Development of an Objective Measure of Knowledge of Factory Farming

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Abstract

Knowledge of human uses of animals is an important, but understudied, aspect of how humans treat animals. We developed a measure of one kind of knowledge of human uses of animals—knowledge of factory farming. Studies 1 (*N* = 270) and 2 (*N* = 270) tested an initial battery of objective, true or false statements about factory farming using Item Response Theory. Studies 3 (*N* = 241) and 4 (*N* = 278) provided evidence that responses to a 10-item Knowledge of Factory Farming Scale predicted a reduction in consumption of animal products (*rs* = -.17- -.27) and approval of political actions aimed at factory farming (*rs* = .2 - .24). Path models from Studies 3 and 4 suggested that different kinds of knowledge uniquely predicted different outcomes. The Knowledge of Factory Farming scale was a unique predictor of approval of political actions concerning factory farmed animals but not animal consumption. Knowledge of Animals Used as Food predicting animal consumption but not political actions concerning farmed animals. These results the highlight that different kinds of knowledge can be relevant for different animal related outcomes.

Development of an Objective Measure of Knowledge of Factory Farming

Do you think the following statement is true or false? In 2019, less than 4,500,000,000 factory-farmed animals were killed in the United States for food.[1]

The correct answer to that statement involves an objective fact about the world—the statement is either true or false. Our primary goal is to provide evidence that eliciting responses from such statements can be used to measure objective knowledge of factory farming. We demonstrate that measuring knowledge of factory farming can help generate better predictive models for animal-related decisions. In four studies, we developed a 10-item objective measure of knowledge of factory farming. We demonstrate the unique value of the measure by showing that knowledge of factory farming is sometimes different from related values, attitudes, and knowledge. Moreover, different kinds of knowledge were associated with different outcomes, with Knowledge of Animals Used as Food uniquely predicting animal consumption, but Knowledge of Factory Farming uniquely predicting approval of political actions aimed at factory farmed animals. These results suggest the utility of measuring knowledge of factory farming, especially in cases where interventions are aimed at increasing knowledge of the conditions of factory farmed animals. Additionally, these results highlight that sometimes different kinds of knowledge are relevant for different outcomes, and interventions should be clear about (and measure) the relevant kinds of knowledge change. We close by discussing when using the Knowledge of Factory Farming Scale is likely to be beneficial.

Knowledge, Values, and Factory Farming

For the most part, research about the psychological factors predicting ways humans relate to non-human animals have focused on attitudes, values, and demographics (for reviews, see A. Feltz and Feltz (2021); Graca, Godinho, and Truninger (2019); Ruby (2012)). A wide variety of attitudes, values, and demographics have been associated with increased tendencies to use animals for human purposes (e.g., for food. See, Graca, Calheiros, and Oliveria (2015, 2016); Herzog (2007); Herzog, Betchart, and Pittman (1991); T. Lund, McKeegan, Cribbin, and Sandoe

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[1] The correct answer to this question is 'false'. According to some estimates, the number of factory farmed *land* animals killed in 2019 is at least twice as high at 9 billion https://www.humanesociety.org/all-our-fights/protect-farm-animals.

(2016); T. B. Lund, Kondrup, and Sandoe (2019); Rothgerber (2013, 2014, 2015a, 2015b)). To illustrate, whether one thinks that eating animals is normal, necessary, nice, and natural positively predicts the amount of animal products one reports consuming (A. Feltz et al., in press; A. Feltz et al., submitted; S. Feltz & Feltz, 2019b; Piazza et al., 2015).

An emerging line of research has focused on what people *know* about animals used for human purposes. While we will not provide an exhaustive account of what knowledge is, on common conceptions, knowledge involves justified true belief, which is having beliefs that are true, and having good evidence of their truth (Kornblith, 2002).[2] Gaining knowledge has been central to human well-being and has often been sought after for its own sake. One reason why knowledge has been valued is that knowledge allows us to understand, predict, and control things in ways that not having knowledge does not. For example, if one knows about engines, then one should be able to predict and control how an engine behaves. If one doesn't know about engines, then one would not reliably be able to predict and control engines.

It stands to reason, then, that to the extent that one knows more about animals used for human purposes, the more likely it is that one will be able to predict and control the impact of one's behaviors on animals compared to one who knows less. One who knows more should also be more likely to integrate that knowledge along with their values and attitudes to behave in a way that is consistent with those values and attitudes (Baron, 2008; Weirich, 2004). For example, if one values the reduction of unnecessary suffering and knows that consuming animals often involves unnecessary suffering, one should be more inclined not to consume animals than one who lacks either those values or knowledge. Along these lines, knowledge is often thought to be one important (although not the only) factor in effectively actualizing one's values (Sturgis & Allum, 2004).

Some research suggests that knowledge and values concerning animals used for human purposes are associated with animal-related decisions. For example, those who know more about animals used as food consume fewer animal products than those who know less (A. Feltz et al., in press; S. Feltz & Feltz, 2019b). Other research suggests that changes in animal consumption

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[2] Any philosophically defensible definition of knowledge is contested. Here, we do not need a fully worked out analysis of knowledge in order to capture the key, relevant features of knowledge and to differentiate knowledge from attitudes and values.

are sometimes a product of an interaction between changes in what one knows about animals used as food and changes in values about using animals (A. Feltz et al., in press). These general results are consistent with the view that many people already have the core value that causing unnecessary suffering is wrong, and that for this value to affect their animal consumption, they need to gain the relevant knowledge of animals and animal farming practices (Engel, 2002).

No measure of objective knowledge of factory farming exists in the literature. We understand factory farming along the lines of the U.S. Environmental Protection Agency's definition of *concentrated animal feeding operations*. The U.S. Environmental Protection agency defines *animal feeding operations* as any operation that over a 12-month period has or will confine animals for a total of 45 days and for which vegetation required for natural feeding is not sustainable (40 CF § 122.23). *Concentrated* animal feeding operations are animal feeding operations that are defined in terms of how many animals they contain (e.g., a "medium" sized concentrated animal feeding operation can have between 300 and 699 mature dairy cattle) (40 CF § 122.23). In 2019, the National Pollutant Discharge Elimination System reported that there were 20,883 concentrated animal feeding operations in the United Sates (https://www.epa.gov/sites/production/files/2020-08/documents/cafo_status_report_2019.pdf).

The conditions in concentrated animal feeding operations are not natural for those animals (e.g., confined spaces, artificial nutrition, over-crowding) and are a unique result of the industrialization of farms over the past 100 years. To help ensure the successful harvest of these animals, concentrated animal feeding operations often implement practices to help ensure the animals are harvestable (e.g., clipping the beaks of chickens; https://www.animallaw.info/article/detailed-discussion-concentrated-animal-feeding-operations). These practices almost always adversely affect animal welfare and health. While similar practices sometimes occur in smaller-scale farms, the practices almost always occur in concentrated animal feeding operations and on a much larger scale and scope than on smaller farms.

Recognizing the important role different kinds of knowledge can play in how humans treat and relate to animals, we set out to develop an instrument that measures knowledge of factory farming, where "factory farming" is meant to refer to concentrated animal feeding operations and the practices that are common in such operations. We used the following plan for developing the Knowledge of Factory Farming scale (pre-registrations for the studies are available at https://osf.io/ckmqs/, https://osf.io/3tkbz/, https://osf.io/5jfxy/, and https://osf.io/s8u4f/). First, we aimed to identify item-level properties using Item Response Theory techniques from an initial set of 38 true/false statements constructed in conjunction with experts about factory farming (Baker, 2017). Then, we attempted to provide initial evidence for some kinds of construct validity (i.e., convergent, discriminant, and criterion validities) (Cronbach & Meehl, 1955; Messick, 1995). Studies 1 and 2 tested an initial set of 38 true/false items concerning factory farming. Using Item Response Theory, we reduced the set to 10 items. Studies 3 and 4 provided evidence that responses to the 10-item scale predict attitudes and behaviors concerning human uses of animals. Studies 3 and 4 suggested that knowledge of animals used as food was a better predictor of animal consumption than knowledge of factory farming, but knowledge of factory farming was a better predictor of agreement with and approval of political actions concerning factory farmed animals.

Study 1

The focus of Study 1 was to estimate the properties of 38 candidate items to measure knowledge of factory farming. We anticipated that some of the items would not do a good job of estimating knowledge of factory farming and that there could be substantial overlap in the information that some items provide. Study 1 was the first in a planned series of studies where items in the knowledge scale would be selected for their desirable properties (e.g., discrimination and difficulty) and validated in subsequent studies.

Participants

Two hundred and seventy participants were recruited from Amazon's Mechanical Turk. For tasks involving responses to questionnaires, Amazon's Mechanical Turk is recognized as an acceptable and common way to recruit participants (Buhrmester, Kwang, & Gosling, 2011; Buhrmester, Talifar, & Gosling, 2018; Crump, McDonnell, & Gureckis, 2013; Mason & Suri, 2012; Paollacci, Chandler, & Ipeirotis, 2010; Rouse, 2015). For example, the results from numerous experiments with different sampling methods have been replicated in Mechanical Turk samples and Mechanical Turk has samples that are often more representative of the U.S. population than some other sampling techniques (e.g., compared to Universities' subjects pools) (A. Feltz & Cokely, 2019; A. Feltz & Cova, 2014; A. Feltz & May, 2017; Gosling, Vazire, Srivastava, & John, 2004; Heen, J., & Miethe, 2014). The mean age was 35.59 (SD = 11.57) and 157 (58%) were female.

Materials

Knowledge items were initially developed by the authors. After the initial set of items were created, the items were reviewed by two independent experts on the ethics and conditions of factory farming. Those experts suggested modifications to the items that were included in the final 38 items administered to participants (see Appendix A for the set of items and correct answers). In the instructions, participants were asked not to look up the answers online. Participants could respond that the statements were true, false, or they could indicate that they did not know. After responding to the 38 items, basic demographic information was gathered.

Results and Discussion

We first analyzed the items according to Item Response Theory.[3] Item Response Theory analyses allows estimating item-level properties. Two particularly important properties for Study 1 were identifying the items' difficulty and discrimination. Difficulty refers to how hard a question is to answer correctly. Discrimination refers to how well an item differentiates people at different knowledge levels (Baker, 2017). One can select items based on how difficult and discriminating items are. For our purposes, we wanted items that had a range of difficulties along with strong discrimination. Selecting items in this way would allow us to have a good chance to identify items that efficiently measure average knowledge of factory farming.

Item Response Theory analyses were conducted in R with the LTM package (Rizopoulos, 2006; Team, 2018). We used a 2-parameter model. The 2-parameter model estimates both an item's difficulty and how well the item discriminates (1-parameter models only estimate difficulty while holding discrimination constant across all items). Percent of correct answers and difficulty and discrimination for each item are reported in Table 1. Correct answers were coded as '1' and incorrect or "I don't know" answers were coded as '0'.

The 38 items displayed strong internal reliability (*Cronbach's alpha* = .88). While the entire instrument displayed strong internal reliability, the item-level analyses revealed some ways to improve and make more efficient the overall instrument. Items 3, 25, and 28 had low or negative discrimination, suggesting that those items could be excluded. Several items had redundant properties with other items, suggesting that no unique information was being contributed to the scale by these items. For redundancy, items that had similar difficulty were

[3] IRT models do not yet have widely accepted power recommendations, However, some lower bound estimates place the minimum sample size of 200 for reliable estimates (Baker, 2017).

identified and then the item with higher discrimination was selected to be retained. Using this method, items 8, 9, 12, 13, 15, 17, 19, 22, 23, 24, 26, 34, and 36 were omitted from subsequent studies. Finally, items 2 and 21 were very easy, therefore not likely to be useful in estimating average knowledge of factory farming. These two items were also eliminated.

Study 2

Study 1 identified 20 items that had the desired item-level properties. Study 2 was designed to replicate the results of Study 1 on a new sample using the 20 items identified in Study 1, and if necessary, to provide evidence for further modifications to the Knowledge of Factory Farming Scale.

Participants

For studies 2-4, qualifications were assigned inside of Amazon's Mechanical Turk to each participant. These qualifications made it so no participant could take part in any subsequent study. Given these restrictions, two hundred and seventy participants were recruited from Amazon's Mechanical Turk. The mean age was 35.02, *SD* = 10.7 and 44% (*N* = 119) were female.

Materials

Participants received 20 knowledge of factory farming items based on the results of Study 1. After responding to the 20 statements, basic demographic information was gathered.

Results and Discussion

Analyses proceeded in the same manner as Study 1. The Knowledge of Factory farming Scale displayed strong internal reliability (*Cronbach's alpha* = .84). Item level analyses largely replicated those found in Study 1 (see Table 1). While the item-level properties were largely similar to those found in Study 1, the Item Response Theory analyses suggested some ways to modify the instrument without losing ability to measure knowledge of factory farming. Item 37 had low discrimination. Item 29 was very easy. Items 1 and 35 were consistently involved in significant margin misfit ($\chi^2_{residuals} > 3.81$). Item 14 had nearly identical difficulty with item 18, but item 18 had higher discrimination, so 14 could be excluded. Items that measured below average knowledge were overrepresented in the instrument (items that had negative difficulty). Because many of the easy items had similar difficulty and discrimination, several of the items could be excluded. Item 4 was eliminated because it had difficulty between items 16 and 30, and item 30 had stronger discrimination. Item 11 was eliminated because it had difficulty between 16 and 10. Item 32 was excluded because it had difficulty between items 16 and 10. Item 38 was eliminated because it had difficulty between items 30 and 16. After these items were excluded, item-level fit analyses were conducted with 8 ability categories using the mean as the category measure and 100 Monte Carlo samples (see Reise (1990); Yen (1981)). Item 6 of the remaining 11 had significant misfit to the model ($p = .02$). For this reason, item 6 was eliminated.

Study 3

Studies 1 and 2 suggested 10 items that are likely to be good estimates of knowledge of factory farming. Study 3 was designed to further develop the Knowledge of Factory Farming Scale based on those 10 items and provide some evidence for convergent, discriminant, and criterion validities. In addition, we attempted to provide evidence that the Knowledge of Factory Farming scale uniquely predicted animal consumption behaviors after including other prominent predictors of self-reported animal consumption (i.e., justifications for animal consumption and knowledge of animals used as food). To offer evidence for the unique predictive power of the Knowledge of Factory Farming scale, we modeled these factors in accordance with the Framework for Skilled Decision Theory (Cokely et al., 2018). This framework highlights the predictive power of domain-specific knowledge and has been applied to a host of domains including acceptance of recycled water (Tanner & Feltz, 2021), attitudes about endangered species (Offer-Westort, Feltz, Bruskotter, & Vucetich, 2020), and consumer choices about dairy products (S. Feltz & Feltz, 2019a).

Participants

Two hundred and forty-one participants were recruited from Amazon's Mechanical Turk. One participant was excluded for not completing the survey. The mean age was 38.66, SD = 11.77, and 53% (N = 128) were female.

Materials

Participants received the 10 items from the Knowledge of Factory Farming scale identified in Study 2. To help establish some elements of construct validity, participants also completed the following instruments.

Three Month Food Frequency Consumption (A. Feltz et al., submitted). The three month food frequency questionnaire measures trait-like tendencies to consume animal products. Previous research suggests that these items provide a reasonable approximation of general tendencies to consume animals. The three-month food frequency questionnaire asks participants how frequently per the average week over the past 3 months they consumed the following products: chicken, fish, pork, beef, bacon, and hamburger. Participants could respond: never, less that 1 time per week, 1-3 times per week, 4-6 times per week, or 1 or more times per day (coded 1-5). The mean of all responses was calculated and used in all analyses. The Three-Month Food Frequency Consumption measure was one of the three major criterion variables. The Knowledge of Factory Farming scale should be negatively related to animal consumption behaviors.

Twenty-four Hour Food Frequency Consumption (A. Feltz et al., submitted)[4]. A second trait-like measure of animal consumption was also included. The twenty-four hour food frequency questionnaire measures participants self-reported intake of animal products over the previous twenty-four hours. These items included: Dairy, chicken, turkey, fish, pork, beef, eggs, bacon, sausages, processed meats, hamburgers, any kind of meat. Participants could report that they consumed each product between 0 and 5+ times over the previous 24 hours (coded 1-6). The mean of all products was calculated and used in analyses. The 24-Hour Food Frequency Consumption measure was second of the three major criterion variables. The Knowledge of Factory Farming scale should be negatively related to animal consumption behaviors.

The Knowledge of Animals as Food Scale (S. Feltz & Feltz, 2019b). The Knowledge of Animals as Food scale is a 9-item, true/false objective measure of what people know about animals used as food (e.g., "The only way to have protein in your diet is to eat animals" correct answer = False). Previous research has suggested that this measure is negatively related to animal consumption (S. Feltz & Feltz, 2019a, 2019b). Correct answers were coded as 1 and incorrect answers as 0. The total number of correct answers was used in analyses. Given that the Knowledge of Animals as Food Scale is a knowledge-based instrument concerning aspects of animal welfare, we should expect positive relations with the Knowledge of Factory Farming scale (i.e., convergent validity).

The 4Ns (Piazza et al., 2015). The 4Ns is a 16-item, Likert scale (1 = strongly disagree, 7 = strongly agree) measure concerning how natural, normal, necessary, and nice eating animals is (e.g., "It is only natural to eat meat"). Scores on the 4Ns scale have been shown to be positively correlated with animal consumption. The mean of responses to the 16-items was used in all analyses. We expected there to be modest negative relations between the Knowledge of Factory Farming Scale and the 4Ns (i.e., convergent validity).

[4] Manuscripts that have the 'submitted' status can be viewed at this study's OSF site at: https://osf.io/s8u4f/.

The Berlin Numeracy Test (Cokely, Galesic, Schulz, Ghazal, & Garcia-Retamero, 2012). The Berlin Numeracy Test is a 7-item, fill-in-the-blank measure of numeracy (e.g., "Imagine we throw a five-sided die 50 times. On average, out of these 50 throws how many times would this five-sided die show an odd number?"). Numeracy refers to one's ability to use and understand statistical information (Peters, Hibbard, Slovic, & Dieckmann, 2007; Peters et al., 2006). The Berlin Numeracy Test has been associated with a variety of decisions (Cokely et al., 2018), including lower animal consumption (S. Feltz & Feltz, 2019b) as well as more normatively correct decisions in natural resource and health management (Garcia-Retamero & Cokely, 2015; Tanner & Feltz, 2021). Correct answers were coded as 1, incorrect answers as 0, and a total of correct answers was used in all analyses. Since there are right answers to the items in the Knowledge of Factory Farming scale, we expected those with higher numeracy to have more questions correct (i.e., convergent validity).

Actions. We also asked participants three Yes/No questions about specific animal-related political actions. These three questions were: "Would you be willing to sign a petition to ban gestation crates for pigs?"; "Would you be willing to sign a letter to your senator to ban veal?"; "Would you vote for a senator who wants to increase protections for farm animals?" ('Yes' = 1, 'No' = 0). Actions was the third of three major criterion variables. We predicted a positive relation between the Knowledge of Factory Farming scale and answers to the Actions items (i.e., criterion validity).

After completing these instruments, basic demographic information was collected including a one-item measure of political affiliation (1 = very liberal, 7 = very conservative). Previous research suggests that those who are more politically conservative consume more animal products than those who are less conservative (A. Feltz et al., in press; A. Feltz et al., submitted; S. Feltz & Feltz, 2019b; Lusk & Norwood, 2016; MacInnis & Hodson, 2017; Pfeiler & Egloff, 2018). However, because we were looking at a knowledge-based instrument, we expected small relations to political orientation (i.e., discriminant validity). We also collected information about sex (0 = male, 1 = female) and age. Again, because we were measuring knowledge, we expected small relations of the Knowledge of Factory Farming scale with both age and sex (i.e., discriminant validity).

Results and Discussion

The item-level properties from previous studies were replicated to a large extent (see Table 1 and Appendix B for the final 10 items of the Knowledge of Factory Farming Scale). The 2-parameter model (AIC = 2821.05, BIC = 2890.66) was a better fit to the data than a 1-paramter (AIC = 2841.52, BIC = 2879.8) model, $p < .01$. We also assessed model fit of the 2-parameter model by analyzing fit of the margins. An analysis of χ^2 residuals indicated that only one pair of items involved a value greater than a commonly accepted value (3.5), $\chi^2_{\text{residual}} = 4.26$. However, an analysis of the item-level fit with 8 ability categories using the mean as the category measure and 100 Monte Carlo samples revealed no significant mis-fitting items (all χ^2s < 17.2, *p*s > .14). So, we can have some confidence that the 2-parameter model fits the data and provides information across a range of knowledge levels (see the test information function in Figure 1). A unidimensionality test of the Knowledge of Factory Farming scale using 100 bootstrapped samples was significant: observed second eigenvalue = 1.24, Monte Carlo simulated second eigenvalue = 0.85, $p = .01$. While the observed second eigenvalue was greater than the simulated value, the observed second eigenvalue was relatively small. Given the small size of the second eigenvalue, we assumed that the instrument was unidimensional for subsequent analyses.

There is some evidence that Amazon Mechanical Turk samples are more liberal than the general U.S. population (Clifford, Jewell, & Waggoner, 2015; Levay, Freese, & Druckman, 2016). The mean political orientation in Study 3 was slightly more liberal on average than other estimates. For example, the mean political orientation in Study 3 was 3.54 whereas estimates from the American National Election Studies' was 4.2 on a 7-point scale (1 = strongly liberal, 7 = strongly conservative) (Levay et al., 2016). To help address potential political bias in the Amazon Mechanical Turk sample, we checked for invariance of the Knowledge of Factory farming scale by comparing liberals (scoring 1-3 on political orientation) and those were not liberal (4-7 on the political orientation scale). We used the difR package in R (Magis, Beland, Tuerlinkx, & de Boeck, 2010) to estimate item invariance. The Mantel-Haenszel method with continuity correction and item purification did not detect any differences in knowledge items as a function of political orientation (χ^2s < 2.44, *ps* > .11). We also used 3 other methods to detect differential item functioning (Lord's χ^2 test, Standardized method, and Raju's area test) and only 1 item using these other methods was detected to be different (the Standardized method identified item 9). Hence, there is little evidence that Knowledge of Factory Farming scale varied between liberals and conservatives.

The second set of analyses involved providing some evidence for construct validity of the Knowledge of Factory Farming Scale by calculating correlations with the other variables gathered in this study. A post-hoc power analysis suggested that the minimal reliably detectable correlation for this study was *r* = |.18| (with *power* = .8 and *alpha* = .05). Theoretically, the Knowledge of Factory Farming Scale should be positively related to the Knowledge of Animals as Food Scale and Action questions, and negatively related to the 4Ns and the animal consumption measures. These relations were found (see correlations, *Ms*, and *SDs* in Table 2).

To test whether the Knowledge of Factory Farming Scale offered unique prediction of outcome variables, a path model was specified in accordance with previous research and the Framework for Skilled Decision Theory (Cokely et al., 2018). We created 3 paths models with the only difference being the outcome variable.[5] One path model had 3-month animal consumption as the outcome variable. A second path model had 24-hour animal consumption as the outcome variable. To simplify analyses, the final model used a sum of the Action questions (McDonald's omega for action items was .64). The only difference in the specification of the three models was the outcome variables. The different outcome variables did not influence the overall model fit statistics, so we only report one model fit statistic for all three models. All models had acceptable fit to the data $\chi^2(2) = 0.37$, $p = .83$, $RMSEA = 0$, 90% CI 0 - .07, $p = .9$, GFI = .99, TLI = 1, CFI = 1.

The relations that emerged in the path models were informative (see Figure 3). For the animal consumption specific outcome variables (24 hour FFQ and 3 Month FFQ), the Knowledge of Factory Farming instrument was not a significant predictor in the model. This suggests that the Knowledge of Animals as Food scale and the 4Ns mediate the relation between the Knowledge of Factory Farming scale and the animal consumption outcome variables. However, this was not the case for the Action outcome variable. In that model, the Knowledge of Factory Farming Scale was a significant predictor of Actions and was not significantly mediated by the Knowledge of Animals as Food scale or the 4Ns.

Study 4

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[5] There are no widely accepted power analyses for path models. Some recommend 5, 10, or 20 cases for each parameter estimated. For our path models, that would result in a sample of 160 (20 * 8 parameters estimated). But, there are many caveats and exceptions to these rules (Wolf, Harrington, Clark, & Miller, 2013).

Study 4 was designed to replicate the findings of Study 3, particularly the path models, on a new sample.

Participants

Two hundred and seventy-eight participants were recruited from Amazon's Mechanical Turk. Forty-three participants were excluded for not completing the survey. Twenty-two participants were excluded for not answering an attention check question correctly.

Materials

Participants received the same materials those in Study 3 received in exactly the same order.

Results and Discussion

Item level statistics for the Knowledge of Factory Farming scale are reported in Table 1. The general item-level statistics seen in previous studies were found in Study 4 (*Cronbach's alpha* = .67). We compared a 2-parameter model (AIC = 2604.71, BIC = 2671.93) to a 1-parameter model (AIC = 2622.9, BIC = 2659.88), and the 2-parameter model fit the data better, $p < .01$. An analysis of margins indicated that only one pair involved a χ^2 residual value greater than commonly accepted values (3.5), $\chi^2_{\text{residual}} = 4.36$. However, an analysis of the item-level fit revelated no significant mis-fitting items to the model with 8 ability categories using the mean as the category measure and 100 Monte Carlo samples (all χ^2s < 18.13, *p*s > .06). So, we can have reasonable confidence that the 2-parameter model fit the data and provides information across a range of knowledge levels (see the test information function in Figure 2). A unidimensionality test of the Knowledge of Factory Farming scale using 100 bootstrapped samples was significant: observed second eigenvalue = 1.17, Monte Carlo simulated second eigenvalue = 0.86, $p = .01$. While the observed second eigenvalue was greater than the simulated value, the observed second eigenvalue was relatively small. Given the small size of the second eigenvalue, we assumed that the instrument was unidimensional for subsequent analyses.

We conducted a test for invariance as a function of political orientation identical to that conducted in Study 3. The Mantel-Haenszel method with continuity correction and item purification suggested no significant differences in the knowledge items as a function of political orientation (χ^2s < 3.02, *p*s > .08). We used 3 other methods 9 (Lord's χ^2 test, Standardized method, Raju's area test) to identify differential functioning of items. Two methods found two items as functioning differently (Lord's χ^2 test identified only Item 1 and the Standardization method identified only Item 8). So again, there is converging evidence that the Knowledge of Factory Farming scale was invariant with respect to political orientation.

The next step was to replicate the relations found in Study 3. We calculated correlations with the other variables gathered in this study to help provide evidence for construct validity. We had the same predictions in Study 4 as in Study 3. A post-hoc power analysis suggested that the minimal reliably detectable correlation for this sample was $r = |.19|$ (with *power* = .8 and *alpha* = .05). Action items were again combined for ease of analysis (McDonald's omega = .7). Largely, similar correlations were found in Study 4 that were observed in Study 3 (see Table 2 for correlations, means, and standard deviations).

The path models specified in Study 3 were retested in Study 4. The only difference in the specification of the three models was the outcome variables. The different outcome variables did not substantially influence the overall model fit statistics, so we only report one model fit statistic for all three models. The hypothesized models fit the data adequately: χ^2 (2) = 1.06, $p = .59$, *RMSEA* = 0, *90% CI* = 0 - .11, $p = .73$ GFI = .99, TLI = 1, CFI = 1. As in Study 3 the Knowledge of Factory Farming scale was not a significant predictor in the path model for animal consumption behaviors but was a predictor in the model for political actions related to farmed animal welfare (see Figure 4).

General Discussion

In four studies, we developed and refined the Knowledge of Factory Farming Scale. Studies 1 and 2 provided evidence that 10 items had acceptable Item Response Theory properties. Studies 3 and 4 provided some initial evidence for construct validity of the scale by showing that the Knowledge of Factory Farming scale was related to—but not identical to—other measures including the Knowledge of Animals as Food Scale, the 4Ns, and some demographic factors. The path models in Studies 3 and 4 contribute to the growing body of evidence suggesting that knowledge is often an important predictor of behaviors and decisions about animals used for human purposes.

Measuring knowledge of human impacts on animals is important for at least two reasons. The first reason is relevant for applied ethics. Some have argued that knowledge about the treatment of animals has little bearing on how people relate to animals and that changing people's knowledge about animals does little to change their behaviors concerning animals (Cooney, 2011). For example, there is evidence that educational interventions (e.g., pamphlets) have limited impacts on animal consumption (A. Feltz et al., in press). One might be tempted, therefore, to conclude that having or acquiring information does not change animal-related consumption behaviors. On these views, if knowledge does not matter to attitudes and behaviors involving animals, there would be little reason to try to inform people about those facts in order to change behaviors. Rather, it would be better to try to change behaviors by manipulating some non-knowledge factors such as emotions, values, or attitudes (Cooney, 2011).

We think that the general view that knowledge does not matter to how we relate to animals is incomplete in many cases. Our studies, along with some previous studies, suggest that knowledge *is* related to attitudes and behaviors that involve animals (A. Feltz et al., in press; S. Feltz & Feltz, 2019b). However, we want to be very clear that we do not think that knowledge is the *only* relevant psychological factor that is involved in how humans relate to animals. Indeed, on our view, there are likely to be important interactions with other psychological factors such as values and general skills (see also Cokely et al. (2018); A. Feltz et al. (in press)). Recall that on common models of decision making, values and beliefs interact when one makes decisions (Baron, 2008). It would be odd (but not impossible) if what one believes about animals does not interact with values to generate behaviors involving animals. Consequently, if one changes beliefs, then the corresponding behavior (given the same values) should tend to change.

Whether changing knowledge in people actually changes behavior is an open question. There may be many reasons why changing knowledge many not change behaviors. For instance, animal consumption may be trait-like (A. Feltz et al., submitted). One way to characterize traits is that they are stable, enduring (but *not* unchangeable) tendencies that occur in different situations. Because traits are stable, they can be difficult to change (but they can be changed). Alternatively, one may simply lack the desire to change, think that change is impossible, or identify too closely with eating animals (Hennecke, Bleidorn, Denissen, & Wood, 2014; Sobal, 2005). Whether any of these potential explanations for lack of change are correct involves estimating and measuring the extent to which one learns the relevant facts about animals. The Knowledge of Factory Farming scale provides one way to measure one kind of knowledge concerning animals used for human purposes.

Despite the difficulties that could be involved in changing behaviors, our data can perhaps help explain why people might be inclined to think knowledge does not matter. First, one might think that simply presenting information to people is the same thing as people learning something or acquiring beliefs. While there is likely a non-zero relation between providing information and people learning something, the relation is not perfect and often people do not acquire the relevant beliefs from information. There are numerous reasons why people may not develop the relevant beliefs in response to information (e.g., inattention, lacking skills, confirmation bias, motivated reasoning, myside bias). Measuring potential changes in knowledge is one way to help estimate whether educational interventions actually change what people believe.

In this light, measuring and estimating knowledge about factory-farmed animals can be philosophically important. To illustrate, we take the following ethical principle as relatively uncontroversial: all else being equal and on average, informing choices is ethically better than manipulating choices. This principle is relatively uncontroversial because it embodies a value that is represented in almost all cultures, professional codes, and individuals: *respecting autonomy*. While there are many philosophical notions of autonomy, they all somehow involve being self-governed, and self-government involves having a full enough set of (true) beliefs to reliably actualize one's values (Baron, 2008; Mele, 1995; Weirich, 2004). Estimating what one knows can be important to understanding if people are making decisions in the way that they would want and if interventions facilitate that kind of decision making. The Knowledge of Factory Farming scale is therefore one way to help estimate the extent to which people make, and interventions promote (or protect), autonomous decisions.

The second implication concerns advocacy. In short, providing information may increase *some* kinds of knowledge but may not increase *other* kinds of knowledge. We take it as a truism that not all knowledge is relevant for every decision (e.g., knowing that the atomic number of gold is 79 is rarely relevant for deciding what to eat for lunch). Our studies suggest that the same is true for knowledge related to animals. Knowing some facts about animals used as food may not be as relevant to animal-welfare political actions as knowing about some of the conditions of factory farming. Likewise, knowing some facts about factory farming may not be as relevant to food choices as knowledge about animals used as food. If one provides information about animals used as food that does not change judgments about animal-welfare legislation, one may be tempted to conclude that *any kind of* knowledge does not matter to animal-welfare legislation. We think that our data cast doubt on that inference because people may gain the wrong kinds of knowledge from the educational interventions. Again, having appropriate measures of the kinds of knowledge in question can help estimate whether people know what is relevant.

One may be worried that some of the questions in the final Knowledge of Factory Farming scale used the terminology “factory farming” (6 of the 10 questions used the term “factory farming”). One can imagine that ‘factory farming’ is a value-laden concept that has a negative connotation. Indeed, some organizations have used the term ‘factory farming’ as a way to negatively describe concentrated animal feeding operations (Lusk, 2016). If ‘factory farming’ has a negative connotation, people may be responding to that aspect of the questions and not to the factual content of the questions. That would result in the scale not measuring objective facts but rather one’s general approval or disproval of factory farms in general.

The worry that the Knowledge of Factory Farming scale measures values and not knowledge is important. However, we think that our data speak against that interpretation for two reasons. First, the tests for convergent validity revealed relatively small relations to a purer measure of values or attitudes represented in the 4Ns and relatively stronger relations to another knowledge construct represented in the Knowledge of Animals as Food scale. If people were cueing on ‘factory farming’ we should expect stronger relations to the 4Ns, but we don’t observe that pattern. Second, the tests for unidimensionality of the Knowledge of Factory Farming scale suggested that the scale measured one latent trait. However, the scale consisted of items that both did and did not include the term ‘factory farming’. The evidence supporting the unidimensionality of the scale along with the associations with the 4Ns and Knowledge of Animals as Food scale together suggest that the Knowledge of Factory Farming scale measures a latent knowledge construct and not values or attitudes. Future studies may explore the relation of values to the Knowledge of Factory Farming scale more fully.

We want to be clear that the work presented here is the first step towards fully validating the Knowledge of Factory Farming scale. We did not demonstrate all possible kinds of construct validity (e.g., consequential validity, generalizability) (Messick, 1995). Future work should help provide evidence for these additional validities. There are also some notable limitations of the current series of studies. First, our studies came from one testing platform using only U.S. IP addresses. While we have reason to think that knowledge of factory farmed animals is likely to be generally predictive of animal-related decisions, the exact items in the measure may be different in different cultures, languages, or locations. Additionally, the items selected for the

Knowledge of Factory Framing scale were mostly specific to animal agriculture as it exists in the United States. Whether these items reflect the practices in other countries is an open question. Second, our studies only evaluated two major outcome variables: self-reported animal consumption and judgments about animal-related political actions. More work needs to be done to see how well the Knowledge of Factory Farming scale predicts other animal-related issues (including issues surrounding non-factory farmed animals) and what the boundary conditions are between different kinds of knowledge. Finally, the Knowledge of Factory Farming Scale should be used in intervention research. Intervention research can provide evidence for whether knowledge of factory farming can change and if that change is related to changes in attitudes or behaviors about how humans treat animals.

Despite these limitations, our studies suggest that there is utility in measuring knowledge of factory farming. The likely benefits of measuring knowledge of factory farming include building better predictive models of some kinds of behaviors and demonstrating that different kinds of knowledge are likely important for different kinds of outcomes. These better predictive models hold the promise of better educational interventions to target changes in relevant knowledge. In these ways, having appropriate measures of knowledge can aid helping people make informed decisions about animals for themselves.

Appendix A

Knowledge of Factory Farming Initial Items

1. Less than 66% of the meat in the U.S. comes from factory farms. (F)
2. The average American consumes more than his or her weight in meat annually. (T)
3. Cows are the vast majority of land animals raised for food. (F)
4. In 2016, more than 110,000 turkeys were slaughtered in the U.S. (T)
5. In 2016, less than one million chickens were slaughtered in the U.S. (F)
6. In the U.S. an estimated 2.2 million sheep and lambs were slaughtered in 2016. (T)
7. In the U.S, an estimated 1.5 million goats are slaughtered for meat every year. (T)
8. On average, each full grown chicken in a factory farm has more than a square foot of living space. (F)
9. Chickens on factory farms are docile and rarely attack each other. (F)
10. Chickens on factory farms are often debeaked (T)
11. Hogs become aggressive in tight spaces and often bite each other's tails (T)
12. Factory farms often cut off the tails of pigs when raising them. (T)
13. Almost all pigs are completely healthy when they are slaughtered. (F)
14. Most factory-farmed animals have been genetically manipulated to produce more food. (T)
15. Veal calves don't live lives different from ordinary calves on factory farms. (F)
16. The natural lifespan of a dairy cow is between 20-25 years but they are often killed before they turn 6 on factory farms. (T)
17. In many egg production farms, the practice of forced molting is used to trick the hens into higher levels of egg production. (T)
18. Animals on factory farms are fed hormones to promote faster growth. (T)
19. Poor sanitation in factory farms can lead to contaminating meat with E. coli. (T)
20. Poor sanitation at factory farms can lead to contamination of food with salmonella. (T)
21. Poor sanitation at factory farms can lead to contamination of food with fecal matter. (T)
22. Each year more than 40 million Americans become ill from food borne illness. (T)
23. Routine use of low-dose antibiotics to compensate for illness on factory farms promotes antibiotic resistant bacteria. (T)
24. United States Department of Agriculture (USDA) inspectors oversee federally inspected slaughterhouses. (T)

25. The USDA is charged with overseeing animal welfare on the farms where they are raised. (F).
26. The Humane Methods of Slaughter Act (HMSA) requires that cows, pigs, and sheep be slaughtered in a humane way. (T)
27. In the United States, the 28-Hour Law requires animals transported via truck across state lines for slaughter to be unloaded every 28 hours for rest, food and water. (T)
28. In 2012, the largest factory farms produced about 2 times more waste than the human population of the United States. (F)
29. Excessive waste created by large concentrations of animals can pollute air and water. (T)
30. Factory farms contribute to air pollution by releasing hydrogen sulfide, ammonia, and methane. (T)
31. Factory farming accounts for less than 5% of methane emissions. (F)
32. Man-made manure lagoons on industrial farms hold millions of gallons of liquid waste that can leach into groundwater. (T)
33. Burning fossil fuels to produce fertilizers for animal feed crops may emit 41 million metric tons of CO2 per year. (T)
34. Property values are often lowered for residents in close proximity to industrial farms. (T)
35. Animal agriculture employs approximately 700,000 full-time and part-time workers in the United States. (T)
36. Factory farm workers are among the healthiest workers in the United States. (F)
37. Less than 15 % of all workers in pig confinement operations experience one or more symptoms of respiratory irritation or illness. (F)
38. Many factory farm workers experience chronic muscle aches due to the repetitive nature of their work. (T)

Appendix B. Final items from the Knowledge of Factory Farming Scale. Truth values for the statements and original item numbers are in parentheses.

1. In 2016, less than one million chickens were slaughtered in the U.S. (F, 5)
2. In the U.S, an estimated 1.5 million goats are slaughtered for meat every year. (T, 7))
3. Chickens on factory farms are often debeaked (T, 10)
4. The natural lifespan of a dairy cow is between 20-25 years but they are often killed before they turn 6 on factory farms. (T, 16)
5. Animals on factory farms are fed hormones to promote faster growth. (T, 18)
6. Poor sanitation at factory farms can lead to contamination of food with salmonella. (T, 20)
7. In the United States, the 28-Hour Law requires animals transported via truck across state lines for slaughter to be unloaded every 28 hours for rest, food and water. (T, 27)
8. Factory farms contribute to air pollution by releasing hydrogen sulfide, ammonia, and methane. (T, 30)
9. Factory farming accounts for less than 5% of methane emissions. (F, 31)
10. Burning fossil fuels to produce fertilizers for animal feed crops may emit 41 million metric tons of CO2 per year. (T, 33)

Table 1. IRT properties of items from Studies 1-4 arranged in order from upper most value to lower most value. All Item numbers correspond to items in the original set represented in Appendix A.

Item #	% Correct	Difficulty	Discrimination
1	44	0.41	0.72
	38	0.62	0.91
2	74	-1.24	1
3	22	25.04	0.05
4	64	-0.48	1.92
	62	-0.41	1.84
5	56	-0.37	0.72
	50	-0.03	0.92
	60	-0.39	1.43
	44	0.44	0.63
6	45	0.27	0.99
	47	0.13	1.08
7	39	0.79	0.65
	38	0.65	0.89
	38	0.96	0.57
	41	0.61	0.71
8	55	-0.38	0.5
9	56	-0.26	1.03
10	53	-0.1	1.53
	44	-0.29	0.92
	50	0	0.74
	48	0.07	1.18
11	60	-0.35	1.85
		-0.35	2.19
12	45	0.24	1.07
13	56	-0.31	0.8
14	67	-0.61	1.64

	65	-0.65	1.24
15	59	-0.46	0.81
16	59	-0.29	1.8
	60	-0.39	1.44
	61	-0.55	1
	57	-0.32	1.16
17	59	-0.31	1.7
18	75	-0.79	2.41
	68	-0.66	1.66
	79	-1.34	1.3
	75	-1.18	1.14
19	75	-0.81	2.2
20	74	-0.84	1.88
	68	-0.74	1.42
	82	-1.04	2.94
	76	-0.87	2.3
21	78	-0.97	1.99
22	56	-0.22	1.24
23	66	-0.59	1.61
24	62	-0.53	1.08
25	24	-6.4	-0.18
26	55	-0.27	0.8
27	37	1.34	0.42
	36	0.86	0.75
	31	1.53	0.57
	34	1.23	0.57
28	17	-2.74	-0.6
29	72	-0.7	2.1
	70	-0.77	1.52
30	67	-0.53	2.5
	66	-0.55	2.15

	72	-0.73	2.22
	70	-0.66	2.3
31	47	0.16	0.84
	42	0.55	0.62
	44	0.29	1.05
	39	1.07	0.46
32	58	-0.24	2.27
	61	-0.37	2.17
33	49	-0.04	1.68
	56	-0.27	1.15
	50	0	0.74
	53	-0.1	1.66
34	67	-0.63	1.53
35	54	-0.15	1.1
	54	-0.17	1.2
36	56	-0.26	0.92
37	33	1.98	0.38
	34	2.13	0.35
38	64	-0.44	2.1
	63	-0.43	2.43

Table 2. Correlations from Studies 3 and 4. Male = 1, female = 2. For actions, yes = 1, no = 0. Note: * $p < .05$, ** $p < .01$.

	1	2	3	4	5	6	7	8	9	10
1. KNOWLEDG OF FACTORY FARMING SCALE	1									
2. 3 Month	-.27**	1								
	-.17*									
3. 24 Hour	-.26**	.73**	1							
	-.26**	.75**								
4. KAFS	.45**	-.47**	-.59**	1						
	.26**	-.47**	-.71**							
5. 4Ns	-.16*	.55**	.42**	-.4**	1					
	-.17*	.59**	.5**	-.41**						
6. Actions	.24**	-.05	-.01	.2**	-.31**	1				
	.2**	0	.07	.07	-.15*					
7.Numeracy	.25**	-.34**	-.44**	.46**	-.21**	.05	1			
	.25**	-.34**	-.5**	.41**	-.2**	-.06				
8. Sex	.1	-.08	-.19**	.16*	-.19**	.17*	.01	1		
	.05	-.23**	-.25**	.22**	-.24**	.05	-.01			
9. Politics	-.28**	.35**	.27**	-.23**	.31**	-.25**	-.15*	-.14*	1	
	-.05	.1	.09	-.13*	.17*	-.25**	-.07	0		
10. Age	-.06	-.04	-.12	.01	-.01	-.07	.02	.1	.22**	1
	-.03	.01	-.15*	.08	.01	-.12	0	.03	.11	
M	5.66	2.63	2.13	6.59	4.5	1.85	2.88	36.66	3.54	
	5.35	1.7	1.48	5.76	4.66	1.64	2.43	37.55	3.78	
SD	2.39	0.7	1.21	1.89	1.15	1.07	1.86	11.77	1.83	
	2.4	0.8	1.3	1.98	1.18	1.13	1.9	12.39	1.92	

Figure 1. Test information function for Study 3.

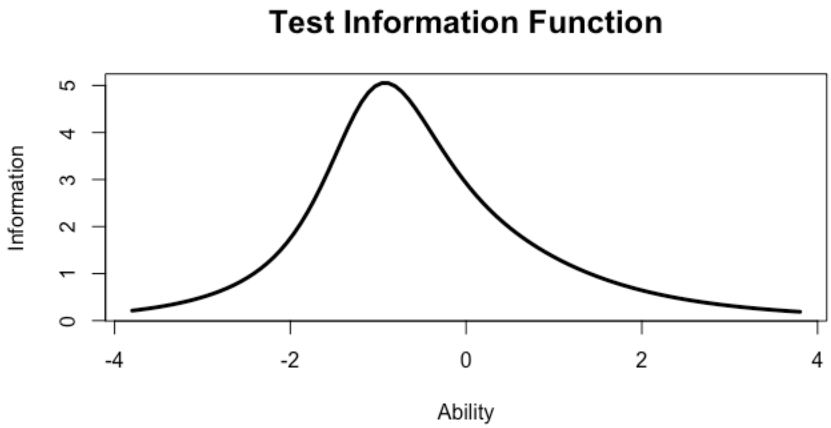


Figure 2. Test information function for Study 4.

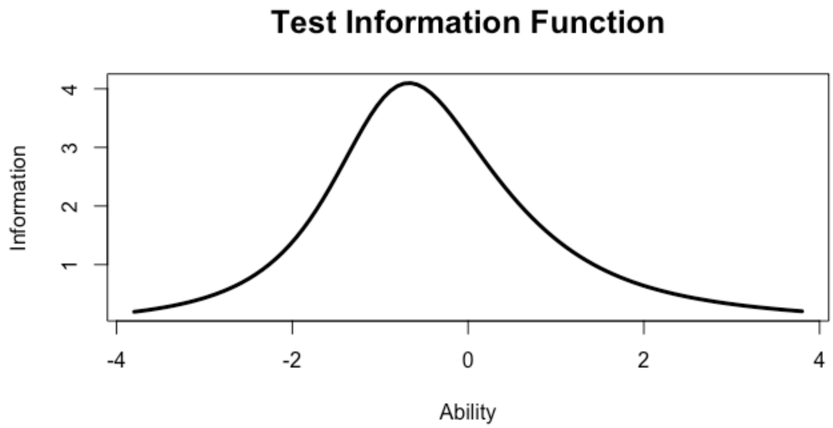


Figure 3. Path model for Study 3. Path coefficients are standardized. Note: * $p < .05$, ** $p < .01$.

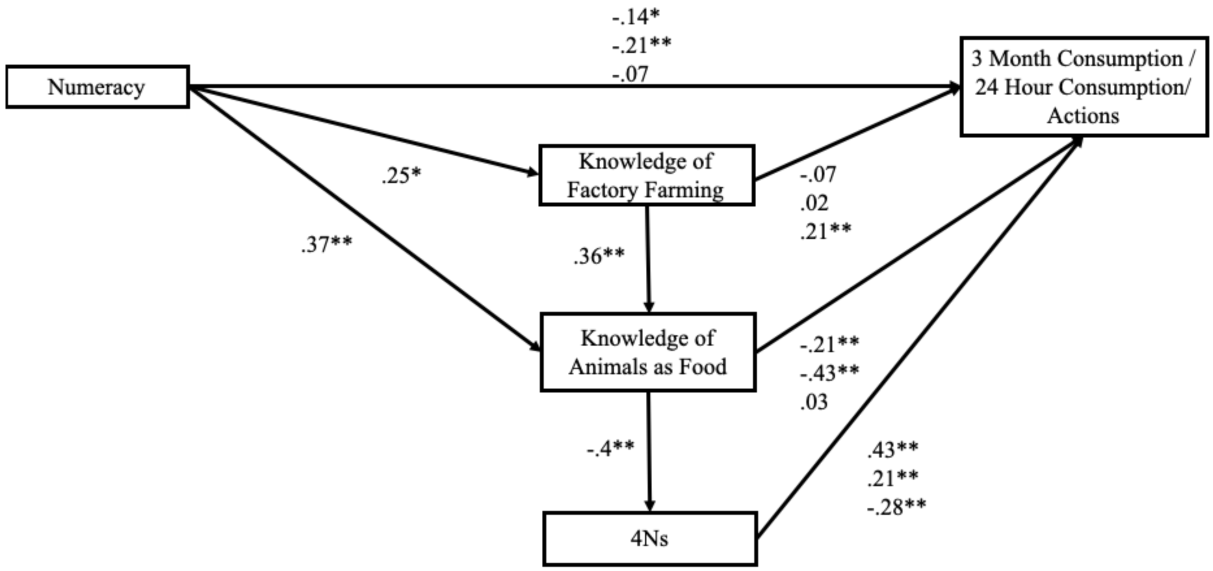
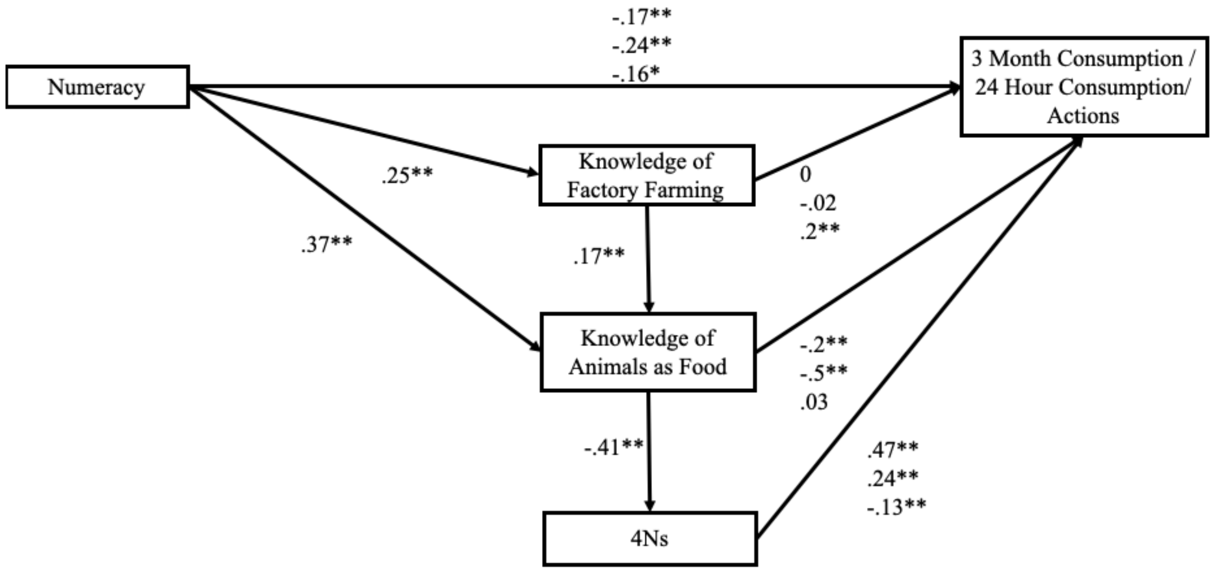


Figure 4. Path model for Study 4. Path coefficients are standardized. Note: * $p < .05$, ** $p < .01$.



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