, women perceive lower benefits in gene technology than men. This confirms the hypothesis that the utility of science is viewed differently by the genders.

Females often play the role of nurturer and care provider in the family. Therefore, females may be more sensitive about genetically modified food than men. As a consequence, women tend to be more reluctant to substitute new products for traditional food. This could explain the difference between males and females regarding the acceptance of genetically modified food. However, the data also are in line with the hypothesis that men perceive more benefits because they have more power and control than women.[17]

More studies are necessary to better understand the causes of the gender differences in risk perception and acceptance of technologies. The present study has shown that the structural modeling approach can be a valuable tool for the achievement of this goal.

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