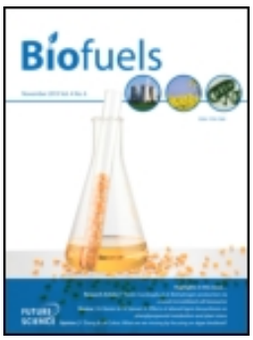

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Public opinions of biofuels: attitude strength and willingness to use biofuels

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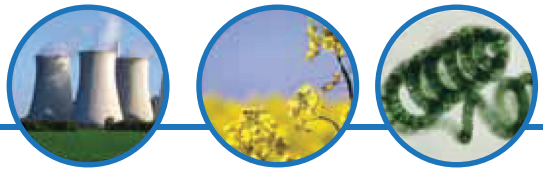

Biofuels (2014) 5(3), 249–259

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Most surveys of public opinion regarding biofuels focus on overall evaluations, but not all support or opposition is created equal. Some opinions are more consequential than others. The current article discusses the literature on attitude strength and presents the results of a national survey of United States citizens. Attitudes predicted a willingness to purchase biofuels and flexible-fuel vehicles, especially when the attitudes were associated with high levels of knowledge or low levels of ambivalence. Therefore, overall support or opposition for biofuels does not provide a complete picture of public opinion. If consequential support for biofuels and related technologies is to be developed, attention must be paid to features of the opinions that predict lasting impact.

Biofuels represent a substantial portion of the transportation fuel currently used in the United States, but a portion that is unlikely to grow without important changes in technology development and adoption. Most consumed biofuel comes in the form of E10 (a 10% ethanol/90% gasoline blend) and is purchased without any necessary recognition on the part of consumers that the fuel is a biofuel blend. It is simply the fuel that is available at the filling station. The ubiquity of E10 developed because of the use of ethanol as an additive to help oil companies meet the emissions standards in the Clean Air Act, after the previous additive, methyl tertiary butyl ether (MTBE), was found to be toxic and had been found in ground water [1,2]. After a quick increase in ethanol-production capacity, capacity outstripped the blending wall (of 10% of consumed gasoline-type fuel by volume), and 7.5 billion liters of ethanol-production capacity were shut down during much of 2009 [3]. Because of the corrosive nature of ethanol, higher concentrations of ethanol require changes in vehicle parts that come in contact with the fuel. Therefore, only a relatively small number of vehicles in use in the United States qualify as flexible-fuel vehicles that can use gasoline or E10 but can also use blends with higher concentrations of ethanol, such as E85 (i.e., 85% ethanol and 15% gasoline) [4].

The United States Environmental Protection Agency has recently proposed to relax biofuel targets for 2014, which would mostly reduce ethanol use in 2014, but also would reduce requirements for the use of advanced biofuels. Debate is likely to be contentious between oil companies and biofuel producers. At this point, the only thing that remains clear is that biofuel use must expand beyond corn-based ethanol if anything close to the original Renewable Fuel Standard is to be realized [3]. This will mean that, as technology and infrastructure changes enable higher proportions of biofuels to be used, it will be important for the supporters of those industries to be able to mobilize adoption of the technologies in consumers' lives.

Many levels of analysis are relevant to discussions of biofuel use. Social psychologists, consumer scientists, or behavioral economists might study the roles of specific attitudes, beliefs, and decision processes that influence

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Key Terms:

Attitudes or Opinions: Overall evaluations of an object (such as biofuel) or issue (such as the Renewable Fuel Standard) as relatively good or bad.

Social Psychology: Basic (theory-building) social science discipline aimed at developing general psychological principles applicable across specific content domains. These principles are intended to explain and predict the impact of the real or imagined presence of other people on human thinking, judgment, and behavior.

Attitude strength: The extent to which an attitude has lasting impact in terms of its persistence over time, resistance to change, and influence on thinking and behavior.

the choice of biofuels or the purchase of vehicles that can use higher concentrations of biofuels. Political scientists and economists might study the impact of policies on biofuel use or on investment in biofuel technology development. Sociologists and political scientists might study the role of institutions and other structural factors that influence public opinion, voting, or regulation. Individual researchers in any one of these areas will examine the topic from the vantage point of their own disciplinary lenses, and cross-talk among disciplines will help to create a comprehensive understanding of biofuel production and use.

The purpose of the current article is to take a *social psychological* approach to examine individual-level factors that influence biofuel-related behaviors. In particular, the presented research examined the attitudes (opinions) that people hold toward biofuels, and specifies some qualities of those attitudes that should be consequential in relating them to willingness, on the part of those people, to purchase and use biofuels. Ideally, the processes examined in relation to current technologies would also be applicable to future technologies as they develop.

For the current purposes, we use the terms *attitude* and *opinion* interchangeably. Both terms refer to the extent to which people evaluate biofuels or biofuel use as relatively good or bad (i.e., along a valence continuum from relatively negative to relatively positive). Research on attitudes has been a core part of social psychology since its inception in the early 1900s. G.W. Allport first called the *attitude* social psychology's most indispensable construct, and one could still argue this point today [5]. This is because attitudes (i.e., overall evaluations of people, objects, or issues) are pervasive and functional [6]. For instance, attitudes independently predict behavior above and beyond other psychological constructs, such as values [7] or subjective norms [8]. Indeed, it is partly because of the impact of attitudes on behavior that researchers began studying techniques to change attitudes [9].

Attitude strength and prediction of behavior

Since the 1970s, researchers have worked to identify qualities of attitudes that would predict which attitudes are "stronger" than others. *Strong attitudes* are those that last over time, that resist change if attacked, and that guide future thinking and behavior [10]. Thus, strong attitudes are not simply extremely positive or negative evaluations, they are evaluations that last and are influential. Many strength-related properties of attitudes have been identified [11,12]. For instance, attitudes predict behaviors better when the person has had direct experience with the attitude object [13]. This would suggest that positive or negative attitudes toward use of E85 would be more likely to guide future fuel choices if the person has previously driven a flexible-fuel vehicle fueled by E85 (compared, for example, with a person who has merely received information about what it is like to drive a vehicle using E85).

The current research addressed two key features of attitudes that seemed particularly relevant to attitudes toward biofuels (and comparisons with other energy sources that were also covered in the survey [14]). The first of these was the amount of knowledge respondents had about the attitude object. Knowledge generally refers to the amount of information the person can call up from memory about the object or issue. Measures of knowledge include self-perceptions of amount of knowledge [15], quizzes about the attitude object [16], or listing of facts and past experiences with the attitude object [17]. Previous research on political and health behaviors suggests that attitudes guide behavior better when the person has much, rather than little, knowledge about the target behavior [15, see also 11]. In fact, this is one of the possible mechanisms for why direct experience also influences attitude strength. Although studies of direct versus indirect experience attempt to equate the amount of knowledge of the object as well as possible, it seems quite reasonable that direct experience would provide insights on the object or activity that cannot be effectively conveyed indirectly.

Regardless of the level of knowledge a person holds, his or her attitude on the topic can be held with relatively little or much ambivalence. Ambivalence refers to the extent to which the person has a mixture of positive and negative reactions to the attitude object. For example, a person could see positive features of biofuels, such as economic development for rural America or reductions in use of foreign oil [18,19], but also have concerns about fertilizer used to grow the biofuel crops contributing to water pollution [20,21]. The fact that both positive and negative features of an attitude object are acknowledged, however, does not mean that a person's overall evaluation has to be neutral. A person could generally support or oppose the use of biofuels, for example, but take that position with varying degrees of ambivalence about the issue. The level of one's ambivalence is sometimes measured by separately asking respondents to report their amount of positivity and negativity toward the attitude object [22, see also 23]. In other settings, ambivalence is measured by asking people the extent to which their reactions are mixed or conflicted [22,24]. As one might expect, attitudes held with ambivalence

do not give as clear a signal for which course of action should be taken. Consistent with an ambivalent attitude conveying a weaker signal for action, attitudes held with ambivalence predict eating behaviors less well than attitudes held with little ambivalence [25,26].

Research aims

The current article reports results of a national survey of attitudes toward a number of potential energy sources. Summaries of overall support of or opposition to biofuels (and a number of specific sources of biofuels) along with a number of other energy sources were previously reported [14]. However, the current report focuses on two specific qualities of attitudes that have previously been found to relate to the impact of those attitudes on related thinking and behavior. Thus, in addition to overall attitudes, the survey also measured the extent of knowledge respondents possessed about biofuels and the extent to which they held their attitudes with ambivalence. Later in the survey, respondents were asked to report the extent to which they were willing to buy biofuels if they were available as well as their willingness to purchase a flexible-fuel vehicle.

Most previous examinations of public support for or opposition of biofuels have measured overall opinions [27,28,29]. However, overall evaluations of biofuels by themselves are likely to miss important parts of the evaluative picture. That is, attitudes should influence related thoughts, judgments, and behaviors, and some attitudes have these consequences to a greater extent than other attitudes. Previous research on support for biofuels has not examined the relations of reported attitudes toward biofuels to willingness to use biofuels or biofuel-related technologies, nor has it examined the extent to which knowledge or ambivalence associated with the attitudes influence the strength of relations between the attitudes and willingness measures. The research thus tested the following specific hypotheses.

H1: Attitudes toward biofuels will predict willingness to use biofuels better when the respondent reports relatively high rather than low levels of knowledge about biofuels.

H2: Attitudes toward biofuels will predict willingness to use biofuels better when the respondent reports relatively low rather than high levels of ambivalence about biofuels.

These influences of knowledge and ambivalence on attitude-willingness relations should not simply reflect the extremity of respondents' positive or negative views of biofuels, because the amount of knowledge or ambivalence should be distinguishable from the extremity of the evaluations.

Sample and survey description

The reported survey research was approved by the Institutional Review Board of Purdue University. A sample of United States citizens was contacted by phone using random-digit dialing techniques between November 30, 2007 and January 27, 2008. They were asked if they would be willing to participate in a survey of opinions toward various energy sources. The aim was to reach a sample representative of the United States population in terms of gender, race/ethnicity, and geography. One thousand and forty-nine participants between the ages of 18 and 107 (median age = 56) responded to the survey (see Table 1 for a summary of demographic characteristics of the sample).

For each of a number of potential energy sources, respondents answered questions about how informed they were about that energy source, their attitude toward that energy source, and how ambivalent they were about the energy source. If respondents reported that they were not at all informed about a particular energy source, no attitude or ambivalence measure was asked about that energy source. Respondents encountered such questions regarding energy from coal, oil, and nuclear sources. Then, respondents answered a number of questions about interpersonal and media sources of information that they would use to seek information on topics they already know a lot about. After these questions, respondents encountered knowledge, attitude, and ambivalence questions regarding solar power and biofuels. The current research report is focused on the biofuels questions (see [14] for overall comparisons of the biofuel responses to the other energy sources). After the general biofuels questions, respondents provided their attitudes toward a number of specific sources of biofuels (i.e., corn, genetically modified plants, switchgrass; see [14]) and also answered a set of questions about interpersonal and media sources for information that people might use to seek information on topics they know little about. Thus, 5-8 minutes after the general biofuels evaluations, respondents were asked about their willingness to use biofuels when they are available. The order of all survey questions was kept constant across participants so differences in reported attitudes and willingness would not be due to differences in the concepts that were recently encountered prior to the biofuel attitude and willingness measures.

Primary measures

■ Knowledge

Respondents were asked, "How informed are you about Biofuels, such as ethanol? Very informed, moderately informed, somewhat informed, or not at all informed?"

Table 1. Distribution of means across demographic characteristics in the sample

	Total Sample	Analyzed sample	Attitude	Knowledge	Ambivalence	Willingness
	n (%)	*n* (%)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)	*M* (*SD*)
Gender						
Male	510 (48.6)	429 (58.1)	3.07 (1.14)	2.84 (0.75)	1.89 (0.93)	3.52 (1.33)
Female	539 (51.4)	309 (41.9)	3.31 (0.95)	2.49 (0.65)	1.96 (0.90)	3.63 (1.24)
Race/Ethnicity						
Black	68 (6.5)	30 (4.1)	3.23 (0.94)	2.57 (0.68)	2.10 (0.89)	3.73 (1.24)
White	836 (79.7)	619 (83.9)	3.18 (1.06)	2.67 (0.72)	1.94 (0.92)	3.55 (1.28)
Hispanic	46 (4.4)	25 (3.4)	3.04 (1.14)	2.68 (0.69)	1.80 (1.04)	3.50 (1.23)
Asian/Pacific Islander	23 (2.2)	12 (1.6)	3.50 (0.91)	2.92 (0.67)	1.58 (0.67)	4.00 (1.11)
Other	76 (7.2)	52 (7.0)	3.02 (1.24)	2.98 (0.78)	1.69 (0.92)	3.50 (1.53)
Education						
11 years or less	56 (5.3)	28 (3.8)	3.18 (1.09)	2.61 (0.74)	2.11 (1.10)	3.70 (1.24)
Completed High School	251 (23.9)	149 (20.2)	3.26 (1.01)	2.54 (0.69)	2.11 (0.89)	3.46 (1.34)
Business or Technical	31 (3)	21 (2.8)	2.81 (1.17)	2.71 (0.78)	2.10 (0.77)	3.26 (1.42)
Some College	252 (24)	180 (24.4)	3.22 (1.05)	2.73 (0.74)	1.81 (0.84)	3.60 (1.37)
Completed College	257 (24.5)	200 (27.1)	3.12 (1.09)	2.69 (0.71)	1.94 (0.99)	3.65 (1.18)
Graduate or Professional	187 (17.8)	154 (20.9)	3.12 (1.12)	2.80 (0.74)	1.77 (0.90)	3.56 (1.30)
Other	15 (1.4)	6 (0.8)	3.83 (0.41)	3.00 (0.63)	2.17 (0.75)	2.58 (0.86)
Political Affiliation						
Republican	305 (29.1)	221 (29.9)	3.05 (1.13)	2.66 (0.72)	1.85 (0.90)	3.41 (1.35)
Democrat	321 (30.6)	218 (29.5)	3.33 (0.89)	2.60 (0.71)	1.89 (0.84)	3.70 (1.23)
Independent	298 (28.4)	225 (30.5)	3.08 (1.15)	2.79 (0.74)	2.01 (0.10)	3.51 (1.31)
Other	125 (11.9)	74 (10.0)	3.30 (1.07)	2.76 (0.74)	1.96 (0.96)	3.80 (1.20)
Region of the Country						
Northeast	200 (19.1)	128 (17.3)	3.13 (1.12)	2.63 (0.74)	1.98 (0.94)	3.55 (1.27)
Midwest	276 (26.3)	201 (27.2)	3.26 (1.03)	2.67 (0.72)	1.83 (0.90)	3.49 (1.22)
South	362 (34.5)	242 (32.8)	3.18 (1.05)	2.74 (0.71)	1.87 (0.86)	3.59 (1.35)
West	211 (20.1)	167 (22.6)	3.08 (1.11)	2.69 (0.74)	2.06 (0.99)	3.61 (1.32)

Note. Northeast region includes CT, DE, MA, ME, NH, NJ, NY, PA, RI, VT. Midwest region includes IA, IL, IN, KS, MI, MN, MO, ND, NE, OH, SD, WI. South region includes AL, AR, DC, FL, GA, KY, LA, MD, MS, NC, OK, SC, TN, TX, VA, WV. West region includes AZ, CA, CO, ID, MT, NM, NV, OR, UT, WA, WY.

Answers were coded with 1 = Not at all informed, 2 = Somewhat informed, 3 = Moderately informed, 4 = Very informed.

■ Attitudes

Respondents were asked two questions. First, they were asked, "Do you agree or disagree with the following statement: Using biofuels, such as ethanol, is a good idea." Next, respondents were asked, "Do you feel strongly or not so strongly about that?" Responses to the two questions were combined to make a 4-point attitude scale with 1 = strongly disagree, 2 = not so strongly disagree, 3 = not so strongly agree, and 4 = strongly agree.

■ Ambivalence

Respondents were asked, "How mixed or conflicted are your feelings about biofuels? Not at all mixed, Somewhat mixed, Moderately mixed, or Very mixed. Answers were coded with 1= Not at all mixed, 2 = Somewhat mixed, 3 = Moderately mixed, 4 = Very mixed.

■ Willingness to use biofuels

Respondents were asked two questions. First, they were asked, "How likely are you to buy a car that runs on biofuel? Very unlikely, Somewhat unlikely, Neither likely nor unlikely, Somewhat likely, or Very likely. Answers were coded with 1 = Very unlikely, 2 = Somewhat unlikely, 3 = Neither likely nor unlikely, 4 = Somewhat likely, and 5 = Very likely. Respondents were also asked, "How likely would you be to try biofuels when they are available at your filling station? Very unlikely, Somewhat unlikely, Neither likely nor unlikely, Somewhat likely, or Very likely. Answers were coded with 1 = Very unlikely, 2 = Somewhat unlikely, 3 = Neither likely nor unlikely, 4 = Somewhat likely, and 5 = Very likely. Answers to the two willingness questions were substantially correlated, $r(749) = 0.56$, $p < 0.0001$, and the effects of attitudes, knowledge, and ambivalence were the same across both measures. Therefore, primary analyses are reported for an average of the two willingness measures.

Analysis and results

Almost 24% of respondents (255) said that they were "not at all informed" about biofuels, such as ethanol, and a number of additional people did not respond to one or more of the primary measures of knowledge, attitude, ambivalence, or willingness (56). Thus, as presented in the second column of Table 1, the sample of people in the primary analysis consisted of the 738 people who reported that they were at least "somewhat informed" about biofuels and provided responses to all of the primary measures.

We first examined zero-order correlations among the primary measures of knowledge, attitudes, ambivalence and willingness. As presented in Table 2, there were small but significant negative correlations between attitude and knowledge, attitude and ambivalence, knowledge and ambivalence, and ambivalence and willingness. As one would expect, attitudes were positively and more substantially correlated with willingness. The only relation that was not significant was between knowledge and willingness.

Next, we conducted a series of regression analyses. We first used the demographic variables to predict our primary variables of attitudes, knowledge, and ambivalence. As presented in Table 3, there were significant gender differences in attitudes toward biofuels, with women holding more favorable biofuel attitudes (see Table 1). There were also effects of political affiliation that reflect Democrats and those not providing a political affiliation reporting more favorable attitudes than Republicans or Independents. The only significant influence on knowledge was gender, with men reporting more knowledge than women. This is also consistent with a larger number of women than men reporting that they were "not at all informed" about biofuels. Finally, for ambivalence, there were differences driven by the level of education (mostly reflecting people with high school or technical education having more ambivalence than people with more education). There were also differences across regions of the country, with people in the Midwest and South reporting less ambivalence than people in the Northeast or West.

Table 2. Zero-order correlations between attitudes, knowledge, ambivalence, and behavioral willingness

	N	*M*	*SD*	1	2	3
1. Attitude	738	3.17	1.07			
2. Knowledge	738	2.69	0.73	−0.106**		
3. Ambivalence	738	1.92	0.92	−0.145**	−0.125**	
4. Behavioral willingness	738	3.56	1.29	0.423**	0.056	−0.077*

Note. Sample size for each correlation is 738, the number of people included in the regression model.
* p < 0.05. ** p < 0.01

Table 3. Regressions using demographic variables to predict attitudes, knowledge, and ambivalence

Demographics	Degrees of freedom	Attitudes		Knowledge		Ambivalence	
		F	*p*	*F*	*p*	*F*	*p*
Gender	1, 720	5.37	0.02	37.75	<0.001	1.43	0.23
Race	4, 720	0.70	0.59	1.63	0.17	1.95	0.10
Education	6, 720	1.28	0.26	1.75	0.11	2.87	0.01
Political affiliation	3, 720	2.84	0.04	1.41	0.24	1.33	0.26
Region of the country	3, 720	0.97	0.41	0.80	0.50	3.26	0.02

Predicting willingness to use biofuels

Our primary analyses used the demographic variables and the measures of attitudes, knowledge, and ambivalence to predict willingness to use biofuels. The regression analyses predicting willingness were each conducted in two blocks. In the first, the variables of gender, race/ethnicity, education, political affiliation, and region of the country were used to predict behavioral willingness. In a second block, the relevant attitudinal variables were centered (i.e., the mean response on that measure was subtracted from the individual's score) and the centered variables were used to create both main effect terms for each variable as well as the relevant interaction(s) [see 30]. These terms were then added to the model while continuing to control for any differences in willingness associated with the demographic factors. Mean centering the predictor variables involved in the interactions prior to analysis allowed us to present the results of a simultaneous regression including the main effect and interaction terms in one model, rather than having to test the main effect and interaction terms in different hierarchical models. Initial analyses focused separately on knowledge or on ambivalence (labeled as Block 2a and Block 2b, respectively in Table 4), and an additional analysis included both knowledge and ambivalence in the same model (labeled as Block 2c).

Finally, because ambivalence is defined by possessing a mixture of positive and negative reactions, ambivalence is frequently associated with less extreme attitudes [11]. In order to control for potential confounds between extremity of the attitude and ambivalence, we conducted additional analyses in which we created a centered ambivalence score separately for each level of the attitude response (by subtracting the mean ambivalence reported across participants who gave that attitude response from each person's ambivalence score – for a similar method when indexing accessibility from scaled rather than dichotomous responses, see [31]). Knowledge is less likely to be associated with attitude extremity [11], but just to be sure, in this analysis, we also conducted the same centering procedures for knowledge that we did for ambivalence to control for any relations between knowledge and attitude extremity. We then re-ran the same regressions that paralleled those reported in Table 4 (extremity-controlled analyses appear in Table 5).

Demographic predictors

In Block 1 of all analyses, the only demographic factor that significantly influenced willingness to use biofuels, was political affiliation (see Table 4). That is, Democrats and those who did not identify a political affiliation were more willing to use biofuels than Republicans or Independents (see Table 1).

Attitudes and knowledge

As presented in Table 4, when the second block of the model included the centered Attitude, Knowledge, and Attitude × Knowledge terms (labeled as Block 2a), attitudes predicted respondents' willingness to use biofuels, with more favorable attitudes toward biofuels relating to higher willingness. The main effect for knowledge was also significant. More importantly, the Attitude × Knowledge interaction was significant. The attitude slope was steeper (i.e., attitudes better predicted willingness to use biofuels) when knowledge was relatively high [$b = 0.55$, $t(717) = 13.14$, $p < 0.001$] rather than low [$b = 0.34$, $t(717) = 3.79$, $p < 0.001$].

The Attitude × Knowledge effects stayed reasonably consistent in analyses that controlled for associations involving ambivalence and attitude extremity. When knowledge and ambivalence were included in Block 2c (in Table 4), the Attitude × Knowledge term remained marginal despite controlling for the effects of ambivalence (when knowledge and ambivalence were significantly correlated; see Table 2). To some extent, the overlap seems to have been due to the relations of knowledge and ambivalence with attitudes, because the Attitude × Knowledge effect was stronger when the indices of both knowledge and ambivalence controlled for the attitude response (see Block 2c in Table 5).

Table 4. Regression predicting willingness to use biofuels

	b	Test statistic (df)	*p*
Block 1: Demographics			
Gender	–	$F(1, 720) = 0.77$	0.38
Race	–	$F(4,720) = 0.25$	0.91
Education	–	$F(6, 720) = 1.27$	0.27
Political Affiliation	–	$F(3, 720) = 2.79$	0.04
Region of the Country	–	$F(3, 720) = 0.19$	0.90
Block 2a: Attitudes and knowledge			
Attitudes	0.443	$t(717) = 8.26$	<0.001
Knowledge	0.219	$t(717) = 3.47$	0.001
Attitudes X Knowledge	0.118	$t(717) = 2.38$	0.02
Block 2b: Attitudes and ambivalence			
Attitudes	0.491	$t(717) = 11.69$	<0.001
Ambivalence	−0.028	$t(717) = -0.58$	0.57
Attitudes X Ambivalence	−0.126	$t(717) = -3.07$	0.002
Block 2c: All attitude strength variables			
Attitudes	0.439	$t(715) = 8.12$	<0.001
Knowledge	0.206	$t(715) = 3.25$	0.001
Ambivalence	−0.014	$t(715) = -0.28$	0.78
Attitudes × Knowledge	0.094	$t(715) = 1.87$	0.06
Attitudes × Ambivalence	−0.108	$t(715) = -2.60$	0.01

Attitudes and ambivalence

When the second block of the model included the centered Attitude, Ambivalence, and Attitude × Ambivalence terms (labeled as Block 2b), attitudes predicted respondents' willingness to use biofuels, with more favorable attitudes toward biofuels relating to higher willingness. The main effect for ambivalence was not significant. More importantly, the Attitude × Ambivalence interaction was significant. The attitude slope was steeper (i.e., attitudes better predicted willingness to use biofuels) when ambivalence was relatively low [$b = 0.62$, $t(717) = 11.57$, $p < 0.001$] rather than high [$b = 0.37$, $t(717) = 5.73$, $p < 0.001$]. The Attitude × Ambivalence effects remained significant in analyses that controlled for associations involving ambivalence, knowledge and attitude extremity (see Block 2c in Table 4; Table 5).

Discussion

Both the knowledge associated with an attitude and the extent to which it is held with ambivalence related to the extent that the attitude predicted the judged likelihood of purchasing a flexible-fuel vehicle or using biofuels when they were available. These patterns emerged despite the fact that some of the weakest attitudes (i.e., those for people who were "not at all informed" about biofuels) were eliminated from consideration by the survey procedure. Thus, even if a researcher attempts to avoid analysis of "non-attitudes" [32], the attitudes reported are likely to vary in their impact on related thinking and behavior.

Most surveys of public opinion focus on overall support or opposition. Yet, the current research suggests that it is also important to consider the strength of opinions that are measured in surveys of public opinions toward biofuels. The overall favorability toward biofuels that was reported in this survey was accompanied by low levels of knowledge [14] and a fair amount of ambivalence. Thus, although overall support for biofuels was relatively high when the data were collected, the potential for vulnerability of that support was evident. Such results also emphasize that attitude strength is not simply the extent to which respondents support or oppose the object, technology, or policy. Despite quite (extremely) positive evaluations of biofuels in 2007/2008, many of those attitudes were quite weak in terms of being associated with relatively low levels of knowledge and some amount of ambivalence. To the extent that respondents' attitudes were associated with greater knowledge or with lower levels of ambivalence, however, those attitudes showed stronger relations with willingness to use biofuels (both in terms of willingness to try biofuels in a vehicle that could use them and to

Table 5. Regression with variables controlled for extremity predicting willingness to use biofuels

	b	Test statistic (df)	*p*
Block 2a: Attitudes and knowledge			
Attitudes	0.512	$t(717) = 12.60$	<0.001
Knowledge	0.197	$t(717) = 3.15$	0.002
Attitudes × Knowledge	0.148	$t(717) = 2.85$	0.004
Block 2b: Attitudes and ambivalence			
Attitudes	0.520	$t(717) = 12.74$	<0.001
Ambivalence	−0.035	$t(717) = -0.67$	0.50
Attitudes × Ambivalence	−0.139	$t(717) = -3.35$	0.001
Block 2c: All attitude strength variables			
Attitudes	0.515	$t(715) = 12.72$	<0.001
Knowledge	0.190	$t(715) = 3.03$	0.003
Ambivalence	−0.019	$t(715) = -0.37$	0.71
Attitudes × Knowledge	0.121	$t(715) = 2.30$	0.02
Attitudes × Ambivalence	−0.118	$t(715) = -2.80$	0.01

purchase a flexible-fuel vehicle). These effects of knowledge and ambivalence occurred even when controlling for the level of attitude extremity.

Although the current research focused on the implications of knowledge and ambivalence for attitude-behavior (or attitude-intention) consistency, the concept of attitude strength extends to other consequences as well. In addition to their impact on behavior, strong attitudes tend to last longer over time (if not attacked), better resist change (if attacked), and play a stronger role in thinking about related issues. Although attitude-behavior (or attitude-intention) consistency is more studied, high levels of knowledge have been previously identified as creating greater resistance to an attacking message [17,33]. Similarly, high levels of ambivalence have been related to a relative lack of attitude stability over time [34] and to a lack of resistance to attacking persuasive messages [35]. Thus, the public opinions of biofuels expressed in late 2007–early 2008 showed both general support for biofuels and also vulnerability of those attitudes (characterized by low knowledge and substantial ambivalence). Consistent with the observed support for biofuels being relatively weak, anti-biofuel information has had substantial impact on public opinion and reduced favorability toward biofuels [36,37].

It may well be that more anti-biofuels information than pro-biofuels information has been present in the media [37]. Consistent with this possibility, Cacciatore and colleagues found a negative correlation between biofuel-related knowledge and support for biofuels [38]. The Cacciatore study differed from the current data in a number of ways, such as focus on a Wisconsin sample, use of a knowledge quiz instead of self-reported knowledge, and measures of perceived benefits and risk rather than overall evaluations of biofuels. Even so, in the current data, we also found a small but significant negative correlation between self-reported knowledge and attitudes toward biofuels (i.e., more knowledge relating to less positive evaluations; see Table 2). At the same time, our willingness data showed a positive effect of knowledge on willingness to use biofuels. It is important to note, however, that the main effect of knowledge is couched within a significant interaction between knowledge and attitudes. It is primarily people who have the most favorable attitudes toward biofuels that show greater willingness when knowledge is high rather than low. Thus, the current data are not as simple as a positive relation between knowledge and support for biofuels. Rather, consistent with the interaction effect, when people have high knowledge, it matters more whether people are relatively favorable or unfavorable toward biofuels.

The overall size (and direction) of the relation between knowledge and support for biofuels could depend crucially on the information about biofuels that is available. Negative relations between knowledge and attitudes might reflect characteristics of the public dialogue surrounding biofuels, and the positivity or negativity of this dialogue may well have shifted over time [37]. Indeed, supporters of first-generation biofuels may

have been somewhat complacent in the early public and political support for corn-based ethanol. However, the weak but positive attitudes of the public proved vulnerable to anti-ethanol information in the media. If next-generation biofuels are to fare better in the long term, it may be necessary for supporters of those next-generation fuels to be more active in creating public and political support that is less vulnerable to attack from opposing forces.

The current research examined the impact of relatively strong versus weak attitudes in the context of general attitudes toward biofuels. However, it is important to note that the general term "biofuels" can refer to different varieties (based on different feedstocks and different production pathways) and people might have different bases for evaluating the different varieties (e.g., because of different levels of sustainability). Although the reported survey included some attitude information about different types of biofuels, the only willingness measures in the study dealt with biofuels more generally. It would be interesting in future research to examine both attitudes and potential behaviors that relate to more specific types of biofuels. In so doing, however, we would emphasize that the theoretical and practical issues related to attitude strength are likely to generalize to evaluations of different types of biofuels (e.g., different feedstocks; different production technologies). That is, because similar attitudinal dynamics have been identified across a number of topic domains, there is little reason to suspect that they would not also be relevant to developing attitudes toward biofuels based on new feedstocks or technologies.

Future perspective

It may well be that individuals with more well-formed positive opinions have withstood the onslaught of negative press for biofuels and will continue to support existing and developing biofuel technologies. However, such people might currently be in a minority. One of the lessons to learn from this phase of the biofuel saga is that support for a new technology is not enough. That support must be cultivated with enough strength for such attitudes to guide purchase decisions and withstand attacks from opposing interests. Therefore, the social-psychological literature on attitude strength is directly relevant to the issue of how public opinion of biofuels will develop and relate to consumer behavior. Future research on public opinion of biofuels would do well to address not only the overall level of support or opposition of biofuels, it would also be worthwhile to assess changes in the properties of those opinions (such as respondents' level of knowledge, ambivalence, or other strength-related properties) [11,14].

We also look forward to future research that more thoroughly incorporates concepts from the attitude strength literature into the biofuels arena. For example, the biofuels domain is likely to be an interesting topic on which to study the effects of persuasive messages (of the types included in television advertising, print editorials, etc.) on the strength-related properties of the attitudes toward biofuels, in addition to any impact on overall evaluations of biofuels. In some settings, a successful persuasive message might not change the message recipients' evaluations, but it might induce doubt or ambivalence that opens the person up to later change.

New technologies generally start with a number of disadvantages in terms of public support for the technology [14]. Support for a new technology must fight against any bias to prefer the status quo (when the status quo is often quite satisfactory to consumers). More germane to the data presented in the current article, attitudes toward new technologies almost necessarily start out relatively weak (i.e., based on little knowledge, experience, and so on). For longevity of support for the new technology to be achieved, proponents of the technology must help potential adopters to develop strong favorable attitudes that are capable of lasting over time, resisting change, and guiding behavior.

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Executive summary

- Surveys of public opinions of biofuels typically address overall support or opposition of biofuels but not the strength-related properties of those attitudes.
- The current research shows that attitudes toward biofuels expressed in late 2007 and 2008 better predicted willingness to purchase a flexible-fuel vehicle or to buy biofuels when the attitudes were associated with low rather than high levels of ambivalence and high rather than low levels of knowledge.
- Not all expressed support for or opposition to biofuels is equally consequential.
- Future assessments of public opinions would do well to include indices of the strength-related properties of the attitudes being assessed.

Ethical conduct of research

The authors state that they obtained appropriate institutional review board approval for the presented research.

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