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Research Paper

An Observational Study of Thermometer Use by Consumers When Preparing Ground Turkey Patties

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ABSTRACT

The purpose of this study was to test the effectiveness of an intervention for consumer thermometer use by using a randomized experimental design and direct observation of meal preparation. The study was conducted in test kitchen facilities in two locations in North Carolina (one urban and one rural). Cameras recorded participants' actions at various locations throughout the kitchen and recorded the meal preparation from beginning to end. Before preparing the meal, a randomized treatment group watched a 3-min U.S. Department of Agriculture (USDA) food safety video "The Importance of Cooking to a Safe Internal Temperature and How to Use a Food Thermometer." Participants in the control and treatment groups were observed while cooking turkey burgers and preparing a salad to determine whether a thermometer was used to check the doneness of the turkey patties. Following meal preparation, all participants responded to a postobservation interview about food handling behaviors. Treatment group participants were also asked about the intervention. A total of 383 people participated in the study (201 in the control group and 182 in the treatment group). Participants who viewed the video were twice as likely to use a thermometer to check the doneness of the turkey patties compared with the participants who were not exposed to the video (75 versus 34%) and twice as likely to place the thermometer in the correct location (52 versus 23%). Sixty-seven percent of participants who watched the video reported that it influenced their behavior in the kitchen. This study demonstrates the importance of timing and framing of a behavioral intervention for thermometer use and highlights considerations for the development of additional messages (e.g., proper insertion).

HIGHLIGHTS

- Participants who viewed a food safety video were twice as likely to use a thermometer.
- Participants who viewed the video were more likely to place thermometer correctly.
- Most (67%) of the participants who watched the video said it influenced their behavior.

Key words: Consumers; Meal preparation; Observation; Test kitchen; Thermometer use

The results of a nationally representative survey indicated that 67% of consumers own a food thermometer but only 19% use one to check doneness when preparing chicken parts and 10% use one for hamburgers *(20)*. Another national survey on raw poultry handling practices found that among the 62% of consumers who reported owning a food thermometer, consumers were more likely to check the doneness of larger cuts of poultry (56 to 73%) than to check smaller cuts (12 to 26%) *(19)*. In a 2016 survey, consumers reported using a food thermometer 30% of the time to check the doneness of meat and poultry items but reported cooking their meat and poultry to the required temperature only 66% of the time *(15)*.

Consumers may not always use meat safety steps recommended by the U.S. Department of Agriculture (USDA), including proper insertion of a thermometer, to determine doneness and instead rely on sensory or subjective indicators. Subjective indicators that are not science based, including visual cues such as the color of meat, are unreliable for gauging whether the product has reached a temperature necessary to kill pathogens of concern *(13, 14)*. Substantial differences can occur between the heating surface and product endpoint temperatures because the center of a hamburger patty is not cooked directly by the pan heat but rather by the heat at the steam-water interface, which is inside the surface of the patty *(17)*. When using an instant-read thermometer, the thermometer probe must be inserted into the side of the food to ensure that the probe is contacting the center (cold spot) of the

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food. Observational research has revealed that many consumers (39 to 78%) rely on visual indicators such as color instead of using a meat thermometer to determine doneness *(5, 18, 23, 24)*.

In the context of food safety, consumers often have optimism bias, which is an underestimation of risk, and occurs when attitudes about perceived risk of food poisoning are inconsistent with safe food handling behaviors *(26)*. Kennedy et al. *(18)* found that study participants attributed a high level of importance to checking that beef burger patties and poultry are sufficiently cooked but failed to use the methods participants stated were important, resulting in 13 to 35% of samples (depending on the product) testing positive for microbial contaminants, suggesting that the foods were undercooked.

In a 2019 review of consumer knowledge, attitudes, and behaviors, Feng and Bruhn *(9)* found 15 studies (5 focused on food workers and 10 focused on consumers) that included educational interventions for thermometer use. These interventions were delivered by media campaigns, lesson plans, workshops, and comic books. In the majority of the studies, based on measuring knowledge and self-reported behaviors a significant increase in thermometer use occurred after an intervention *(9)*. However, self-reported data collected through surveys of consumers' food safety practices may be unreliable because consumers tend to overreport their behavior (e.g., simply rinsing their hands instead of washing with soap and water for 20 s as recommended) *(25)*. To overcome problems of interpretation and verification of self-reported data, direct observation has been used to collect data on consumer food safety behaviors *(12)*. Several researchers have used direct observation to evaluate consumers' food safety practices and have compared their results with those obtained through questionnaires collecting self-reported behaviors *(1, 5, 16, 24, 29)*.

The purpose of the present study was to use direct observation to determine the effect of a USDA educational video on the rate of thermometer use among participants cooking ground turkey patties. We predicted that participants in the intervention group (exposed to the video) would have a higher rate of correct thermometer use and a higher rate of cooking turkey patties to the proper internal temperature of 165°F than would the control group (not exposed to the video).

MATERIALS AND METHODS

Research design. The experiment was designed with participants randomly assigned to either a treatment group that was exposed to a video intervention or a control group that was not exposed to the video. We calculated the sample size to determine the minimum number of participants needed to provide a level of statistical confidence in the outcome of the meal preparation experiment. Based on this analysis, the desired sample size was 400 (200 per group) to provide 80% statistical power and a 95% level of confidence. The sample size calculation took into consideration the anticipated base rate for thermometer use, the anticipated distributional characteristics of a dichotomous outcome, and a feasible research design given the logistical constraints of conducting test kitchen observations in one location. After enrolling in the study, participants were randomly assigned to the treatment group or the control group, with the goal of 200 participants in each group. The North Carolina State University Institutional Review Board office approved the study protocol (protocol 10599).

Recruitment of participants. Convenience sampling was used to recruit participants that reflected demographic characteristics of the U.S. population based on the most recent (2014) census data. Participants were recruited through social media posts such as Facebook, Craigslist, and Instagram, e-mails to Expanded Food and Nutrition Education Program participants to reach low-income consumers, and flyers about the study distributed to approximately 150 locations (e.g., grocery stores, community centers, libraries, churches, and food pantries) within driving distances of test kitchens. Because of the challenges associated with recruiting people with a high school education or less, adults $\geq$55 years of age, and Hispanic people, outbound recruiting and screening for eligibility of individuals with these desired demographic traits was done by market research firms.

Screening criteria. Recruitment materials directed prospective participants to call or e-mail the study team to be screened for eligibility or to go to a Web link that hosted the screening questionnaire. Participants had to meet specific inclusion criteria: age $\geq$18 years, speak English or Spanish as a first language, do all or most of the grocery shopping in the household, prepare meals at home at least four times per week, and having cooked raw meat or poultry at home in the past 3 months. The exclusion criteria were having ever received any type of food safety training such as ServSafe, having ever been employed as a food worker or manager in a food preparation setting, and being vegetarian or vegan.

Participants were told that the purpose of the study was to test recipes and that participation would involve a short interview at the end of the meal preparation session. Appointments were scheduled during work hours, evenings, and weekends to allow for a broader participant pool. A confirmation e-mail or letter was sent, and a reminder call was made 1 or 2 days before the appointment. Participants were informed that they would receive a $75 gift card and a gift (food thermometer) for taking part in the 2-h study.

Study procedures. Data were collected in six test kitchen facilities in two locations in North Carolina (one urban and one rural) from July to December 2017. Scheduled participants were greeted by a study team member upon arrival at the test kitchen and instructed to read and sign an informed consent form if they agreed to take part in the study. Each test kitchen had four to six cameras that recorded participants' actions at various locations throughout the kitchen and recorded the meal preparation from beginning to end.

Participants in the treatment group viewed the USDA video on thermometer use (described below) before beginning the meal preparation. Initially, all participants were told that the purpose of the study was recipe testing. Consistent with the approach used in other observation studies, participants were informed of the real purpose of the study after the meal preparation session and were told why it was important from a scientific perspective to inform them after the study was complete *(6, 7)*. After being informed of the study's true purpose, participants could choose to opt out of the study and have their data deleted. No participants chose to opt out of the study.

Participants were given a double-sided laminated recipe card with a chef's salad recipe on one side and a turkey burger recipe with a lettuce and tomato garnish on the other side of the card and instructed to prepare the foods as they would at home. Participants were provided with all of the necessary ingredients, and items requiring refrigeration were stored in the refrigerator. The two turkey patties were preformed and packaged on a foam tray wrapped in plastic. Participants were not told which item to prepare first (burger versus salad). A study team member pointed out cabinets containing utensils, dishes, pans, and a clamshell grill, and the cabinets were labeled accordingly. The turkey burger recipe stated (i) season the burger patties with salt, pepper, garlic powder, and onion powder on both sides; (ii) cook the patties at medium-high heat to your desired level of doneness; and (iii) assemble cooked burgers with sliced tomato and sliced onion. The chef's salad recipe stated (i) cut lettuce into bite-size pieces; (ii) cut ham into matchstick-size pieces; (iii) dice tomato; (iv) mix all ingredients together; and (v) serve with dressing on the side.

Intervention. Treatment group participants watched the USDA video "The Importance of Cooking to a Safe Internal Temperature and How to Use a Food Thermometer" (https://www.youtube.com/watch?v=-2KkV2yFiN0) before the meal preparation session. The video focused on the following messages: visual cues are not sufficient to assess safety, a proper internal temperature is needed to determine doneness, the only way to ensure safety is to use a food thermometer, and the food thermometer must be cleaned with soap and water after use (the cleaning thermometer step was not observed during this study). The video showed cooking of various meat, poultry, and egg products, including the cooking of ground beef patties. The burger patty portion of the video showed flipping of the patties and demonstrated inserting the thermometer from the side. The poultry portion of the video indicated that all poultry should be cooked to 165°F.

Coding and analysis. The project team viewed videos collected during the preliminary pilot study and through a series of iterations defined how coding would occur. Incorrect and inconsistent coding situations were discussed by the project team. Trained coders viewed each video to record attempted thermometer use: whether the thermometer was used, correct placement of thermometer, number of patties checked for doneness, number of patties flipped, number of flips per patty, and methods used to determine doneness in addition to or instead of using a thermometer. A thermometer attempt was defined as a participant using the food thermometer to check the doneness of one or both turkey patties. The number of total attempts was defined as the total number of times the participant inserted the thermometer into the turkey patty to check doneness. Correct thermometer use was defined as placement of the thermometer into the side of the turkey patty to reach the center to determine temperature. Incorrect thermometer use was defined as inserting the thermometer into the patty anywhere that did not result in reaching the center, cooking to a temperature of less than 165°F (as recorded by the data logger), or using an indicator other than temperature to determine doneness. For other methods of determining doneness, color was defined as the method of doneness when the participant visually inspected the patty (either looking at the outside or cutting into the patty and looking at the inside color). Touch was defined as the method of doneness when the participant used a utensil or finger to push on the patty to assess firmness. In some cases, participants used more than one method to determine doneness. Whether the thermometer was used on one or two patties was coded because the USDA recommends that consumers measure the temperature of each patty because the temperature may differ between patties, as was mentioned in the video. Although not mentioned in the video because of run-time considerations, the number of flips per patty was coded because flipping can lead to more even heating of the product *(21, 30)*. A flip for a patty was defined as inverting the patty so that the side touching the pan was changed to the opposite side.

The thermometer available in the test kitchen was specially constructed for this project. The device was a data logger (HOBO UX100 series, Onset Computer Corporation, Bourne, MA) placed inside the housing of a thermometer constructed to look like a commercially available thermometer for consumer use. When participants used the thermometer–data logger, the logger recorded the temperature of the probe tip every second. The data were imported using HOBOware software (Onset Computer Corp.).

The screening questionnaire included multiple-choice questions to collect self-reported information on thermometer ownership (participants indicated ownership of various kitchen tools, including a food thermometer) and methods used to determine doneness (thermometer, color, texture, or a combination of methods).

The postobservation interview was conducted to collect information on how the video influenced the behavior of participants in the treatment group. Participants were asked what they considered the key takeaway points of the video, whether watching the video influenced their action and how, whether they thought the video would influence their behavior in the future, and whether they related to the people and situations shown in the video. Responses were classified as "yes" or "no," and additional information provided during answers was grouped to identify common themes.

The coded data on behaviors and thermometer temperatures were analyzed with Excel 365 (Microsoft, Redmond, WA). The significance of the difference between the control and treatment groups for each outcome was determined by calculating P values for a chi-square test for dichotomous variables and for a repeated-measures analysis of variance for continuous variables. Differences were considered significant at $P < 0.05$.

RESULTS

Study sample. The study sample size was 383 participants: 182 in the treatment group and 201 in the control group. This sample size is slightly less than the desired number (400) because of recruiting challenges and kitchen availability but was sufficient for the purposes of this study. Table 1 lists the characteristics of the study participants. The demographic characteristics of the participants differed from the 2014 U.S. census data targets primarily in terms of education level and family status (i.e., whether there were children in the household). Only 24% of the study participants had less than a high school degree, a high school diploma, or a general education diploma (GED) compared with the census target of 42%. This difference was a result of the higher educational level of the local population, initial classification of technical or vocational training in the "some college" category, and higher study exclusion rates due to food safety training and food industry experience for the population with less than a high school degree, high school diploma, or GED. The U.S. census data target for a nonfamily household (i.e., no children) was

TABLE 1. *Sample characteristics of participants in control and treatment groups*

Characteristic	% (no.) of participants		
	Total ($n = 383$)	Control ($n = 201$)	Treatment ($n = 182$)[a]
Race			
Caucasian or White	66 (253)	71 (142)	61 (111)*
Black or African American	30 (117)	26 (54)	35 (63)*
Other[b]	3 (13)	3 (5)	4 (8)
Ethnicity			
Not Hispanic or Latino	86 (330)	86 (173)	86 (157)
Hispanic or Latino	14 (53)	14 (28)	14 (25)
Age (yr)			
18–34	35 (134)	36 (71)	34 (61)
35–54	40 (154)	37 (73)	44 (81)
≥55	25 (95)	28 (55)	22 (40)
Education			
Less than high school, a high school diploma, or a GED[c]	24 (93)	25 (49)	24 (44)
Some college	26 (99)	23 (47)	29 (52)
Bachelor's degree	31 (119)	33 (65)	30 (54)
Graduate or professional degree	19 (72)	20 (40)	17 (32)
Have child ≤17 yr old living in household	46 (176)	46 (91)	46 (85)
Have at-risk individual living in household[d]	34 (130)	40 (80)	27 (50)*
Self-reported thermometer ownership	62 (238)	61 (123)	63 (115)

[a] * $P \leq 0.05$ (chi-square test for significance of differences between the control and treatment groups for each characteristic).
[b] American Indian or Alaska Native, Asian, Native Hawaiian or other Pacific Islander, and two or more races.
[c] Toward the end of data collection, we revised the screening questionnaire to include people with technical or vocational training in this category.
[d] At-risk populations are people who are ≥60 years of age, children ≤5 years of age, pregnant women, people diagnosed with diabetes or kidney disease, and people diagnosed with a condition that weakens the immune system.

TABLE 2. *Observed behavior of participants in control (did not receive video intervention) and treatment (received video intervention) groups*

Behavior	Control	Treatment[a]
% (no.) of participants that attempted thermometer use[b]	34 (69)	75 (137)*
No. of total attempts (multiple attempts per observation counted)	168	322*
% (no.) of correct placements among total attempts[c]	23 (38)	52 (168)*
% (no.) of participants among thermometer users,[d] number of patties checked		
1	27 (16)	18 (23)
2	73 (44)	82 (105)*
% (no.) of participants, number of flips per patty[e]		
None (used clamshell grill or baked in oven)	3 (12)	3 (9)
1	16 (61)	15 (50)
2	17 (64)	20 (66)
≥3	63 (237)	62 (201)
Mean no. of flips per patty	2.4	2.4

[a] Treatment group participants watched the FSIS video "The Importance of Cooking to a Safe Internal Temperature and How to Use a Food Thermometer" before meal preparation. The video focused on determining meat doneness by using a food thermometer. * $P \leq 0.05$ (chi-square test for significance of differences between the control and treatment groups for each behavior).
[b] An attempt is defined as a participant using a food thermometer to check the doneness of one or both turkey patties.
[c] Correct placement is defined as a participant inserting the thermometer into the side of the turkey patty to reach the center and held for at least 5 s before the temperature is determined.
[d] Usable data: $n = 60$ for control; $n = 120$ for treatment.
[e] Usable data: 374 patties for control; 326 patties for treatment.

34%, but 54% of the study participants were in this category. The difference for our study population was likely due to a higher percentage of participants (35%) in the age category of 18 to 34 years. More highly educated respondents were recruited and scheduled first, which made it more difficult to recruit people from other target demographic groups (e.g., high school only, Hispanic, and ≥55 years of age), resulting in the need for outbound recruiting. Although the U.S. census targets were not met, the study sample was still considered diverse regarding the demographic characteristics of interest.

The participants in the treatment and control groups were similar in terms of ethnicity, age, education, and presence of a child in the household. The two groups were significantly different for the distribution of race ($P = 0.05$); the control group had a larger percentage of White participants (71 versus 61%) and a smaller percentage of Black participants (26 versus 35%) compared with the treatment group. Participants in the control group (40%) were significantly more likely than participants in the treatment group (27%) to have at least one individual in the household at risk for foodborne illness ($P = 0.04$).

Thermometer ownership and usage. Sixty-one percent of control group participants and 63% of treatment group participants reported owning a thermometer (Table 1), which aligns with the 2016 nationally representative survey conducted by the U.S. Food and Drug Administration in which 67% of respondents reported owning a food thermometer *(20)*. During the meal preparation session, control group participants used the thermometer to check doneness 34% of the time ($n = 69$), whereas treatment group participants used the thermometer 75% of the time ($n = 137$) ($P < 0.001$) (Table 2).

Thermometer placement. The treatment group participants were more likely than the control group partici-

TABLE 3. *Methods used to determine doneness for participants who did not use a food thermometer when cooking a turkey patty*

Method	% (no.) of participants			
	Self-reported[a]		Observed[b]	
	Control	Treatment	Control	Treatment
Only color	26 (33)	32 (10)	4 (5)	16 (5)
Only touch (firmness or texture of patty)	5 (7)	5 (2)	46 (59)	29 (9)
Color and touch	70 (93)	71 (29)	25 (32)	42 (13)
Unobservable method[c]	NA	NA	24 (31)	10 (3)*

[a] Self-reported data were collected with a screening questionnaire before the meal preparation session. NA, not applicable.
[b] Number of observations with usable data: $n = 122$ for control; $n = 30$ for treatment. * $P \leq 0.05$ (chi-square test for significance of differences between the control and treatment groups for each method).
[c] Unobservable methods include cooking time and looking at the outside color (without touching the patty).

pants to insert the thermometer into the side of the patty, which is the recommended practice. Participants may have cooked the patty further after the initial temperature check, but subsequent temperature and whether further cooking occurred was not recorded. Substantial differences between heating surface and product endpoint temperatures can occur because the center of the meat patty is not cooked directly by the pan heat but rather by the heat at the steam-water interface, which is inside the surface of the hamburger *(17)*. Berry and Bigner-George *(2)* found substantial temperature variability within beef patties due to differences in thickness.

Number of patties checked with thermometer. Among thermometer users, treatment group participants were significantly more likely than control group participants to check the temperature of both patties (82 versus 73%; $P < 0.001$), which is the recommended practice (Table 2).

Number of flips per patty. Two factors that can affect even heating are the state of the product before cooking (e.g., frozen, refrigerated, or room temperature) and the number of times during cooking the product is turned over (i.e., flipped) *(2, 10, 21)*. The side of the patty that is farther away from the heat of the grill or the bottom of the pan can differ from the contact surface by as much as 80°F. Yang et al. *(30)* and Luchansky et al. *(21)* evaluated the impact of flipping meat while cooking and found that more than three flips of nonintact beef resulted in the highest reduction of *Escherichia coli* O157:H7. In the present study, about one-third of participants in the treatment and control groups flipped the patties fewer than three times (Table 2).

Endpoint temperatures. Of participants who used the thermometer and for whom temperature data were available, in 54% of control observations and 73% of treatment observations the patties reaching the instant temperature of 165°F ($P = 0.008$). About 20% (27 of 137) of the endpoint temperature recordings were <150°F, and the lowest recorded endpoint temperature was 65°F. Of the 39 participants with recorded temperatures <165°F, 10 of 17 control and 15 of 22 treatment participants continued to cook patties after taking their final temperature reading and did not use the probe again with either patty to confirm a safe final temperature. These participants could have used a subjective measure (such as cutting open) to determine doneness after initially using the thermometer to determine doneness.

Use of other methods to determine doneness. A total of 45% ($n = 172$) of participants used another method to determine doneness instead of using the thermometer. Among participants who did not use the thermometer to determine doneness and for whom usable data were available ($n = 152$), 46% in the control group and 29% in the treatment group relied on the firmness or texture of the patty to determine doneness, and 4% in the control group and 16% in the treatment group relied on patty color (inside and/or outside) (Table 3). Twenty-five percent of participants in the control group and 42% of participants in the treatment group were observed using more than one method—firmness and color of the patty—to determine doneness. These differences were not statistically significant.

Among participants who used the food thermometer and for whom useable data were available ($n = 178$), 38% in the control group and 42% in the treatment group appeared to rely solely on the food thermometer (Table 4). However, self-reported rates from the screening questionnaire for thermometer use as the sole method for determining doneness of burger patties (did not specify ground beef versus turkey) were considerably lower: 6% for the control group and 5% for the treatment group. One possible explanation for the difference between the observed and self-reported rates is that participants cooked turkey patties, which participants may have been less familiar with. It is also possible that in the screening questionnaire, participants considered visual checks throughout the cooking process as part of their response (thereby decreasing "thermometer only" responses). From the postobservation interviews, many participants mentioned feeling less comfortable determining doneness from color and/or texture with ground turkey patties than with patties made from ground beef. This lack of experience or comfort with cooking turkey patties could be one reason for the higher

TABLE 4. *Methods used to determine doneness by participants in the observational study who used the food thermometer to determine doneness of a turkey patty*

Method	% (no.) of participants[a]			
	Self-reported		Observed	
	Control	Treatment	Control	Treatment
Only thermometer	6 (4)	5 (7)	38 (23)	42 (52)
Only color	22 (13)	26 (36)	0	0
Only touch (firmness or texture of patty)	1 (1)	2 (3)	0	0
More than one method	30 (50)	68 (97)	62 (37)	58 (76)
Thermometer and color			70 (26)	79 (60)
Thermometer and touch			3 (1)	5 (4)
Thermometer, color, and touch			27 (10)	16 (12)

[a] Number of participants with usable data: 178; data were not available for 28 participants. No significant differences were found between the control and treatment groups for each method (chi-square test).

rate of thermometer use as the sole method for determining doneness. The most commonly observed methods to determine doneness among thermometer users using multiple methods were thermometer use and the color of the patty (70% of control and 79% of treatment). No significant differences between groups were observed.

Response to USDA video on thermometer use among treatment group participants. Postobservation interviews included collecting information about response to the USDA video on thermometer use viewed by participants in the treatment group before the meal preparation session. Table 5 lists the questions and common participant responses. Approximately two-thirds of participants reported that watching the video influenced their cooking behavior while participating in the study; 61% of these respondents reported using the thermometer to check doneness as a result of the video, 9% said they learned about a specific safe temperature for poultry, and 8% said they learned about the correct placement of a thermometer. However, 33% of participants reported that the video did not influence their cooking behavior in the kitchen even though 55% of these participants reported that they use a thermometer on a regular basis in their home kitchen. The most frequently cited reason (8%) for not using a thermometer in the test kitchen was participants' own experiences and confidence with other methods of determining doneness.

DISCUSSION

Participants exposed to the video (treatment group) were twice as likely to use a thermometer to check the doneness of the turkey patties compared with the control participants, who were not exposed to the video (75 versus 34%), suggesting an intervention effect. Among thermometer users, treatment group participants were more likely to place the thermometer in the correct location (52 versus 23% of attempts for thermometer placements), also suggesting an intervention effect.

In the interviews following the meal preparation session, 33% of treatment group participants self-reported that the video did not influence their cooking behavior in the kitchen; however, 55% of these participants reported that they use a thermometer on a regular basis in their home kitchen, and the video simply reaffirmed this practice. Among total attempts to use the thermometer, 42% were correct with regard to proper placement (23% of control group attempts and 52% of treatment group attempts), which highlights the need for emphasis in education materials on both thermometer use and proper placement. The higher rate of proper placement by the treatment group compared with the control group suggests that the information in the video on proper placement was useful to some participants.

Subjective indicators of meat patty doneness were commonly used by the participants in our study (45% in total). In previous studies of food safety practices on popular cooking shows, subjective indicators (e.g., color and touch) also are more commonly used than thermometers to determine doneness *(3, 22, 23, 28)*. In a study of cooking instructions in egg-based recipes, the recipes specified a variety of indicators not related to temperature, most frequently time *(11)*. Relying on subjective indicators is a riskier way to determine doneness because some indicators, such as the color of poultry and other meat and of their juices, are not correlated with safe internal cooking temperatures *(13, 27)*. Some sources of cooking information match gradations (rare, medium rare, medium, medium well, and well done) to internal cooking temperatures and visual descriptions, but no peer-reviewed scientific evidence supports these temperature gradations. Educational materials on thermometer use should continue to emphasize that subjective indicators of doneness are not reliable and that use of a food thermometer is the only way to ensure that foods are cooked to a safe internal temperature. The USDA video mentioned that indicators other than temperature should not be used to test doneness. However, the video could be improved by adding more explicit information to emphasize the risk, such as the direct statement that reliance on other indicators of doneness instead of a thermometer puts meal preparers and their families at a higher risk of foodborne illness. Focusing on the negative (i.e., the risk of foodborne illness) allows the communication to emphasize

TABLE 5. *Participants' responses to a USDA video on thermometer use viewed immediately before the meal preparation experiment*[a]

Question	% (no.) of participants	
	Yes	No
Did the video influence your action in the kitchen today? Why or why not?[b]	67 (121)	33 (60)
Used thermometer to check doneness of patties	61 (74)	0
Comfortable with cooking experience and other methods of determining doneness	0	8 (5)
Obtained new information about temperatures	9 (11)	0
Learned about correct placement of thermometer	8 (10)	0
Reinforced existing thermometer use, normally use a thermometer at home	4 (5)	55 (33)
Other	7 (8)	8 (5)
Not answered, answer not clear, answer not relevant	11 (13)	28 (17)
Total	100 (121)	100 (60)
Do you think the video will influence how you cook at home in the future? Why or why not?[c]	67 (115)	33 (61)
Used thermometer to check doneness of patties	57 (66)	3 (2)
Comfortable with cooking experience and other methods of determining doneness	0	18 (11)
Obtained new information about temperatures	12 (14)	0
Learned about correct placement of thermometer	11 (13)	2 (1)
Reinforced existing thermometer use, normally use a thermometer at home	3 (3)	40 (24)
Other	2 (2)	8 (5)
Not answered, answer not clear, answer not relevant	15 (17)	30 (18)
Total	100 (115)	100 (61)
Did you relate to the people or situations in the video? Why or why not?[d]	83 (148)	17 (31)
Similar, believable people	16 (24)	0
Prepare similar food	34 (51)	2 (1)
Cooking at home for family, others	18 (26)	13 (4)
Thermometer use	7 (10)	3 (1)
Family size similar, participant cooks for self or one other person	5 (8)	50 (15)
Other	7 (10)	20 (6)
Not answered, answer not clear, answer not relevant	13 (19)	27 (8)
Total	100 (148)	100 (31)

[a] The treatment group participants watched the USDA video "The Importance of Cooking to a Safe Internal Temperature and How to Use a Food Thermometer," which focused on determining meat doneness by using a food thermometer.
[b] Number of participants with usable data: 181.
[c] Number of participants with usable data: 176.
[d] Number of participants with usable data: 179.

what exactly is meant by a subjective indicator and why these indicators are not reliable. When developing messages for cooking patties specifically, emphasizing the need to flip patties multiple times while cooking and to check the temperature of multiple patties should also be considered. Future research regarding messaging on thermometer use should focus on (i) learning more about consumer attitudes regarding barriers to thermometer use and how consumers could be motivated to overcome those barriers, (ii) promoting public trust and credible information sources, and (iii) incorporating everyday context into food safety education communications.

Limitations to this study included use of convenience sampling (instead of probability-based sampling), which meant that the conclusions could not be generalized to the population of U.S. meal preparers. However, the use of quotas yielded a diverse study sample with regard to demographic characteristics. External validity also was a concern because only certain types of people may have chosen to take part in the study (e.g., those interested in cooking), and they may differ from people who did not wish to participate in ways that could potentially limit the generalizability of the results. By using an experimental design with random assignment to study conditions, we were able to obtain an unbiased assessment of whether participants in the treatment group adhered more closely to recommended food safety practices after intervention exposure than did participants in the control group.

As with any study that involves observed behavior, participants may have subconsciously altered their usual behavior because they were being observed (the Hawthorne effect), although many participants did not follow recommended practices *(4)*. Exposing the treatment group participants to the video immediately before the meal preparation session likely resulted in a recency effect and is not a completely realistic representation of when consumers are likely to receive food safety messaging, which is another limitation of the study. However, this approach was the only way to ensure that all participants watched the video and indicates that the timeliness of the message is important. Delivering the message to consumers close to a decision-making time plays an important role in consumer adherence to recommended food safety practices. The challenge lies in how to ensure messaging reaches consumers at that critical

time. One approach is to partner with grocery stores or other retailers that track consumer purchases to provide a reminder through an alert on a mobile device to use a thermometer at mealtime.

This study is the first of a suite of studies that are being conducted focusing specifically on food handling practices of consumers and the resulting microbiological impacts throughout the kitchen. This focus will continue to provide insights into the effectiveness of current food safety messages and gaps in understanding. Future research directions could include examination of the impact of interventions on other food handling behaviors (e.g., hand washing, cleaning and sanitizing, and separating raw and ready-to-eat foods) and on the attitudes and motivators surrounding these behaviors. Consumers may be more receptive to risk communication and messages at teachable moments, such as following publicized outbreaks of foodborne illness related to undercooking of raw poultry or other meats.

In conclusion, the effectiveness of the video intervention for changing consumer behavior highlights the opportunity for a social marketing campaign related to thermometer use. A coordinated effort is needed and must include more than outreach based on posted videos alone *(8)*. Communicator implementation of all message options (written, verbal, and visual) will provide the most robust food safety communications, thus increasing the likelihood of changing consumer behavior.

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