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Differential Effects of Perceived and Objective Knowledge Measures on Perceptions of Biotechnology

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This paper compares the effects of perceived and objective knowledge measures and their relationship to a series of agricultural biotechnology applications using data gathered in a survey of regional Southwestern adults (*N* = 432). Findings showed that there were differences between perceived and objective knowledge measures and that these differences varied by application. Differences between the two knowledge measures appeared to be most significant among respondents who indicated that they had no knowledge of biotechnology applications. It is likely that perceived knowledge is more important than actual knowledge for some animal and plant biotechnology applications.

Key words: animal biotechnology, biotechnology, nutriceuticals, objective knowledge, perceived knowledge, plant biotechnology, plant molecular farming.

The agricultural biotechnology revolution has been targeted at three sectors. First, specific traits are added or enhanced in plants and animals to increase yields by making them more pest and disease resistant, hardier, and less energy intensive. Second, specific traits are added or enhanced in plants and animals to increase nutrients or improve taste in foods. These processes are now often referred to as *nutraceuticals* or *functional foods* and are marketed as providing healthier and better tasting foods to consumers. Third, crops and animals are grown for other purposes than food. Often referred to as *molecular farming*, the idea is that plants and animals will grow pharmaceutical, cosmetic, and industrial byproducts, which will then be harvested and processed into drugs, chemical compounds, and plastics. Although these types of plants and animals are not being manufactured for food, environmental groups and food manufacturers have expressed concerns about the containment of these products for fear that they might find their way into the food supply. Despite the growth of agricultural biotechnology products, most studies on consumer perceptions have focused on genetically modified (GM) foods, particularly dealing with ranking of food risks (e.g., Hwang, Roe, & Teisl, 2005; Priest, 2000) and economic models such as willingness to pay (e.g., Evenson & Santaniello, 2004; Harrison, Boccaletti, & House, 2004; Onyango, Nayga, & Shilling, 2004).

Knowledge is one of the central concepts in understanding consumer perceptions of biotechnology. Previous studies have measured knowledge in three ways. Some studies measured knowledge as awareness (e.g., Chern, Rickertsen, Tsuboi, & Fu, 2003; Hoban, 1999; King, 2003; Zhong, Marchant, Ding, & Lu, 2002). Others asked people to self-report their level of knowledge (e.g., Boccaletti & Moro, 2000; Li, Curtis, McCluskey, & Wahl, 2002; Lusk et al., 2004; Priest, 2000); still others attempted to develop and use objective measures of knowledge by asking respondents a series of true/false questions about the life sciences and/or biotechnology (e.g., Chern et al., 2003; Gaskell, Bauer, Duran, & Allum, 1999; Hoban, 1998; Priest, 2000).

This paper examines the latter two measures of knowledge and their relationship to a series of agricultural biotechnology applications. Survey research has continually found that people have low awareness and knowledge of biotechnology (e.g., Hallman, Adelaja, & Schilling, 2002; Hoban, 1996; Priest, 2000). How can researchers, marketers, and policy makers heed results in which consumers acknowledge they have little proficiency? Perhaps because of the lack of consumer knowledge, proponents of biotechnology often suggest that educating consumers will result in higher levels of support for biotechnology applications (McCluskey, Grimsrud, & Wahl, 2004; Priest, Bonfadelli, & Rusanen, 2003). However, consumer studies examining the impact of knowledge and acceptance of GM foods have produced inconsistent results, regardless of the measurements used. Some studies reported a positive correlation between knowledge and acceptance, while others found that knowledge did not affect acceptance levels (House et al., 2004). One plausible explanation for these inconsistent results is the operationalization of knowledge variables. Further, Hallman, Hebden, Aquino, Cuite, and Lang (2003) claimed that respondents overestimate their knowledge of biotechnology and the food system. By comparing the results of perceived (or self-reported) knowledge and objective measures of knowledge, this research addresses these discrepancies.

House et al. (2004) investigated the impact of perceived and objective knowledge on the willingness to accept GM foods systematically. They found that objective and perceived knowledge varied by sociodemographics. Education was significantly related to both knowledge measures, but religion and location were only significantly related to perceived knowledge. Furthermore, perceived knowledge was positively associated with willingness to accept GM foods, whereas objective knowledge was not significantly related to willingness to accept.

This study extends the research of House et al. (2004) by examining the relationship between perceived/self-reported and objective knowledge measures about a range of animal and plant applications. House et al.'s (2004) sample was limited to females with particular demographic characteristics, combined results from three countries and three US states, and measured subjective and objective knowledge on different scales. This paper compares perceived and objective knowledge measures by first examining the relationship between these measures. Regression models are then employed to determine whether knowledge measures vary by sociodemographics and to test how these two knowledge measures relate to animal and plant biotechnology applications. The final section discusses the relevance of these findings to the study of consumer perceptions and the marketing of GM products.

Data and Methods

The data for this study were gathered in a regional Southwestern telephone survey conducted from March 28 through May 4, 2004 on alternate evenings. To insure the inclusion of both listed and unlisted telephone numbers, random-digit dialing procedures were used. The sampling frame comprised a sample of five states—Arkansas, Louisiana, New Mexico, Oklahoma, and Texas. The total sample size was 432 adults (18 years or older).

Knowledge variables were measured through self-reporting and objectively by asking respondents whether they agreed or disagreed with three knowledge statements, which are presented in Table 1. Similar questions and scales were used to measure the self-reporting of animal and plant biotechnologies. For both of the subjective knowledge measures, "do not know" responses were coded as "not at all knowledgeable." Instead of asking objective statements as true or false questions, respondents were asked whether they agreed or disagreed with each statement. The three items were added together to create an objective knowledge scale which ranged from 0 to 3, where 0 represented a respondent who failed to answer any of the statements correctly, and 3 represented a respondent who answered all three statements correctly. For each of the objective knowledge measures, "do not know" responses were coded as incorrect responses.

Table 1. Knowledge measures.

	Questions	Answer options
Perceived (self-reported) knowledge	1. How would you rate your knowledge about the genetic modification or cloning of animals? 2. How would you rate your knowledge about the genetic modification of plants?	1 = not at knowledgeable 2 = a little knowledgeable 3 = somewhat knowledgeable 4 = very knowledgeable
Objective knowledge	1. Genetically modified or cloned animals are always bigger than ordinary ones. 2. It is impossible to transfer animal genes into plants. 3. By eating a genetically modified fruit, a person's genes could also become modified.	1 = agree 2 = disagree

Results

The descriptive results presented in Table 2 show that the self-reported and objective knowledge measures were similar. Similar to previous survey results, respondents had very low knowledge levels of biotechnology. Despite the similarities presented in Table 2, analysis of variance was used to determine whether there were statistically significant differences between the self-reported knowledge measures and objective knowledge. The results in Table 3 show the relationship between objective knowledge and perceived knowledge about the GM of animals. Scheffe tests indicated that respondents who stated they were "not at all knowledgeable" were different than all other knowledge categories. Moreover, there were differences between those who reported themselves to be "very knowledgeable" and "a little knowledgeable." The analysis of variance results testing the relationship between objective knowledge and perceived knowledge of the GM of plants are pre-

Table 2. Frequency distributions for perceived knowledge and objective knowledge (percent).

Perceived knowledge of GM or cloning of animals (*N* = 430)	
Not at all knowledgeable	32.6
A little knowledgeable	39.8
Somewhat knowledgeable	24.4
Very knowledgeable	3.3
Perceived knowledge of GM of plants (*N* = 431)	
Not at all knowledgeable	38.5
A little knowledgeable	37.1
Somewhat knowledgeable	21.3
Very knowledgeable	3.0
Objective knowledge (number of correct answers) (*N* = 427)	
0	36.1
1	32.1
2	25.5
3	6.3

Table 3. Relationship between objective knowledge and perceived knowledge of the GM or cloning of animals (*N* = 427).

Perceived knowledge	*N*	Mean	*F*
Not at all knowledgeable	138	.64	18.192*
A little knowledgeable	170	1.06	
Somewhat knowledgeable	105	1.33	
Very knowledgeable	14	1.93	

$*p < .001$.

Table 4. Relationship between objective knowledge and perceived knowledge of the GM of plants (*N* = 427).

Perceived knowledge	*N*	Mean	*F*
Not at all knowledgeable	165	.73	9.921*
A little knowledgeable	158	1.16	
Somewhat knowledgeable	92	1.23	
Very knowledgeable	12	1.58	

$*p < .001$.

sented in Table 4. The results were similar to those of the perceived knowledge of the GM of animals, as the "not at all knowledgeable" category was statistically different from all other categories. It should also be noted that in both instances objective knowledge increased with perceived knowledge.

In order to investigate whether there were further differences between perceived and objective knowledge measures, regression models were used to test first the relationship between sociodemographic variables and knowledge and then the relationship between knowledge and support for animal and plant agricultural biotechnology applications. To measure the level of support for animal and plant agricultural biotechnology applications, eight statements were devised. Each statement represented a different biotechnology application with the goal of covering a range of agricultural biotechnology applications. A five-point Likert scale was used to measure the level of support for each application, where 1 = *strongly opposed* and 5 = *strongly support*. The four statements about animal applications were "genetic modification of animals to produce human organs;" "genetic modification of animals to be resistant to diseases, such as Mad Cow;" "genetic modification of animals to produce more tasty and tender meat;" and "genetic modification of animals to increase production, like milk."

The four statements about plant applications were "the genetic modification of plants to produce industrial products, such as plastics;" "genetic modification of nonfood plants, like cotton;" "genetic modification of plants to produce pharmaceutical drugs, like vaccines;" and "genetic modification of fruits and vegetables." Principal axis factor analysis with a varimax rotation revealed that that the animal and plant items were each measuring one concept. The Cronbach alpha for the animal items was .74 and .71 for the plant items. The items were then added together to form an animal support scale ranging from 4 to 20 and a plant support scale ranging from 4 to 20.

Sociodemographic variables included as controls in this analysis were age, sex, race, and education. Age was measured by asking respondents their age on their last birthday. Females were coded 0 as the reference category and males were coded 1. Race was measured by asking respondents their race/ethnicity with the following categories: Caucasian/White (coded 0 as the reference category), Black/African-American, Hispanic, and other. Education was measured by asking respondents their educational level measured categorically. Respondents with a high school degree or less were coded 0 and used as the reference category; the other two categories were some postsecondary and a bachelor's degree or higher. Descriptive statistics for these variables are presented in Table 5. The regression equations for all models are listed in Table 6.

The relationships between sociodemographics and perceived knowledge of the GM of animals, objective knowledge, and the perceived knowledge of the GM of plants are presented in Table 7. The results indicate that there were differences among all three knowledge measures. Race/ethnicity and education were related to per-

Table 5. Summary of descriptive statistics.

Variable	Means
Support for the GM of animals	11.87
Support for the GM of plants	14.08
Age	46.51
Sex (reference = female)	.65
Males	.35
Race (reference = white)	.73
Blacks	.13
Hispanics	.11
Other	.03
Education (reference = high school or less)	.34
Some postsecondary	.36
Postsecondary or higher	.30

Table 6. Regression equations for all models.

Model	Regression equation
1	Perceived $\text{knowledge}_{animals} = B_0 + B_1(\text{Age}) + B_2(\text{Sex}) + B_3(\text{Race}) + B_4(\text{Education})$
2	Objective knowledge $= B_0 + B_1(\text{Age}) + B_2(\text{Sex}) + B_3(\text{Race}) + B_4(\text{Education})$
3	Perceived $\text{knowledge}_{plant} = B_0 + B_1(\text{Age}) + B_2(\text{Sex}) + B_3(\text{Race}) + B_4(\text{Education})$
4	$\text{Support}_{animals} = B_0 + B_1(\text{Age}) + B_2(\text{Sex}) + B_3(\text{Race}) + B_4(\text{Education}) + B_5(\text{Perceived knowledge}_{animals})$
5	$\text{Support}_{animals} = B_0 + B_1(\text{Age}) + B_2(\text{Sex}) + B_3(\text{Race}) + B_4(\text{Education}) + B_5(\text{Objective knowledge})$
6	$\text{Support}_{plant} = B_0 + B_1(\text{Age}) + B_2(\text{Sex}) + B_3(\text{Race}) + B_4(\text{Education}) + B_5(\text{Perceived knowledge}_{plant})$
7	$\text{Support}_{plant} = B_0 + B_1(\text{Age}) + B_2(\text{Sex}) + B_3(\text{Race}) + B_4(\text{Education}) + B_5(\text{Objective knowledge})$

ceived knowledge of animals; age, sex, and education were related to objective knowledge; and sex and education were related to perceived knowledge of plants. Only education was significantly related to all three knowledge measures.

The relationships between perceived knowledge, objective knowledge, and support for biotechnology applications, controlling for sociodemographics, are presented in Table 8. As illustrated in models 4 and 5, neither perceived knowledge nor objective knowledge was significantly related to support for the GM of animals. However, the results in models 6 and 7 show that perceived knowledge was positively associated with support for the GM of plants, while the relationship between objective knowledge and support for the GM of plants was not statistically significant. These results provide evidence that differences between objective and perceived knowledge are likely to vary by the application investigated. It should also be noted that the magnitude of the standardized coefficients varied between the perceived and objective knowledge models for support of the GM of plants but were rather similar in the support for the GM of animals. Moreover, the signs for perceived knowledge differed between the GM of animals and plants models. Perceived knowledge was positively related to support for the GM of plants, but negative for the GM of animals.

Table 7. Standardized coefficients for the relationship between sociodemographics and perceived knowledge of the GM of animals, objective knowledge, and perceived knowledge of the GM of plants.

	Model 1: Perceived knowledge of the GM of animals (*N* = 417)	Model 2: Objective knowledge (*N* = 415)	Model 3: Perceived knowledge of the GM of plants (*N* = 418)
Age	.066	-.126*	-.013
Sex	.061	.117*	.164***
Race (reference = white)			
Blacks	.015	-.051	-.022
Hispanics	.069	.098	-.026
Other	.094*	.034	.086
Education (reference = high school or less)			
Some postsecondary	.243**	.075	.184***
Postsecondary or higher	.298**	.219***	.197***
Constant (Unstd. B value)	1.448**	1.071***	1.599***

$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

To examine whether differences varied by application, individual regression models were analyzed for each biotechnology application by perceived knowledge and objective knowledge controlling for sociodemographic variables (data not shown). The results are presented in Table 9. Perceived knowledge was positively related to two GM of animal applications—"to produce human organs" ($p < .05$) and "to produce more tasty and tender meat" ($p < .01$). Objective knowledge was not significantly related to support for any of the GM of animal applications. Perceived knowledge was positively related to all four of the individual GM of plant applications at $p < .05$. In contrast, objective knowledge was not significantly related to any of the GM of plant applications. These results persisted even when perceived knowledge was controlled for objective knowledge (data not shown), which provides evidence that perceived and objective knowledge variables were measur-

Table 8. Standardized coefficients for the relationships between perceived knowledge, objective knowledge and support for the GM of animals and plants, controlling for sociodemographics.

	Model 4: Support for the GM of animals (*N* = 384)	Model 5: Support for the GM of animals (*N* = 382)	Model 6: Support for the GM of plants (*N* = 372)	Model 7: Support for the GM of plants (*N* = 370)
Age	.025	.018	-.074	-.074
Sex	.193**	.197***	.015	.049
Race (reference = white)				
Blacks	-.093	-.102*	-.160**	-.177***
Hispanics	.024	.016	.039	.023
Other	-.084	-.073	-.138**	-.098
Education (reference = high school or less)				
Some postsecondary	.147*	.132*	.100	.120
Postsecondary or higher	.201**	.178**	.128*	.139*
Perceived knowledge	-.044		.199***	
Objective knowledge		-.001		.062
Constant (Unstd. B value)	10.875**	10.682***	13.099***	14.023***

**p* < .05. ***p* < .01. ****p* < .001.

ing two independent concepts. An examination of the correlations between perceived and objective knowledge in all models also showed that they appeared to be measuring independent concepts (data not shown). Although the relationship between perceived and objective knowledge was statistically significant at $p < .001$ in all models, the highest correlation was only .32. Consistent with the analysis of variance results, objective knowledge scores increased with higher perceived knowledge.

Discussion

This research examined the relationships between perceived knowledge and objective knowledge on support for the GM of animals and plants. Findings demonstrated that there were differences between perceived and objective knowledge measures and that these differences varied by application. Whereas perceived knowledge was related to two animal biotechnology applications and all plant biotechnology applications, objective knowledge was not related to any of the applications when controlled for sociodemographics. These results confirm House et al.'s (2004) conclusions that perceived and objective knowledge measures impact acceptance differently.

Which knowledge measure yields the most valid results for consumer research? Unfortunately, there is not a definitive answer to this question, as each knowledge measure appears to be measuring an independent concept. Perception of knowledge measures the level of knowledge a consumer thinks he or she has, while objective knowledge measures actual knowledge about a particular phenomenon. However, consumers may possess additional knowledge that is not measured by objective measures. For example, if a respondent does

Table 9. Relationships between perceived and objective knowledge and support for agricultural biotechnology applications, controlling for sociodemographics.

Type of application	Perceived knowledge	Objective knowledge
Genetic modification of animals to produce human organs	+	n.s.
Genetic modification of animals to be resistant to diseases, such as Mad Cow	n.s.	n.s.
Genetic modification of animals to produce more tasty and tender meat	+	n.s.
Genetic modification of animals to increase production, like milk	n.s.	n.s.
Genetic modification of plants to produce industrial products, such as plastics	+	n.s.
Genetic modification of nonfood plants, like cotton	+	n.s.
Genetic modification of plants to produce pharmaceutical drugs, like vaccines	+	n.s.
Genetic modification of fruits and vegetables	+	n.s.

Note. + represents a statistically significant positive relationship (p < .05); n.s. = not statistically significant at p < .05.

not know much about the science involved in biotechnology, it does not mean that the consumer does not follow debates surrounding biotechnology. It only means that the person does not possess knowledge about the science involved. Differences between the two knowledge measures appeared to be most significant among respondents who indicated that they had no knowledge of biotechnology applications, lending some support to Hallman et al.'s (2003) claim that respondents tend to exaggerate their level of knowledge. Before this conclusion should be accepted, however, there is a need to understand better what knowledge consumers actually possess. In other words, consumers may not be exaggerating their level of knowledge but may be incorporating other dimensions of knowledge.

This research also supports the conclusions of Hallman et al. (2003), who stated that it is unlikely that scientific information will resonate with consumers. The trick is to learn what information will resonate with consumers and whether this information can change existing attitudes. Clearly, other issues, such as ethical, moral, and social issues, are at play in the debates surrounding biotechnology applications. Consumers may be more likely to make purchase decisions based on their perceived level of knowledge even if that information is erroneous. As demonstrated in this research, it is likely that perceived knowledge is more important than actual knowledge for some animal and plant biotechnology applications.

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