Confusion and nutritional backlash from news media exposure to contradictory information about carbohydrates and dietary fats

Danielle Clark[1], Rebekah H Nagler[2] and Jeff Niederdeppe[1],*

[1]Department of Communication, Cornell University, 476 Mann Library Building, Ithaca, NY 14853, USA: [2]Hubbard School of Journalism and Mass Communication, University of Minnesota, Minneapolis, MN, USA

Abstract

Objective: To test the effect of news media exposure to contradictory information about carbohydrates and dietary fats on levels of confusion, nutritional backlash and dietary intentions.

Design: We conducted an online survey experiment between 11 and 28 February 2018, randomizing participants to one of six experimental conditions. Two 'contradictory information' conditions asked participants to read one news article on the risks of a low-carbohydrate diet and one article on the risks of a low-fat diet. Two 'convergent information' conditions asked participants to read two articles with similar information on the risks of one of these two diets. A fifth 'established health recommendations' control condition asked participants to read two articles on the harms of smoking and sun exposure. A sixth 'no information' condition served as a second control group. We used general linear models to test hypotheses on the effects of exposure on confusion, nutritional backlash and dietary intentions.

Setting: USA.

Participants: Adults (*n* 901) registered with Amazon's Mechanical Turk (M-Turk).

Results: Exposure to contradictory information about carbohydrates and dietary fats increased confusion and nutritional backlash compared with exposure to established health recommendations for non-dietary behaviours and a no-exposure control. Exposure to contradictory information also increased confusion compared with exposure to consistent nutrition information regarding carbohydrates and dietary fats.

Conclusions: Contradictory nutrition information in the news media can negatively affect consumers' attitudes, beliefs and behavioural intentions. Dietary debates that play out in the media may adversely influence both short-term dietary decisions and future efforts to communicate about unrelated nutrition issues.

Seemingly conflicting or contradictory information about diet and nutrition topics – including fish, coffee and red wine consumption – is prevalent in the news media[1–3]. While some of this information might not be seen as contradictory from the perspective of nutrition researchers and clinicians[4] who are trained to recognize that seemingly incongruent information can accurately reflect the incremental nature of scientific discovery, there is growing evidence that the public perceives widespread contradictory nutrition information in the media[5–8]. One population-based study of US adults found that more than 70 % of participants reported substantial levels of media exposure to contradictory nutrition information[5]. Similar levels of self-reported exposure have been observed in more recent national surveys[9,10].

Public awareness of contradictory nutrition information is troubling if it translates into adverse public health effects. Theory and research in public health and communication science suggest that a variety of negative effects are possible. Behaviour change theories, including the health belief model and the theory of reasoned action/planned behaviour, posit that beliefs about the risks and benefits associated with a dietary behaviour can shape dietary decisions[11,12]. Indeed, public health campaign evaluations have confirmed that media messages can play an important role in shaping specific health behaviours, for

Corresponding author: Email jdn56@cornell.edu

better or worse[13–15]. Theories of media effects, including agenda-setting, framing and cultivation, further suggest that larger meta-messages conveyed via accumulated exposure to media systems can shape broader beliefs about institutions and society[16–18]. These theories suggest that exposure to contradictory nutrition information could influence both discrete dietary behaviours (via specific effects on beliefs about the risks/benefits of a behaviour) and more general beliefs about public health nutrition science, knowledge and institutions. While the source and channel of media messages matter, widespread public exposure to health information from a variety of sources and channels can be consequential[15].

Clinicians and researchers have long assumed that negative effects of contradictory information exposure exist[19,20], but the evidence base has been limited. Early focus group studies identified public perceptions of contradictory or inconsistent nutrition information in the media, but none of these studies directly tested the role of media exposure in producing potential effects[8,21–25]. Two observational survey studies – using cross-sectional[5] then longitudinal population-based survey data[9] – showed that media exposure to contradictory nutrition information was associated with adverse cognitive outcomes, including: (i) confusion about nutrition recommendations; and (ii) negative sentiment towards nutrition research and science more generally (the latter termed 'nutrition backlash'). Such cognitions were, in turn, associated with lower intentions to follow dietary recommendations about fruit and vegetable consumption. Several experimental studies further strengthened this evidence base by manipulating participants' exposure to contradictory media messages about nutrition. Chang[26,27] randomly assigned participants to read either (i) a one-sided story that discussed positive research findings about and/or positive health outcomes linked with a food or supplement (e.g. tofu, vitamin B_6, milk) or (ii) a two-sided story that provided both positive and negative findings and/or outcomes associated with the particular food or supplement. Exposure to two-sided (contradictory) nutrition information increased ambivalence about consuming the food/supplement in question, increased negative attitudes towards the advocated food/supplement and decreased intentions to consume the advocated food/supplement[26]. Contradictory exposure also increased participants' broader uncertainty about health research, increased negative attitudes towards health research and lowered perceptions of overall news credibility[27].

Conceptualizing contradictory nutrition information

Research assessing the effects of media exposure to contradictory nutrition information has defined such exposure in one of two ways. The first conceptualization examines messages that provide 'information about a single behavior producing two distinct outcomes' (Nagler[5], p. 25; Lee et al.[9]). This involves examining the consequences of exposure to messages that provide both supporting (positive) and opposing (negative) information about a particular dietary issue[26–29]. For example, a study using this conceptualization might examine the consequences of exposure to one or more messages that link wine consumption with heart health (outcome 1), as well as one or more messages that link the same behaviour with increased breast cancer risk (outcome 2).

A second conceptualization of contradictory messages has been advanced that, to our knowledge, has not yet been empirically tested: messages that provide 'information about two distinct behaviors and their effects on the same outcome' (Nagler and LoRusso[28], p. 355). For instance, someone might come across one or more messages that link low-carbohydrate diets (behaviour 1) with a lower risk of premature death (a single outcome), as well as one or more messages that link low-fat diets (behaviour 2) with the same outcome. While consuming low-carbohydrate and low-fat diets are related insofar as they both fall under the larger behavioural category of diet, they offer very different dietary prescriptions. Someone who comes across both streams of messages might wonder whether consuming a low-carbohydrate or a low-fat diet is preferable. The current study is guided by this conceptualization of contradictory messages about low-carbohydrate and low-fat diets.

Exposure to contradictory information about low-carbohydrate and low-fat diets

Content analyses document widespread news coverage of contradictory information about a variety of nutrition topics, including dietary fats[1–3]. While studies have not yet documented the volume of contradictory coverage about low-carbohydrate v. low-fat diets, there is reason to expect that the public has been frequently exposed to contradictory information about these diets in recent years. Both types of diets have been subject to extensive empirical study and findings have received considerable media attention. For example, drawing on data from eighteen countries, a recent study published in *The Lancet* found that high-carbohydrate diets were associated with higher risk of total mortality, while high fat intake was associated with a lower risk[30]. In contrast, a few years earlier a meta-analysis published in *PLoS One* concluded that 'low-carbohydrate diets were associated with a significantly higher risk of all-cause mortality' (Noto et al.[31], p. 1). Importantly, scientific debates about the benefits and drawbacks of different diets are not confined to research circles. Rather, these often play out in the news and social media, whether via news coverage of specific studies like the one published in *The Lancet*[32,33], or broader analyses of or commentaries on the seemingly ever-shifting advice

regarding which type of diet is best for one's health[34,35]. While nutrition researchers and clinicians are typically well-equipped to make sense of conflicting findings given their knowledge of the process of scientific discovery[4], the public may struggle to reconcile such messages[5] – whether because of gaps in their understanding of scientific research[36] or the tendency for media sources to streamline and provide limited methodological and contextual information about scientific research[37–39].

Research goals and hypotheses

The goal of the current study, then, was to use a rigorous experimental design to test whether exposure to contradictory information about low-carbohydrate and low-fat diets produces a variety of negative public health outcomes[5,9,26,27]. Specifically, building on the nascent literature documenting effects of exposure to contradictory nutrition messages and consistent with media effects theories which emphasize the impact of messages on larger institutional and societal beliefs[16–18], we hypothesize that exposure to contradictory information about carbohydrates and dietary fats will lead to two cognitive effects – greater nutrition confusion and nutrition backlash – compared with exposure to convergent information about carbohydrates or dietary fats, exposure to established non-dietary health recommendations (serving as one form of control) and a no-exposure condition (serving as a second form of control). These outcomes are likely consequential because previous work shows that confusion and backlash are associated with decreased intentions to adhere to nutrition recommendations in general, decreased ability to assess the credibility of sources of nutrition information and increased anxiety[5,9,40].

In light of previous work finding that exposure to conflicting information about a dietary behaviour can also lower intentions to engage in that behaviour[26], we also expect to observe effects of contradictory information exposure on intentions to consume low-fat and low-carbohydrate diets. Here, we predict that exposure to contradictory information about carbohydrates and dietary fats will lead to lower intentions to consume a low-fat diet, compared with exposure to convergent information regarding low-carbohydrate diets, exposure to established non-dietary health recommendations and a no-exposure control condition. Conversely, we predict that exposure to convergent information arguing that low-fat diets are bad or ineffective will produce lower intentions to eat a low-fat diet than any other condition. Similarly, we predict that exposure to contradictory information about carbohydrates and dietary fats will lead to lower intentions to consume a low-carbohydrate diet, compared with exposure to convergent information regarding low-fat diets and exposure to either of the two control conditions. Again, we expect that exposure to convergent information arguing that low-carbohydrate diets are ineffective or harmful will produce lower intentions to eat a low-carbohydrate diet than any other condition.

Methods

Participants

We recruited 1001 participants through Amazon's Mechanical Turk (M-Turk) for an online survey experiment. We required participants to be aged ≥18 years, be a US resident, and have an M-Turk Human Intelligence Task (HIT) approval rate of greater than 95 % (consistent with best practice recommendations for research on the platform)[41]. As described below, we removed 100 participants who spent 10 s or less on any of the news articles, and thus failed the manipulation check, or did not provide consent to use their data after they completed the study. The final analytic sample thus had 901 participants, with approximately 150 participants in each of the six conditions described below.

Participants in the analytic sample ranged in age from 18 to 74 years (mean = 38·0 years, sd = 12·0 years); 51·6 % of participants identified as male and 48·1 % as female; and the majority identified as White (79·6 %; see Table 1 for all measured demographic variables).

Study design and procedure

We first asked participants to read what we described as two news articles that summarized published scientific research (except for those in the no-exposure control group described below). We randomly assigned participants to one of three overall groups: (i) contradictory information, (ii) convergent information or (iii) control (Table 2). Each of these groups contained two subconditions that varied in either the order of presentation of the news articles (for contradictory and convergent) or the type of control group (information about two well-established but non-nutritional health behaviours or no articles at all), yielding six total conditions.

Participants in the two contradictory conditions read one article about the disadvantages of a low-carbohydrate diet and one article about the disadvantages of a low-fat diet. The order of presentation had no effect on any outcome, so we combine these conditions for all analyses. Participants in the two convergent conditions read two articles which reported on the disadvantages (article 1) then the ineffectiveness (article 2) of either a low-carbohydrate diet (first convergent condition) or a low-fat diet (second convergent condition). Participants in the control groups either: (i) read two articles about non-nutritional topics describing well-established health recommendations unrelated to dietary behaviour (avoiding smoking and sun exposure; control group 1) or (ii) proceeded directly to a short questionnaire (control group 2).

Table 1 Demographics of study participants in the analytic sample (*n* 901) of Amazon Mechanical Turk workers aged >18 years, USA, February 2018

	Analytic sample		Test for differences by randomized condition
	%	*n*	χ^2/*P* value
Randomized condition			
Contradictory	33·1	298	
Convergent with low-carbohydrate articles	15·6	141	
Convergent with low-fat articles	16·4	148	
Established non-dietary health recommendations (control group 1)	16·0	144	
No-exposure (control group 2)	18·9	170	
Total with ≤10 s excluded		901	
Age (years)			$\chi^2_{(24)} = 18\cdot439$, *P* = 0·781
18–24	8·9	80	
25–34	38·9	351	
35–44	25·2	228	
45–54	14·2	128	
55–64	9·3	84	
≥65	3·2	29	
Sex			$\chi^2_{(4)} = 1\cdot041$, *P* = 0·903
Male	51·6	465	(for male *v.* female only)
Female	48·1	433	
Transgender male/man	0	0	
Transgender female/woman	0·1	1	
Genderqueer/gender non-conforming	0·1	1	
Prefer not to answer	0·1	1	
Race/ethnicity (non-exclusive categories)			
White	79·6	717	$\chi^2_{(4)} = 4\cdot935$, *P* = 0·294
Black	7·9	71	$\chi^2_{(4)} = 1\cdot250$, *P* = 0·870
Asian	8·7	78	$\chi^2_{(4)} = 6\cdot560$, *P* = 0·161
Hispanic/Latinx	6·4	58	$\chi^2_{(4)} = 4\cdot348$, *P* = 0·361
American Indian or Alaska Native	1·0	9	(insufficient sample size)
Hawaiian or other Pacific Islander	0·1	1	(insufficient sample size)
Other	1·2	9	(insufficient sample size)
Highest level of education			$\chi^2_{(16)} = 12\cdot475$, *P* = 0·711
Some high school, high school diploma or equivalent (GED)	11·5	104	
Some college or technical school (college 1–3 years)	36·3	327	
Bachelor's degree	39·8	359	
Master's degree	8·9	80	
Professional school (JD, MD, etc.) or doctorate degree (PhD, EdD)	3·4	31	
Diets used in past 12 months (non-exclusive)			
Low-carbohydrate	33·4	301	$\chi^2_{(4)} = 25\cdot828$, *P* < 0·001
Low-fat	24·8	223	$\chi^2_{(4)} = 6\cdot777$, *P* = 0·148
Other	65·3	588	$\chi^2_{(4)} = 10\cdot770$, *P* = 0·029
Weekly exercise			$\chi^2_{(28)} = 34\cdot930$, *P* = 0·172
0 d	9·8	88	
1 d	13·4	121	
2 d	22·5	203	
3 d	15·1	136	
4 d	16·8	151	
5 d	6·0	54	
6 d	7·8	70	
7 d	8·7	78	

GED, General Educational Development; JD, junior doctor; MD, medical doctor.

Participants in all conditions except control group 2 next answered questions included as a manipulation check. All participants then answered questions measuring confusion, nutritional backlash and intentions to eat a low-carbohydrate and low-fat diet. The study concluded with questions about self-reported prior exposure to contradictory nutrition information, nutrition knowledge, attention paid to nutrition topics in the media, attention paid to diet information in the media, levels of physical activity, past diet types and demographics.

Stimulus materials

Participants in the five news article conditions received digital reproductions of newspaper articles reporting on scientific findings related to carbohydrates and dietary fats

Table 2 Summary of randomized conditions

	Contradictory		Convergent		Control	
	Condition 1	Condition 2	Condition 1	Condition 2	Condition 1	Condition 2
Order 1	Low-carbohydrate Harmful	Low-fat Harmful	Low-carbohydrate Harmful	Low-fat Harmful	Established Smoking	N/A
Order 2	Low-fat Harmful	Low-carbohydrate Harmful	Low-carbohydrate Ineffective	Low-fat Ineffective	Established Sun exposure	N/A
n	146	152	141	148	144	170

N/A, not applicable.

Table 3 Means and 95 % CI for the manipulation check, by condition, in the analytic sample (*n* 901) of Amazon Mechanical Turk workers aged >18 years, USA, February 2018

		Contradictory	Convergent condition 1 (low-carbohydrate)	Convergent condition 2 (low-fat)	Control condition 1 (non-nutrition)
Total sample	Mean	3·77	2·42	2·65	2·55
(*n* 1001)	95 % CI	3·66, 3·88	2·29, 2·55	2·51, 2·79	2·45, 2·65
≤10 s	Mean	2·91	2·99	3·26	2·76
(*n* 96)	95 % CI	2·60, 3·21	2·65, 3·33	2·85, 3·68	2·49, 3·04
Total sample without ≤10 s	Mean	3·86	2·32	2·58	2·52
(*n* 901)	95 % CI	3·75, 3·98	2·19, 2·46	2·43, 2·72	2·41, 2·63

The manipulation check was measured on a scale of 1–5. '≤10 s' includes any participant who spent 10 s or less on one or both of the stimulus materials. 'Total sample without ≤10 s' excludes any participants who spent 10 s or less on any of the stimulus materials from the original total sample.

(Appendix 1). Participants saw only the title and body of the article, omitting information about the date, author and source. We based the articles in the contradictory and convergent conditions on actual news reports of scientific studies about low-carbohydrate and low-fat diets from recent years, identified from a search of the LexisNexis database using search terms 'low-carb diet' and 'low-fat diet'. We edited the articles to standardize their length and format (e.g. whether or not an author was quoted) but kept relevant scientific details of the studies consistent. We modelled the stories after actual news reports about a meta-analysis and a large cohort study about each dietary topic. We used the search terms 'health effects of cigarettes' and 'health effects of sun exposure' to create stories for the established, non-nutritional recommendations control group (avoid cigarettes because they are deadly; avoid unprotected sun exposure to prevent skin cancer).

Manipulation check

We asked participants in the five news article conditions (*n* 827) four questions after they viewed the news articles: 'The two articles I just read . . . : (i) agreed with one another; (ii) said similar things; (iii) made very different arguments about what is healthy; and (iv) contradicted one another', with response categories from 'strongly disagree' (= 1) to 'strongly agree' (= 5). We recoded negatively worded items so that higher values indicated more disagreement. The items were reliable (Cronbach's $\alpha = 0.90$; mean = 3·04,

$\text{sd} = 1.12$) so we averaged them into a scale. A general linear model (using randomized condition to predict scale values) revealed substantial differences between conditions ($F_{(3,823)} = 124.04$, $P < 0.001$). Comparing means for the full sample (*n* 1001), the perception of disagreement was higher in the contradictory conditions (mean = 3·77, $\text{sd} = 1.03$, 95 % CI 3·66, 3·88) than in the convergent dietary fat condition (mean = 2·65, $\text{sd} = 0.90$, 95 % CI 2·51, 2·79), the convergent carbohydrate condition (mean = 2·42, $\text{sd} = 0.85$, 95 % CI 2·29, 2·55) and the control condition with established recommendations (mean = 2·55, $\text{sd} = 0.64$, 95 % CI 2·45, 2·65).

We then stratified the sample based on unobtrusively recorded time spent on the stories and re-examined evidence for successful manipulation (Table 3). Participants who spent less than 10 s on any of the stimulus materials failed the manipulation check ($F_{(3,92)} = 1.34$, $P = 0.27$, *n* 96); differences began to emerge if we included participants spending more time on the stimuli. Therefore, we removed participants from the study who spent less than 10 s on any of the stories, producing a total analytic sample size of *n* 901. Within the final analytic sample, the contradictory condition had higher levels of perceived disagreement (mean = 3·86, $\text{sd} = 1.01$, *n* 298) than the convergent carbohydrate condition (mean = 2·32, $\text{sd} = 0.81$, *n* 141), the convergent dietary fat condition (mean = 2·58, $\text{sd} = 0.89$, *n* 148) and the control condition with established non-nutritional health recommendations (mean = 2·52, $\text{sd} = 0.65$, *n* 144).

Measures

Confusion

Participants responded to six statements adapted from Nagler[5] on a five-item scale from 'strongly disagree' (= 1) to 'strongly agree' (= 5): 'It is not always clear to me what foods are best for me to eat', 'I find nutrition recommendations to be confusing', 'Nutrition research findings make sense to me' (reverse coded), 'I don't know what I should be eating to stay healthy', 'I find nutrition research studies hard to follow' and 'I understand scientists' recommendations about what foods I should eat' (reverse coded). We randomized item order and averaged the items into a scale (Cronbach's $\alpha = 0.91$; mean = 2·73, SD = 0·95).

Nutritional backlash

The Nutritional Backlash Scale measures negative sentiment towards dietary science and health recommendations[42,43]. Participants responded to eleven statements derived from the original scale[43] including items such as 'Scientists really don't know whether a low-fat diet is good for you' and 'Dietary recommendations should be taken with a grain of salt'. We modified items from the original scale that referenced carbohydrates or dietary fats (e.g. 'Scientists really don't know whether a low-fat diet is good for you') and replaced them with terms to reference diets in general so that the items reflected general nutritional backlash, not backlash specific to low-carbohydrate or low-fat diets ('Scientists really don't know what diet is good for you', 'Most nutrition scientists agree on what type of diet is most healthful'). We reverse coded items where necessary such that higher values reflect greater backlash. We randomized item order and averaged them into a scale (Cronbach's $\alpha = 0.78$; mean = 2·78, SD = 0·63).

Dietary intentions

We measured intentions to eat a low-fat and low-carbohydrate diet using response categories from 'very unlikely' (= 1) to 'very likely' (= 5). We included four items for each diet. For low-fat diets, the items read: 'I will eat a diet low in dietary fat in the next 30 days'; 'I will eat a diet low in dietary fat in the next week'; 'I plan to eat a diet low in dietary fat in the next 30 days'; and 'I plan to eat a diet low in dietary fat in the next week'. We replaced the terms 'low in dietary fat' with 'low in carbohydrates' to gauge intentions to eat a low-carbohydrate diet. We averaged the four items for each diet into scales (low-fat diet: Cronbach's $\alpha = 0.98$; mean = 2·55, SD = 1·22; low-carbohydrate diet: Cronbach's $\alpha = 0.98$; mean = 2·63; SD = 1·25).

Demographic and additional variables

We measured self-reported prior exposure to contradictory nutrition information[6], nutrition knowledge[44], attention paid to nutrition topics in the media[6], attention paid to diet, levels of physical activity[45] and past diet types (Appendix 2). We used these items in exploratory analyses to gauge whether message effects on confusion, backlash and dietary intentions varied as a function of these factors.

Analytic approach

Measured demographic and prior exposure/attention/dietary behaviour variables did not differ between randomized conditions, with two exceptions. The proportion of participants who reported being on a low-carbohydrate diet in the past 12 months was higher in the established recommendations control condition (48·6 % of that condition's sample) than in the contradictory conditions (25·8 %) or the convergent conditions (27·7 %; $\chi^2 = 4.56$, df = 4, $P = 0.03$). The proportion of participants who had been on another (neither low-carbohydrate nor low-fat) diet in the past 12 months was higher in the convergent conditions (41·1 % of that condition's sample) than in the established recommendations condition (24·3 %; $\chi^2 = 4.56$, df = 4, $P = 0.03$). To account for any potential confounding of causal interpretations, all analyses controlled for these two factors. Specifically, we ran general linear models that included having been on a low-carbohydrate diet and having been on an 'other' diet type in the past 12 months as covariates in tests of study hypotheses. All reported analyses show marginal (adjusted) means that account for these factors.

The series of adjusted general linear models revealed significant effects of randomized conditions on confusion, nutritional backlash, intentions to eat a low-fat diet and intentions to eat a low-carbohydrate diet. Given that the overall models were significant, we compared means between the contradictory condition and each of the other conditions as proposed in study hypotheses. We considered means with 95 % CI that did not overlap as evidence of significant differences between conditions.

Results

Confusion

There were significant differences between conditions for confusion ($F_{(4,895)} = 37.09$, $P < 0.001$). Mean comparisons provided unanimous support for study hypotheses related to this outcome (Table 4). Confusion was higher in the contradictory condition (mean$_{adj}$ = 3·15, 95 % CI 3·05, 3·25) than the convergent condition regarding low-fat diets (mean$_{adj}$ = 2·85, 95 % CI 2·70, 3·00) and the convergent condition regarding low-carbohydrate diets (mean$_{adj}$ = 2·64, 95 % CI 2·49, 2·78). Confusion was also higher in the contradictory condition than the established health recommendations control group (mean$_{adj}$ = 2·17, 95 % CI 2·03, 2·32) or the no-exposure control condition (mean$_{adj}$ = 2·45, 95 % CI 2·32, 2·58).

Table 4 Marginal means and 95 % CI for confusion, nutritional backlash and intentions, by condition, in the analytic sample (*n* 901) of Amazon Mechanical Turk workers aged >18 years, USA, February 2018

		Confusion	Nutritional backlash	Intentions low-carbohydrate	Intentions low-fat
Contradictory	Mean	3·15	2·93	2·56	2·43
	95 % CI	3·05, 3·25	2·86, 3·00	2·44, 2·69	2·30, 2·56
Convergent condition 1 (low-carbohydrate)	Mean	2·64	2·80	2·33	2·58
	95 % CI	2·49, 2·78	2·70, 2·90	2·15, 2·50	2·38, 2·77
Convergent condition 2 (low-fat)	Mean	2·85	2·88	2·62	2·05
	95 % CI	2·70, 3·00	2·78, 3·00	2·45, 2·80	1·86, 2·24
Control condition 1 (established)	Mean	2·17	2·50	2·81	2·84
	95 % CI	2·03, 2·32	2·40, 2·60	2·64, 3·00	2·65, 3·04
Control condition 2 (no exposure)	Mean	2·45	2·63	2·84	2·93
	95 % CI	2·32, 2·58	2·54, 2·73	2·67, 3·00	2·76, 3·11

Confusion, nutritional backlash, intentions low-carbohydrate and intentions low-fat were measured on a scale of 1–5. These means were adjusted for two variables (having been on a low-carbohydrate diet in the past 12 months and having been on an 'other' diet type in the past 12 months) that differed between randomized conditions.

Nutritional backlash

There were significant differences between conditions for nutritional backlash ($F_{(4,896)} = 15\cdot74$, $P < 0\cdot001$). Means comparisons provided conditional support for study hypotheses related to backlash (Table 4). Contrary to our hypothesis, the 95 % CI surrounding means for nutritional backlash overlapped between the contradictory condition (mean$_{adj}$ = 2·93, 95 % CI 2·86, 3·00) and both convergent conditions (low-fat diets: mean$_{adj}$ = 2·88, 95 % CI 2·78, 3·00; low-carbohydrate diets: mean$_{adj}$ = 2·80, 95 % CI 2·70, 2·90). However, consistent with predictions, nutritional backlash was significantly higher in the contradictory condition than in both the established recommendations condition (mean$_{adj}$ = 2·50, 95 % CI 2·40, 2·60) and the no-exposure control group (mean$_{adj}$ = 2·63, 95 % CI 2·54, 2·73).

Intentions to eat a low-fat diet

There were significant differences between conditions for intentions to eat a low-fat diet ($F_{(4,896)} = 14\cdot22$, $P < 0\cdot001$). Means comparisons provided conditional support for hypotheses related to low-fat dietary intentions (Table 4). Contrary to predictions, intentions to eat a low-fat diet were not statistically different between the contradictory condition (mean$_{adj}$ = 2·43, 95 % CI 2·30, 2·56) or the convergent condition regarding low-carbohydrate diets (mean$_{adj}$ = 2·58, 95 % CI 2·38, 2·77). Consistent with hypotheses, however, intentions to eat a low-fat diet were lower in the contradictory condition than in the established health recommendations control group (mean$_{adj}$ = 2·84, 95 % CI 2·65, 3·04) and the no-exposure control condition (mean$_{adj}$ = 2·93, 95 % CI 2·76, 3·11). Intentions to eat a low-fat diet were lowest in the convergent condition about low-fat diets being bad/ineffective (mean$_{adj}$ = 2·05, 95 % CI 1·86, 2·24), consistent with *a priori* predictions.

Intentions to eat a low-carbohydrate diet

There were also significant differences between conditions for intentions to eat a low-carbohydrate diet ($F_{(4,896)} = 9\cdot89$, $P < 0\cdot001$). Means comparisons did not offer support for hypotheses related to low-carbohydrate dietary intentions (Table 4). Intentions to eat a low-carbohydrate diet were statistically equivalent in the contradictory condition (mean$_{adj}$ = 2·56, 95 % CI 2·44, 2·69) and the convergent condition regarding low-fat diets (mean$_{adj}$ = 2·62, 95 % CI 2·45, 2·80). Intentions to eat a low-carbohydrate diet were also comparable in the contradictory condition, the established recommendations condition (mean$_{adj}$ = 2·81, 95 % CI 2·64, 3·00) and the no-exposure control condition (mean$_{adj}$ = 2·84, 95 % CI 2·67, 3·00). Intentions to eat a low-carbohydrate diet in the convergent condition regarding low-carbohydrate diets were comparable to other conditions (mean$_{adj}$ = 2·33, 95 % CI 2·15, 2·50), also contrary to expectations.

Exploratory analyses testing for effect moderation by individual differences

We tested whether effects of exposure to contradictory nutrition information differed based on respondent characteristics by adding a series of interaction terms to the models described above. Potential moderators included past exposure to contradictory information, nutrition knowledge, attention paid to nutrition topics in the media, attention paid to diet, levels of physical activity and past diet types. There were eight potential moderators, four outcomes (confusion, backlash, intentions to eat low-fat and low-carbohydrate diets), and three or four tests per statistical model (contradictory *v.* convergent (combined into one condition for confusion and backlash, but run separately for low-fat and low-carbohydrate diet intentions), established non-dietary recommendations and no-exposure control), resulting in 112 different statistical tests of effect moderation. This raises a high probability of alpha inflation; we focus on consistent patterns.

Across six of the potential moderators (knowledge, attention to nutrition information, levels of physical activity and all three past diet types), only three of eighty-four statistical tests were significant at $P < 0\cdot05$ and one at $P < 0\cdot01$, a rate roughly equivalent to what one would expect by chance

alone. For prior exposure to contradictory information and attention to diet, however, nine of thirty-two tests were significant at $P < 0.05$ and six of these were significant at $P < 0.01$. These models demonstrated a clear and consistent pattern: effects of exposure to contradictory news stories on confusion and backlash were attenuated among those with high prior exposure or high attention to dietary topics, and effects of exposure to these contradictory news stories on intentions to consume low-fat or low-carbohydrate diets were stronger among these two groups. These results indicate that negative effects of contradictory news stories are most pronounced among those least likely to have encountered these contradictions in the past.

Discussion

The present randomized controlled study provides evidence that exposure to contradictory nutrition information can have deleterious effects on consumers' attitudes, beliefs and intentions. We summarize and interpret results for each study outcome in the paragraphs that follow.

First, exposure to contradictory information about carbohydrates and dietary fats led to significantly higher levels of confusion than exposure to convergent information, established non-dietary health recommendations and a no-exposure control. These results are consistent with earlier population-based observational studies, which found that greater levels of self-reported media exposure to contradictory nutrition information predicted greater nutrition confusion, both cross-sectionally[5] and longitudinally[9]. Interestingly, post hoc analyses (not detailed in results but seen by examining means and 95 % CI in Table 4) reveal that exposure to any information about the harmfulness or ineffectiveness of a low-fat or low-carbohydrate diet produced greater confusion than exposure to established non-nutrition health recommendations or no articles at all. We speculate that participants may be accustomed to exposure to varied news media information about low-carbohydrate and low-fat diets such that additional information about these topics primed them to feel more confused.

Second, exposure to contradictory information about carbohydrates and dietary fats also led to significantly higher levels of nutritional backlash than did exposure to established non-nutrition health recommendations and a no-exposure control. These results are again consistent with prior observational studies where self-reported media exposure to contradictory nutrition information predicted greater nutritional backlash[5,9]. We did not, however, observe significant differences in backlash between those exposed to contradictory information and those exposed to convergent information about low-fat and low-carbohydrate diets. However, further analysis of mean values revealed that exposure to any information about diet – whether contradictory or convergent – led to greater backlash than exposure to established health recommendations unrelated to diet or no

articles at all. This again suggests that mere attention to these topics in the news media has potential to undermine public confidence in nutritional recommendations more broadly, a concerning finding since reports of dietary studies are commonplace in the news media cycle[3].

Third, exposure to contradictory information produced lower intentions to eat a low-fat diet relative to exposure to established health recommendations or no article exposure. We did not observe this pattern for intentions to eat a low-carbohydrate diet. Post hoc analyses show that exposure to convergent information about the harmfulness or ineffectiveness of low-fat diets led to the lowest levels of intentions to eat a low-fat diet. While we can only speculate, low-fat diets have been promoted by nutrition and health promotion officials for decades, while low-carbohydrate diets are a newer phenomenon, at least in public discourse. Stories that contradict long-established recommendations may be particularly confusing and prompt backlash because they undermine trust and reflect a greater shift from longstanding dietary guidance.

Combined, these results underscore the fact that news media coverage of dietary topics can shape behavioural intentions for the topic at hand (specifically low-fat diets) and for broader attitudes towards nutrition recommendations and dietary information in general. The present study builds upon a foundation of health behaviour prediction[11,12] and media effects theories[16–18] and adds to the existing evidence base – both from observational studies that assessed self-reported exposure to contradictory information[5,9] and experimental studies that gauged reactions to contradictory information within a single news story[26,27] – by testing a previously untested conceptualization of contradictory health messages[28]. Findings also demonstrate that major dietary debates that play out in nutrition science and media sources may be consequential for both dietary decisions in the short term and future efforts to communicate effectively about unrelated dietary issues.

Study context and limitations
We acknowledge that the contemporary media system is increasingly complex and that citizens receive dietary information from a variety of non-news or pseudo-news sources, including those disseminated via social media and other websites. The current study presented news stories without source attribution and in the absence of additional information about their origin or context. Source information and the broader context of exposure (whether received via a social media feed, on a website, in print, etc.) may interact with the content of the message in complex ways that we were unable to test here. However, by holding these factors constant in a between-subjects randomized experiment, we are able to establish that exposure to contradictory dietary information can produce confusion and backlash under some conditions. Future studies should explore how source information, audience trust in specific news sources and

contradictory information interact to influence confusion, nutritional backlash, dietary intentions and behaviour.

While we measured various cognitions (confusion and backlash) and behavioural intentions, both of which have been associated with health behaviour in prior work, we did not measure actual dietary behaviour. Researchers[5,9] suggest nutritional backlash may lead to even more severe consequences, such as failure to adhere to subsequent health recommendations about which there is little contradictory information (e.g. fruit and vegetable consumption, exercise) – a phenomenon described as carryover or spillover effects[5,46]. Future work should assess effects of nutritional backlash, confusion and dietary intentions on longer-term health behaviours, as well as other potential outcomes of contradictory exposure, such as diet information overload[47].

Participants saw two news stories at a single time. Real-world exposure to contradictory nutrition information likely unfolds over a longer time period. Therefore, the present study may not represent the effects of exposure to health information in the real media landscape where intervals of exposure to health/nutrition information and attributes such as the source, date, article length and writing quality can vary significantly.

Finally, M-Turk workers (the study sample) are unlikely to reflect the broader demographics of US residents. Recent work, however, does make a compelling case that M-Turk studies produce results very similar to more representative samples when assessing the effects of health information via randomized experiments[48]. Our results also echo findings from two population-based observational studies[5,9] which lends some credence to the argument that observed effects may be generalizable beyond this context.

Implications for research and practice

Despite these limitations, study findings have implications for the public and the news media. Nutrition and health promotion officials should be aware that exposure to news media stories summarizing scientific evidence about dietary recommendations can cause confusion and could erode broader levels of trust in future dietary guidelines among some audiences. This also highlights the need to identify strategies to mitigate these potential deleterious effects. One strategy could involve training scientists, journalists and nutritionists to ensure that they acknowledge research limitations and describe how any new scientific evidence builds upon past research. Acknowledging sources of uncertainty and study limitations can increase trust in science and may render audiences less prone to nutritional backlash[42,49]. There also have been recent calls to reform nutritional epidemiology amid claims that such work is undermined by cumulative biases via residual confounding and selective reporting[50]. Such reform would influence the way research is conducted and, in turn, could shape how the media covers this work.

Conclusion

The present study provides new evidence that sequential exposure to contradictory news stories in the media about carbohydrates and dietary fats can negatively influence consumers' attitudes, beliefs and behavioural intentions. In the long term, these outcomes may reduce the likelihood that individuals adhere to nutrition and other health recommendations writ large, presenting a vexing challenge for nutrition education and public health promotion. Future work should test strategies to reduce confusion and nutritional backlash that may result from inevitable future exposures to contradictory nutrition information in the news media, via social media and beyond.

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Appendix 1
Full text of each message

Message summary	Full text
Low-carbohydrate diet (harmful)	Low carbs a killer: study finds long-term harm outweighs benefits New research finds that low-carb diets, including recent trends like Atkins, Paleo and the Mediterranean Diet, could increase your chance of dying prematurely by 30 per cent. A major long-term study, published in the journal *PLoS One*, found low-carbohydrate diets increase the chance of dying from any cause. According to the lead author of the study, Dr Hiroshi Noto, a low-carbohydrate diet substantially increases the odds of all-cause mortality – dying early from any cause – compared to a regular diet with much higher levels of carbs and fats. According to Dr Noto, 'There is evidence that whole grains and fibre protect against bowel cancer, heart disease, diabetes and other chronic diseases. These critical protective nutrients are often lacking in low-carbohydrate diets, which also tend to be much higher in dietary fat.' 'When you start restricting carbohydrates, you're cutting out bread, cereals and fruit and you're losing a lot of good, protective things,' Dr Noto said. Differences in free fatty acids, protein, fibre, minerals, vitamins and phytochemicals of low-carbohydrate diets could also help to explain why these diets appear to have a detrimental effect on health. Another researcher unaffiliated with the study, Dr John Esserman, says that carbohydrates form the majority of the diet for Japanese, who have one of the longest life expectancies in the world. The Japanese diet also tends to be lower in fat, and saturated fat in particular. The study did not find any cardiovascular benefit from a low-carbohydrate diet that was higher in other macronutrients, such as dietary fat, 'and supports their potential long-term health harm' when such nutritional quality is not considered, according to the study. The authors say that greater intake of carbohydrates, combined with lower intake of dietary fats, particularly saturated fats, reduces risk of heart disease, cardiovascular disease and mortality.
Low-fat diet (harmful)	A low-fat diet could kill you, major study shows Contrary to decades of dietary advice, new research finds that low-fat diets could raise the risk of early death by almost one-quarter. A major long-term study, published in *The Lancet*, found those who cut back on fats had far shorter lives than those enjoying plenty of butter, cheese and meats. Dr Marshid Dehghan, lead author of the study, said that 'Those eating low-fat diets tend to eat far too much high-carbohydrate food like bread, cereals, pasta and rice while missing out on vital nutrients.' Researchers said the study was at odds with repeated health advice to cut down on fats. For years, the US Department of Health has cautioned against having too much saturated fat, on the grounds it raises cholesterol levels and increases the risk of heart disease. Saturated fat is found in animal products, such as butter, cheese and red meat. But the latest research found those who avoid saturated fat in particular have a 13 per cent higher chance of early death compared to those eating plenty of it. And consuming high levels of all fats cut mortality by up to 23 per cent. Dr Andrew Metton, a researcher from the University of Pennsylvania who was not an author on the study, said: 'These new data suggest that low-fat diets put populations at increased risk for cardiovascular disease. 'Loosening the restriction on total fat and saturated fat and imposing limits on carbohydrates . . . would be optimal.' Another nutrition expert, Dr Paul Anderson, echoed the findings: 'A high-carbohydrate diet increases your risk of dying, while a high fat diet helps you to live longer.' Dr Anderson said it was time 'for a complete U-turn' in the United States' approach to diet, and demonization of fat. 'The sooner we do that the sooner . . . we start improving health.'
Low-carbohydrate diet (ineffective)	Low-carb diets show little weight loss success in the long term Researchers set out to answer this age-old debate: In a weight-loss contest between a low-carbohydrate diet and low-fat diets, who would come out on top? Of all the diets they looked at, which emerged the lightweight champion? Neither. There have been reams of research on the subject and the researchers recently analysed 23 randomized controlled trials that compared the amount of weight that people had lost on a low-carbohydrate to low-fat diets. The trials were conducted in adults and had an intervention of 6 months or more from multiple countries with a total of 2788 participants. The large sample size 'had the power to detect even very small potential differences' between the diets, the study said. Trials were excluded from the analysis if the treatment allocation was not random, if study participants were less than 18 years of age, and/or if there was no difference between intake of carbohydrates or fat in the diets. The main verdict was that low-carbohydrate diets did not lead to significantly more weight loss than low-fat diets. And other major long-term studies have shown that low-carbohydrate diets can even increase the risk of mortality and other pathologies. The researchers thought comparing the diets would help to identify the optimal diet, but the findings show, in the authors' words, that 'low-carbohydrate diets are at least as effective as low-fat diets for weight loss.' Neither diet type maintained statistically significant weight loss over the long term. In conducting the analyses, the researchers followed stringent protocol by reviewing only randomized controlled trials, which 'are subject to fewer biases than observational studies and are the gold standard for evaluating the effects of an intervention,' the study says. 'In general, avoiding emphasis on low-carb or low-fat and focusing on healthy foods . . . will up your chances of weight loss success,' said head researcher William Yang.

Continued

Message summary	Full text
Low-fat diet (ineffective)	**Low-fat diets show little weight loss success in the long term** Researchers set out to answer this age-old debate: In a weight-loss contest between a low-fat diet and low-carbohydrate diets, who would come out on top? Of all the diets they looked at, which emerged the lightweight champion? Neither. There have been reams of research on the subject and the researchers recently analysed 23 randomized controlled trials that compared the amount of weight that people had lost on a low-carbohydrate to low-fat diets. The trials were conducted in adults and had an intervention of 6 months or more from multiple countries with a total of 2788 participants. The large sample size 'had the power to detect even very small potential differences' between the diets, the study said. Trials were excluded from the analysis if the treatment allocation was not random, if study participants were less than 18 years of age, and/or if there was no difference between intake of carbohydrates or fat in the diets. The main verdict was that low-fat diets did not lead to significantly more weight loss than low-carbohydrate diets. And other major long-term studies have shown that low-fat diets can even increase the risk of mortality and other pathologies. The researchers thought comparing the diets would help to identify the optimal diet, but the findings show, in the authors' words, that 'low-carbohydrate diets are at least as effective as low-fat diets for weight loss.' Neither diet type maintained statistically significant weight loss over the long term. In conducting the analyses, the researchers followed stringent protocol by reviewing only randomized controlled trials, which 'are subject to fewer biases than observational studies and are the gold standard for evaluating the effects of an intervention,' the study says. 'In general, avoiding emphasis on low-fat or low-carb and focusing on healthy foods … will up your chances of weight loss success,' said head researcher William Yang.
Control filler article (smoking)	**Even a cigarette a day is bad for your health** A person who habitually smokes just one cigarette a day is nine times as likely to die from lung cancer as a non-smoker, and even if he or she quits at age 50, still has a 44 per cent increased risk of premature death. These findings, from a large study in *JAMA Internal Medicine*, provide further evidence that even the lowest levels of exposure to tobacco smoke are unsafe. Researchers questioned more than 500 000 men and women about their lifetime smoking habits, and then questioned 290 215 of them again ten years later, when their average age was 71. They gathered data about age of smoking initiation, number of cigarettes per day and age at cessation, plus information about race, education level, body mass index, alcohol intake and physical activity. After controlling for other health factors, the researchers found that compared with non-smokers, those who smoked 1 to 10 cigarettes a day throughout their lives had a 50 per cent increased risk of cardiovascular disease and six times the risk of respiratory disease. Including arsenic, lead and tar, there are over 7000 chemicals in tobacco smoke. According to the Centers for Disease Control and Prevention, smoking leads to disease and disability and harms nearly every organ in the body. Each day, 3200 people younger than 18 years of age smoke their first cigarette. Another 2100 young adults transition from occasional smokers to daily cigarette smokers. But even a cigarette a day can have detrimental health effects. 'There is a growing number of people only smoking a few cigarettes a day, and that's the main reason for performing this study,' said the senior author, Neal D. Freedman, an epidemiologist with the National Cancer Institute. 'Even these people benefit substantially from quitting smoking.'
Control filler article (skin cancer)	**Sun safety: how to avoid skin cancer** While sun exposure is important for many reasons – for example, production of vitamin D, your mood and healthy circadian rhythms – our time in the sun can also be associated with a significant health risk: cancer. According to the National Institutes of Health, the most common type of cancer in the US is skin cancer, and the two most common types are basal cell cancer and squamous cell cancer. Both of these are serious and require prompt treatment, but survival rates are quite good with therapy. However, melanoma – the deadliest form of skin cancer – has a far worse prognosis. A major review of 960 studies, published in the *European Journal of Cancer*, found that there is a clear relationship between reported sunburn and overall melanoma risk. Dr Julia Newton-Bishop, lead author of the study, said that in particular, 'individuals with sun-sensitive skin types are at increased risk of melanoma, and advice to them should be to avoid sunburn and behaviours associated with sunburn such as sunbathing.' It's estimated that almost 10 000 people in the US are diagnosed with skin cancer every day. It's important to note that 75 per cent of all skin cancer deaths are from malignant melanoma. It's most commonly found among fair-skinned people, but people of all skin types can get it. There are pre-cancerous abnormalities from sun exposure that your dermatologist can detect during routine screening, and it's important to get regular skin exams. One of the most common pre-cancerous skin lesions is a patch of thick, scaly or crusty skin. Since exposure to ultraviolet light from the sun is a major risk factor for melanoma and all other skin cancers and pre-cancers, wearing sunscreen should be top of the list as a prevention aid.

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Appendix 2
Potential moderators and post hoc analysis of potential moderators

Self-reported exposure to contradictory information regarding carbohydrates v. *fats*
We accounted for previous exposure to contradictory health information about carbohydrates and dietary fats in the media. We used a validated measure of media exposure to contradictory health information[6] to ask participants: 'How much conflicting information regarding carbohydrates versus fats have you seen over the past year in the media – including newspapers, TV, radio, magazines and the Internet?' A response scale of 'a lot' (= 1), 'some' (= 2), 'a little' (= 3) and 'not at all' (= 4) was used (range = 1–4; mean = 2·17, SD = 0·89).

Nutrition knowledge
Five questions measuring nutrition knowledge were derived from the validated General Nutrition Knowledge Questionnaire[44]. For example, questions included: 'How many servings of fruit and vegetables per day do experts advise people to eat as a minimum (One serving could be, for example, an apple or a handful of chopped carrots)?' and 'How many times per week do experts recommend that people eat fish that are low in mercury (e.g. salmon and shellfish)?' Every correct answer was given a score of 1 and incorrect answers a score of 0. Each participant's scores were summed to derive the total nutrition knowledge questionnaire score (range = 1–11; mean = 9·1, SD = 1·79).

Attention to nutrition topics in the media
We used an existing measure[6] to ask participants: 'How much attention do you pay to information about nutrition topics that you hear from the media?' Response options ranged from 'a lot' (= 1) to 'not at all' (= 4) (range = 1–4; mean = 2·55, SD = 1·09).

Attention to diet
We asked participants four questions regarding attention to dietary components on a five-point scale ranging from 'strongly disagree' to 'strongly agree'. These questions included: 'I carefully pay attention to how many carbohydrates I consume'; 'I carefully pay attention to how much dietary fat I consume'; 'I carefully pay attention to how many calories I consume'; and 'I carefully pay attention to how much sugar I consume'. These four items were scaled and showed high internal consistency, and were thus combined into one variable named 'attention to diet' (Cronbach's α = 0·81; range = 1–5; mean = 3·00, SD = 0·97).

Levels of physical activity
We gauged levels of physical activity by asking: 'In a typical week, how many days do you do any physical activity or exercise of at least moderate intensity, such as brisk walking, bicycling at a regular pace and swimming at a regular pace?' This measure was derived from the Health Information National Trends Survey[45]. Response options ranged from 0 d to 7 d (range = 1–8; mean = 4·08, SD = 2·03).

Past diet types
We asked participants: 'Have you used any of the following diets in the past 12 months?' with response options including 'low-carb', 'low-fat' and 'other diet type (please specify).' See Table 2 for descriptive statistics.