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Three Essays on Applied Human Behavioral Economics and Individual Choices

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Three essays on applied human behavioral economics and individual choices

by

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Major: Economics

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To Jinlong Wu, Xia Lv, and Cheng Chen.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

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ABSTRACT

Using primary data from a survey of livestock industry experts, the first chapter provides valuable insights into adoption of Tier 1 disease biosecurity measures among U.S. swine, beef cattle, and dairy industries. Experts believe adoption rates would be highest in the swine industry and lowest in the beef cattle industry in the first year of a large Tier 1 disease outbreak. Risk reduction has a positive marginal effect on the biosecurity adoption, and an own firm's risk reduction matters as much as a closest neighbor's risk reduction. Costs have a negative marginal effect on biosecurity adoption. A key reason explaining partial adoption of biosecurity might be that experts indicate that costs would not cover the private benefits for producers to invest in biosecurity. Education materials and costs are less important adoption decision drivers than the producer's experience, the likelihood of future experience of Tier 1 diseases, and the effectiveness of the biosecurity measures.

The second chapter studied brain activity using a functional magnetic resonance imaging (fMRI) whole-brain analysis while healthy adult Democrats and Republicans make non-hypothetical food choices. While the food purchase is not significantly different, we find that brain activation in distinct regions differs by a subject's political affiliation during the choice. Republicans exhibit stronger activities in left brain regions while Democrats show more activation in regions of the right hemisphere. Single variable models of partisanship based on left insula or premotor/supplementary motor area activations achieve better accuracy in predicting participants' political views than a political ideology questionnaire.

The third chapter studied behavior and corresponding brain activity when females and males made non-hypothetical food purchases using functional magnetic resonance imaging (fMRI). We found the brain activity difference segmented gender more accurately than their choice differences via a logit model. We also tested the hypothesis that male-female differences were due to differences between primary and non-primary shoppers. Our study has implications for food marketers and food product developers.

CHAPTER 1. USING EXPERT KNOWLEDGE TO UNDERSTAND ADOPTION OF BIOSECURITY MEASURES FOR MITIGATING TIER 1 DISEASE RISKS IN THE U.S. SWINE, BEEF CATTLE, AND DAIRY INDUSTRIES

Abstract

Using primary data from a survey of livestock industry experts, this study provides valuable insights into adoption of Tier 1 disease biosecurity measures among U.S. swine, beef cattle, and dairy industries. Experts believe adoption rates would be highest in the swine industry and lowest in the beef cattle industry in the first year of a large Tier 1 disease outbreak. Risk reduction has a positive marginal effect on the biosecurity adoption, and an own firm's risk reduction matters as much as a closest neighbor's risk reduction. Costs have a negative marginal effect on biosecurity adoption. A key reason explaining partial adoption of biosecurity might be that experts indicate that costs would not cover the private benefits for producers to invest in biosecurity. Education materials and costs are less important adoption decision drivers than the producer's experience, the likelihood of future experience of Tier 1 diseases, and the effectiveness of the biosecurity measures.

1

Introduction

Conceptually, biosecurity adoption is easy to embrace. The goal is to avoid the entry of pathogens into a herd or farm (external biosecurity) and to prevent the spread of disease to uninfected animals within a herd or to other farms, when the pathogen is already present (internal biosecurity) (FAO and OIE, 2010, pp. viii-ix). Biosecurity adoption involves making resource allocation choices about low probability risks that may materialize in the indefinite future (Hennessy, 2008). However, difficulties arise in practical implementation, such as how to implement biosecurity within the economic constraints of livestock production.

Existing biosecurity plans offer protection against endemic diseases (Lewerin et al., 2015) but heightened safeguards are needed for foreign animal diseases. An analysis of data from the National Animal Health Monitoring System indicates 32.1% of beef cow-calf operations strongly disagreed or disagreed with the statement, “The United States is well prepared to handle outbreaks of livestock disease currently not found in this country, such as foot-and-mouth disease and rinderpest” (USDA-APHIS-VS, 2010).

If a high-consequence foreign animal disease, hereafter referred to as a Tier 1 disease[1], were to be introduced in the United States, the disruption would be significant, especially if the disease is not quickly identified and confined to a small area. Quickly culling and disposing of infected and potentially exposed animals, or stamping out, could be effective in the case of a small, confined Tier 1 disease outbreak. If a Tier 1 disease were to spread to multiple areas, a stamping out strategy would become logistically and economically impractical. In that case, some combination of stamping out, biosecurity, vaccination, and slaughter of exposed animals

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[1] Tier 1 diseases are those of national concern. They pose the most significant threat to animal agriculture in the United States, as they have the highest risks and consequences. Tier 1 diseases include African swine fever, classical swine fever, foot-and-mouth disease, avian influenza, and virulent Newcastle disease (USDA-APHIS, 2013).

would be needed (Roth and Spickler, 2014). Of these, the only tool that currently is realistically available is biosecurity (Roth and Spickler, 2014). Enhanced biosecurity is a key component of the Secure Food Supply Plans currently being designed to provide business continuity in the face of a foreign animal disease outbreak (http://www.cfsph.iastate.edu/Secure-Food-Supply/).

The objective of this article is to examine prospective biosecurity adoption and compliance following a large Tier 1 disease outbreak in the United States. Our analysis involves forecasting how sensitive biosecurity adoption is to a firm’s own risk reduction and a neighbor’s risk reduction, and upfront implementation costs and annual maintenance costs. Identification of this sensitivity allows forecasting adoption rates under different scenarios. The relative importance of other factors impacting adoption and persistent compliance with additional biosecurity measures aimed at reducing Tier 1 disease risks are also provided. This study is the first known evaluation aimed at improving understanding of how risk reduction, costs, and other factors impact biosecurity adoption and compliance.

Materials and Methods

Given the enormous uncertainty about Tier 1 disease outbreaks and the difficulty in measuring expected biosecurity adoption, we rely on a sample of experts. Stakeholders in the livestock industry are regarded as key players in the communication, decision-making, and implementation of biosecurity measures. Hernández-Jover et al. (2012) found that successful livestock disease risk reduction depends on trust and co-management among stakeholders. In the event of a Tier 1 disease outbreak, it will be a producer and their team of experts’ responsibility to protect animals from becoming infected, as with any other disease.

Questionnaire design

Survey procedures were approved by the Kansas State University Committee for Research Involving Human Subjects (#8132.1). Survey software Qualtrics (Qualtrics, Provo, UT) was used to develop the surveys.

Three similar and almost identical surveys were designed and circulated to swine, beef cattle, and dairy industry experts.[2] Each survey contained six questions of primary interest in this article. We present questions here as they were asked in the swine survey. Analogous questions were asked in the beef cattle and dairy surveys.

Questions 1 was designed to estimate how sensitive biosecurity adoption would be to risk reduction. Specifically, this question was presented as:

- *Q1: What share of national adoption do you expect the U.S. swine industry would achieve in the first year of a large Tier 1 disease outbreak if a given biosecurity measure reduced a firm's own risk of a Tier 1 disease outbreak by X% and reduced their closest neighbor's risk by Y%?*

Available answers to this question included 0%, 1%-10%, 11%-20%, 21%-30%, 31%-40%, 41%-50%, 51%-60%, 61%-70%, 71%-80%, 81%-90%, and 91%-100%. Two dimensions of risk reduction were used. A firm's own risk reduction (*X%*) and their closest neighbor's risk reduction (*Y%*) were both presented as random variables from 0% to 100%. These two representations of risk reduction were chosen because the probability that a producer's herd can become infected depends not only on own self-protection but also protection of neighbors (Reeling and Horan, 2014). Actions to protect against the entry of a disease into a region are strategic complements as the nature of spatial interactions matter (Hennessy, 2007b).

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[2] Survey questionnaires are available from the authors upon request.

Question 2 was designed to estimate how sensitive biosecurity adoption would be to investment costs. Specifically, this question was presented as:

- *Q2: What share of national adoption do you expect the U.S. swine industry would achieve in the first year of a large Tier 1 disease outbreak if a given Tier 1 disease targeted biosecurity measure costs $FC/operation in one-time, up-front implementation costs and $VC/animal/operation/year in annual maintenance costs on the operation?*

Available answers to this question included 0%, 1%-10%, 11%-20%, 21%-30%, 31%-40%, 41%-50%, 51%-60%, 61%-70%, 71%-80%, 81%-90%, and 91%-100%. Two dimensions of investment costs were used. Fixed costs (*$FC*) and variable costs (*$VC*) were both presented as random variables. Fixed costs ranged from $1 to $10,000 per operation and variable costs ranged from $1 to $5 per animal per operation per year. Biosecurity investments entail a mixture of fixed and variable costs. Fixed costs are costs that are independent of output. Variable costs are costs that vary with output. By including fixed and variable costs, economic tradeoffs can be considered and the relative influence of each for biosecurity adoption identified.

Biosecurity implementation depends not only on risk reduction and costs, but also on attitudes towards and motivations for undertaking/not undertaking disease prevention (Gilmour, Beilin, and Sysak, 2011). Questions 3 and 4 were designed to comparing the relative importance of a myriad of factors impacting biosecurity implementation and compliance. These questions were specifically presented as:

- *Q3: How important are the following factors in a typical swine producer's decision to adopt and implement new, additional biosecurity measures aimed at reducing Tier 1 disease risks in the swine industry during the first year of a large outbreak?*

- *Q4: How important are the following factors in a typical swine producer's persistent compliance (e.g. rigorous, ongoing maintenance of effort over time) with biosecurity measures previously implemented for reducing Tier 1 disease risks in the swine industry Z years after initial implementation?*

These questions were asked with an importance scale response such that 0 = not important to 100 = utmost importance. Years after initial implementation was presented randomly and ranged from 1 to 10.

For questions 3 and 4, nine factors were evaluated including 1) up-front fixed (one-time) monetary costs of implementation; 2) ongoing (recurring) monetary costs of implementation; 3) availability of governmental cost-share to reduce out-of-pocket expense; 4) producer's view on own their own likelihood of experiencing a Tier 1 disease given their own situation; 5) producer's view on effectiveness in reducing Tier 1 disease risks; 6) producer having personally experienced a Tier 1 disease on their operation; 7) producer having a neighbor who personally experienced a Tier 1 disease on their operation; 8) producer having more educational materials available to explain Tier 1 disease risks and the benefits of risk mitigating biosecurity measures; and 9) governmental indemnity payment eligibility requiring evidence of implementing Tier 1 disease risk mitigating biosecurity measures. These factors are mentioned in many discussions of biosecurity adoption and compliance (Hennessy, 2007a; Hennessy, 2008; Horan et al., 2010; Reeling and Horan, 2015; Wu et al., 2017).

Knowledge of all factors can help governing entities serve the current efforts aimed at increasing biosecurity adoption as well as identifying the factors not currently being addressed but are relatively import to adoption decisions and, thus, enabling more efficient resource allocation for the efforts to increase the adoption rate.

Biosecurity investment is an example of a private behavior that generates positive spillovers affecting the supply of a public good, that is, infectious disease prevention (Buchanan and Kafoglis 1963; Olson and Zeckhauser 1970; Reeling and Horan, 2014). This makes it less clear to tell who will benefit and who will pay for it in the supply chain. To gain corresponding expert insight, questions 5 and 6 were designed to help explain the perceived distribution of benefits and costs.

- *Q5: If biosecurity measures aimed at reducing Tier 1 disease risks were put in place industry-wide, how do you think the resulting benefits would be distributed through the pork industry's supply chain?*
- *Q6: If biosecurity measures aimed at reducing Tier 1 disease risks were put in place industry-wide, how do you think the resulting costs would be distributed through the pork industry's supply chain?*

For questions 5 and 6, respondents were asked to allocate the percentage (summing to 100%) each of the sectors incurs. Sectors of the pork industry's supply chain presented were sow/breeding, nursery, finishing, processors/packers, and retailers.

Survey procedure and data collection

The surveys were distributed by partner organizations, the National Institute for Animal Agriculture (NIAA) and the American Association of Swine Veterinarians (AASV). This sampling method relied on these two partner organizations to distribute the survey to their members or subscribers by using their own preferred means of communication. Participant recruitment was email list serves for NIAA members and online newsletters for AASV members. These communications included a link to the survey website and author-generated text describing the study. Partner groups were asked to send a reminder message three weeks after the initial recruitment notice. One of the authors attended the 2016 National Institute for Animal Agriculture Annual Meeting during the study period to describe the study and encourage participation.

In March and April of 2016, communication of the surveys was circulated to 778 NIAA members (226 registered in the 2016 NIAA Annual Conference and 552 past members) and 1,965 AASV members (1,350 U.S. members, 285 international members, and 330 student members). These NIAA and AASV members were asked to complete the survey best aligned with the industry they were most familiar and engaged with—swine, beef cattle, or dairy cattle. Respondents were also welcome to complete a survey for more than one industry.

Statistical analysis

Following Hobbs (1997), a censored Tobit regression model was used to estimate the relationship between the share of national adoption of a Tier 1 disease targeted biosecurity measure in the first year of a large Tier 1 disease outbreak and risk reduction and costs. The empirical model can be generalized as:

$$A^* = f(\text{firm's own risk reduction and closest neighbor's risk reduction}) \tag{1}$$

$$A^* = f(\text{fixed costs and variable costs}) \tag{2}$$

The share of national adoption in the survey took the values of 0%, 1%-10%, 11%-20%, 21%-30%, 31%-40%, 41%-50%, 51%-60%, 61%-70%, 71%-80%, 81%-90%, and 91%-100%. For this analysis we used the midpoint of each of the ranges. The dependent variable, A = share of national adoption, therefore took the values 0%, 5.5%, …, 95.5%.

The Tobit model censors the predicted dependent variable A such that:

$$A^* = B'X + e \tag{3}$$

$$A = 0 \text{ if } A^* \leq 0$$

$$A \;\; = A^{*} if \; 0 < A^{*} < \; 1$$

$$A \;\; = 1 \text{ if } A^{*} \geq 1$$

where X is a $n \times 1$ matrix of independent variables, B is a vector of coefficients to be estimated, and e is a normally distributed error term, $E[e] = 0$ and $E[e'e] = v^2$. Maximum likelihood procedures yield consistent coefficient estimates and asymptotic *t*-values (Judge et al., 1988).

The Tobit coefficients do not directly give the marginal effects of the associated independent variables on the dependent variable. However, their signs show the direction of change in the probability of adoption and the marginal intensity of adoption as the respective independent variables change (Amemiya, 1984; Goodwin, 1992; Maddala, 1985; Nkonya, Schroeder, and Norman, 1997). The effect of a change in the independent variable X on A^* cab be obtained from:

$$\partial E[A_i^{*}|X_i]/\partial x_i = BF_i[(B'X_i)/v] \tag{4}$$

where F_i is the cumulative distribution function of a standard normal random variable evaluated at $Z_i = X_iB/v$ (McDonald and Moffitt, 1980). The independent variables include a firm's own risk reduction and closest neighbor's risk reduction and fixed costs and variable costs.

Means were used to summarize the importance of factors influencing a producer's decision to adopt and implement new, additional biosecurity measures aimed at reducing Tier 1 disease risks during the first year of a large outbreak. Similarly, for the importance of factors affecting a producer's persistent compliance with biosecurity measures previously implemented for reducing Tier 1 disease risks, we used means to summarize and compare the overall (1 to 10 years after initial implementation), near-term (1 to 3 years), medium-term (4 to 6 years), as well as long-term (7 to 10 years) periods.

To compare the allocation of benefits and costs in each sector if biosecurity measures aimed at reducing Tier 1 disease risks were put in place industry-wide, we used *t*-tests assuming equal variances calculated using STATA (StataCorp LP, 2016).

Results

Response rate and respondent profile

Among the 2,743 experts approached to participate in the survey(s), 190 completed questionnaires—55 swine industry experts, 70 beef cattle industry experts, and 65 dairy cattle industry experts. However, some participants only partially completed the survey. The observation numbers for each question of interest are listed in Tables 1 through 5 and Figure 1.

The number of responses from experts with beef cattle, dairy, or swine experience were fairly even and geographically representative of the areas of highest concentrations of production. The swine experts most commonly interact with producers in states (GA, IA, IL, IN, KS, MN, NC, NE, OH, OK, TX) that represent 48% of U.S. swine operations and 84% of the U.S. hog inventory (USDA NASS, 2014). The beef cattle experts most commonly interact with producers in states (AL, AR, CA, CO, GA, IL, IA, KS, KY, MI, MS, MO, NE, ND, OH, OR, PA, TN, TX, VA, WA, WY) that represent 70% of U.S. beef cow operations, 67% of the U.S. beef cow inventory, 63% of U.S. cattle on feed operations, and 84% of the U.S. cattle on feed inventory (USDA NASS, 2014). The dairy experts most commonly interact with producers in states (AZ, CA, FL, IN, ID, MD, MI, MN, MO, NJ, NM, NY, OH, PA, TX, VA, VT, WA, WI) that represent 77% of U.S. dairy cow operations and 84% of the U.S. dairy cow inventory (USDA NASS, 2014).

The specific production segment most familiar to experts differs by industry. Eighty-four percent of dairy cattle experts most commonly interact with commercial operations, and the rest of the dairy cattle expert respondents most commonly interact with non-commercial operations. The beef cattle experts most commonly interact with cow-calf (79%), stocker (3%), feedlot (11%), and other operation (8%). Swine experts most commonly interact with farrow-finish (36%), farrow-wean (27%), feeder-finish (3%), wean-finish (9%), and other operations (24%).

Forecasts of biosecurity adoption

Table 1 presents summary statistics for the values employed in the risk reduction and investment cost survey questions. The mean for a firm's own risk reduction was 46%, 46%, and 50%, for the swine, beef cattle, and dairy surveys, respectively. The mean for their closest neighbor's risk reduction was 57%, 56% and 51%, respectively. Considerable variation was provided in these risk reduction values, ranging from 0% to 100% or so, allowing us to estimate how sensitive biosecurity adoption would be to risk reduction. The mean for one time, upfront implementation costs ($/operation) was $5,317, $4,406, and $3,799 and the mean for annual maintenance costs ($/animal/operation) was $2.97, $2.85, and $3.14 for the swine, beef cattle, and dairy surveys, respectively. Again, considerable variation was provided in these cost values allowing us to estimate how sensitive biosecurity adoption would be to fixed and variable cost impacts and the relative trade-off between the two cost components.

The mean response by experts giving a forecast of the share of national adoption of a Tier 1 disease targeted biosecurity measure in the first year of a large Tier 1 disease outbreak was the highest for the swine industry, lowest for the beef cattle industry, and intermediate for the dairy industry. Under varying levels of a firm's own risk reduction and their closest neighbor's risk reduction, the share of national adoption was forecast to be 65.8% in the swine industry, 47.2%

in the beef cattle industry, and 56.0% in the dairy industry (Table 2). When considering alternative levels of fixed and variable costs the forecasted share of national adoption was 56.0%, 36.3%, and 48.8% in the swine, beef cattle, and dairy industry, respectively (Table 3).

Tables 2 and 3 also present the marginal effects for the share of national adoption with respect to risk reduction and costs. It is important to note that the marginal effects are interpreted at the mean, thus for the average producer within the industry. Risk reduction was found to have a positive marginal effect on national adoption across the swine, beef cattle, and dairy industries (Table 2). Interpretation of the marginal effect estimates reveals that for every additional percentage point of a firm's own risk reduction experts forecast 0.25% higher adoption in the beef cattle industry of a Tier 1 disease targeted biosecurity measure in the first year of a large Tier 1 disease. Experts forecast 0.20% higher adoption in the dairy industry. The marginal effect on a firm's own risk reduction was not statistically significant for the swine industry responses. For every additional percentage point of their closest neighbor's risk reduction, they forecast 0.17%, 0.23%, and 0.18% higher biosecurity adoption in the swine, beef cattle, and dairy industry, respectively. There was found to be no statistically significant difference in the marginal effects between a firm's own risk reduction and their closest neighbor's risk reduction within each industry.

As expected, the marginal effects on fixed and variable costs on adoption were found to be negative (Table 3). For every additional $1,000 of one time, upfront implementation cost experts forecast 2% lower adoption in the beef cattle industry. This was slightly higher for the dairy industry responses at 3% lower adoption for every additional $1,000 of fixed cost. The marginal effect on fixed cost was not statistically significant for the swine industry responses. For every additional $1 of annual maintenance costs, experts forecast 5.1% lower biosecurity adoption in the swine. The marginal effects on annual maintenance cost was not statistically significant for the beef cattle and dairy industry responses. For the swine industry variable costs were found to have a larger impact than fixed costs on national adoption. No statistically significant differences were found between fixed and variable costs in the beef cattle and dairy industries.

Relative importance of factors affecting biosecurity adoption and compliance

Figure 1 displays expert opinions on the absolute and relative importance of nine factors to the adoption and implementation of new, additional biosecurity measures aimed at reducing Tier 1 disease risks in the first year of a large outbreak. It is in the form of a two-dimensional chart with nine factors represented by the node. The importance scores are represented on axes starting from 50, the central point. To summarize the common findings across the three industries, experts ranked a producer having personally experienced a Tier 1 disease on their operation and a producer’s view on their own likelihood of experiencing a Tier 1 disease given their own situation as generally being the most important factor to adoption. A producer having more educational materials available to explain Tier 1 disease risks and the benefits of risk mitigating biosecurity measures was commonly ranked lowest in importance.

The importance rankings are almost identical between the beef cattle and dairy industries across the nine factors except ongoing (recurring) monetary costs of implementation was ranked higher in the beef cattle industry. The importance ranking of a producer’s view on their own likelihood of experiencing a Tier 1 disease and a producer’s view on effectiveness in reducing Tier 1 disease risks are higher for the swine industry than beef cattle and dairy industries; while the importance ranking of governmental indemnity payment eligibility requiring evidence of implementing Tier 1 disease risk mitigating biosecurity measures and availability of governmental cost-share to reduce out-of-pocket expense are lower for swine industry than beef cattle and dairy industries.

Tables 4, 5, and 6 show the importance rankings for adoption of biosecurity measures during the first year of a Tier 1 disease outbreak and with respect to persistent compliance with biosecurity measures previously implemented for reducing Tier 1 disease risks. The importance rankings for persistent compliance are shown for the overall period (1 to 10 years after initial implementation), near-term (1 to 3 years), medium-term (4 to 6 years), and long-term (7 to 10 years).

When comparing the importance rankings for adoption of biosecurity measures during the first year of a Tier 1 disease outbreak to the average of 1 to 10 years after initial implementation one common theme arises across all three industries. Up-front fixed (one-time) monetary costs of implementation were found to be ranked more important (means statistically different at the 5%, 10%, 5% level for the swine, beef cattle, and dairy industry responses, respectively) to adoption in the first year of a Tier 1 disease outbreak than to compliance in subsequent years. This is intuitive as fixed costs (also known as sunk costs) are items that do not vary with level of use while variable costs change with use. For example, if a producer stops complying with a biosecurity measure previously implemented, variable costs will drop to zero, but fixed costs will remain essentially unchanged.

Supply chain allocation of benefits and costs of biosecurity implementation

Table 7 provides results of experts' perceptions concerning the allocation of benefits and costs when implementing biosecurity measures aimed at reducing Tier 1 disease risks industry-wide. Experts believe most of the benefits are distributed rather evenly, whereas they believe costs are largely born by the live animal production sectors. Benefits and costs were significantly different between the sectors within each industry except feedlots in the beef cattle industry. The significant gap between the benefits and costs for producers may outweigh the Tier 1 disease risks in influencing producers' willingness to invest in biosecurity implementation.

Discussion and Conclusion

How livestock biosecurity risk is perceived is paramount to agricultural policy makers. We used an expert survey to assess adoption of biosecurity measures for mitigating Tier 1 disease risks in the U.S. swine, beef cattle, and dairy industries. Two results from the expert surveys are of particular importance. First, the experts surveyed forecast national enhanced biosecurity adoption as limited in the livestock industries, mostly less than 50% in the first year of a large Tier 1 disease outbreak. Second, the survey indicates that additional biosecurity investment would likely bring benefits primarily to downstream sectors in the supply chain and producers would bare most of the costs. Thus, the reason for insufficient biosecurity adoption may be rational decision making reflecting the fact that producers lack economic incentives to adopt new biosecurity measures. One possible solution could be the creation of additional economic incentives to producers so that the share of national adoption would increase and the whole supply chain would benefit more.

Past research has shown that biosecurity can be considered a public good best managed by the government (for reviews, see Horan et al., 2010). Our survey indicates that upstream private farms (live animal segments) lack strong incentives to make investments with broader, public good benefits. While, the downstream firms may also lack incentives for biosecurity investments because asymmetric information on sick animals and daily biosecurity measures could exist between the upstream private farms and the other sectors in the supply chain. The economic incentives to the producers could be the increased live animal values.

This study analyzes expert opinions on factors that affect biosecurity adoption. The surveys indicate biosecurity adoption is positively related to risk reduction and negatively related to costs. Wu et al. (2017) has shown that some under-implemented biosecurity measures such like daily monitoring, maintaining separation lines, and daily observation were both useful and achievable. Our survey indicates that one reason behind the low implementation of the recommended biosecurity measures may be their corresponding costs. Another evidence driven by our expert surveys is that a firm weighs variable costs more than fixed costs when considering adopting biosecurity measures. One implication that our study provides is that variable-cost-share programs may work better than fixed-cost-share programs in new biosecurity adoption.

One important fact revealed by our survey is that firms care about their closest neighbor's risk reduction as much as their own risk reduction. During adverse events, past research suggests altruistic motives exist to help a neighbor reduce loss (Hoffman 1981; Smith 1986). At the same time, a producer might recognize that what helps his/her neighbor also helps himself/herself. The equality of a producer's view on the importance of own risk reduction and their closest neighbor's risk reduction should be taken as an assumption in biosecurity adoption incentive modeling research.

The survey indicates that the swine industry would have highest adoption of enhanced biosecurity measures in the first year of a large Tier 1 disease outbreak, and the beef cattle industry would have the lowest. The possible reasons behind the different forecasts of adoption across these industries is multifold. This ranking confirms with the rankings of animal density (measured by number of animal inventory within a geographic area) as the swine industry ranks the highest, dairy cattle industry in the middle, and beef cattle industry the lowest (USDA-NASS, 2012). Not surprisingly, the higher the animal density is, the riskier the animals are to diseases, and the higher the biosecurity adoption would be. Varied production marketing structures determine how animal disease risks and economic incentives are shared across the supply chain. Among these three industries, the swine industry is the most vertical integrated, followed by the dairy industry, and the beef industry is the least integrated (National Research Council, 1999). A small number of firms manage the U.S. swine production, while a large number of independent operations run the beef cattle and dairy productions (Ward 1997; Hayenga et al. 2000; Miller 2011).

Our survey shows that a producer’s view on their own likelihood of a Tier 1 disease experience and personal or neighbor’s past Tier 1 disease experience as more important than additional available educational materials in biosecurity investment decision making. It is likely that producers see Tier 1 disease as more probable if such experience exists around them. However, it is always “too late” to adopt biosecurity measures when a larger Tier 1 disease has already occurred. The last major swine disease outbreak was porcine epidemic diarrhea virus in 2014 and the last major cattle disease outbreak bovine spongiform encephalopathy in 2003. A more recent animal disease outbreak in the U.S. swine industry may also help explain why the biosecurity adoption rate is higher in swine industry than beef cattle and dairy industries. Moore et al. (2008) has reviewed over a hundred sources of available biosecurity educational materials. Our survey suggests that the marginal benefits of additional educational materials may be low. This provides implications to researchers and educators that additional traditional biosecurity recommendations for producers may not help improve current biosecurity adoption status.

Our survey indicates that the factors in a producer’s decision to long-term compliance biosecurity is as important as the first year new adoption except that the fixed costs matter more in the initial adoption. It means that biosecurity investment is a long-term investment that shortterm benefits may be unobservable. However, the lack of compliance may have adverse effects. This finding indicates that to improve long-term national biosecurity implementation, it requires persistent investments, and a one-time subsidy may make no difference. In addition, the support needed to achieve adequate biosecurity compliance can vary significantly by industry due to the variations in management and marketing structure.

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Table 1.1. Summary statistics of firm’s own risk reduction, closest neighbor’s risk reduction, one time, upfront implementation cost, and annual maintenance cost values employed in the survey questions

Survey Variable	Swine	Beef Cattle	Dairy
Firm’s own risk reduction, %			
Number of observations	39	48	43
Mean	46%	46%	50%
Std Dev	26%	31%	31%
Minimum	5%	0%	1%
Maximum	98%	100%	98%
Closest neighbor’s risk reduction, %			
Number of observations	39	48	43
Mean	57%	56%	51%
Std Dev	28%	32%	31%
Minimum	6%	0%	3%
Maximum	100%	100%	99%
One time, upfront implementation costs, $/operation			
Number of observations	38	48	43
Mean	$5,317	$4,406	$3,799
Std Dev	$3,238	$2,799	$2,554
Minimum	$247	$61	$331
Maximum	$9,873	$9,883	$8,813
Annual maintenance costs, $/animal/operation/year			
Number of observations	38	48	43
Mean	$2.97	$2.85	$3.14
Std Dev	$1.42	$1.46	$1.49
Minimum	$1.00	$1.00	$1.00
Maximum	$5.00	$5.00	$5.00

Table 1.2. Share of national adoption in the first year of a large Tier 1 disease outbreak of a biosecurity measure that reduces a firm's own risk and their closest neighbor's risk

Variable	Swine Industry Marginal Effect (Standard Error)	Beef Cattle Industry Marginal Effect (Standard Error)	Dairy Industry Marginal Effect (Standard Error)
Firm's own risk reduction	0.105 (0.093)	0.247*** (0.092)	0.196** (0.096)
Closest neighbor's risk reduction	0.165* (0.087)	0.234*** (0.089)	0.183* (0.093)
National adoption, %	65.8	47.2	56.0
Standard Deviation	[18.28]	[25.04]	[24.39)]
H_0: Firm's own risk reduction = Closest neighbor's risk reduction			
F-statistic	0.24	0.01	0.01
p-value	0.629	0.914	0.918
Number of observations	39	48	43

Notes: Estimated coefficient estimates are available on request. Likelihood ratio test (parameters equal to zero) was -165.93041 (p = 0.1078) for swine industry, -216.34376 (p = 0.0029) for beef cattle industry, -194.22915 (p= 0.0264) for dairy industry. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 1.3. Share of national adoption in the first year of a large Tier 1 disease outbreak of a biosecurity measure with varying one time, upfront implementation costs and annual maintenance costs

Variable	Swine Industry Marginal Effect (Standard Error)	Beef Cattle Industry Marginal Effect (Standard Error)	Dairy Industry Marginal Effect (Standard Error)
One time, upfront implementation costs	0.0004	-0.002**	-0.003**
	(0.001)	(0.001)	(0.001)
Annual maintenance costs	-5.082**	0.310	-1.403
	(2.165)	(1.770)	(2.003)
National Adoption, %	56.0	36.3	48.8
Standard Deviation	[23.24]	[23.05]	[26.52]
H_0: One time, upfront implementation costs = Annual maintenance costs			
t-statistic	5.69	0.03	0.49
p-value	0.0224	0.8607	0.4876
Number of observations	38	48	43

Notes: Estimated coefficient estimates are available on request. Likelihood ratio test (parameters equal to zero) was -170.26072 ($p = 0.0671$) for swine industry, -215.88554 ($p = 0.0981$) for beef cattle industry, -198.30123 ($p = 0.0424$) for dairy industry. Single, double, and triple asterisks (*, **, ***) indicate statistical significance at the 10%, 5%, and 1% level, respectively.

Table 1.4. Experts' importance ranking of factors in the decision to adopt and comply with biosecuirty measures aimed at reducing Tier 1 disease risks in the swine industry

Importance Ranking	Implement new, additional biosecurity measures aimed at reducing Tier 1 disease risks			Persistent compliance (e.g. rigorous, ongoing maintenance of effort over time) with biosecurity measures previously implemented for reducing Tier 1 disease risks											
	First year of a large outbreak			Overall 1 to 10 years after initial implementation			Near term 1 to 3 years after initial implementation			Medium term 4 to 6 years after initial implementation			Long term 7 to 10 years after initial implementation		
	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev
Up-front fixed (one-time) monetary costs of implementation	37	67.5[a]	22.6	34	53.5[a]	28.0	7	52.4	29.3	11	52.5	28.2	16	54.8	29.1
Ongoing (recurring) monetary costs of implementation	37	74.6	16.5	34	78.3	17.3	7	83.3	13.0	11	78.5	16.3	16	75.9	19.8
Availability of governmental cost-share to reduce out-of-pocket expense	37	68.3	25.5	34	69.1	23.8	7	69.6	20.7	11	65.4	29.2	16	71.5	22.0
Producer's view on their own likelihood of experiencing a Tier 1 disease given their own situation	37	82.4	17.3	34	84.5	12.5	7	77.9	16.9	11	88.3	12.0	16	84.8	10.2
Producer's view on effectiveness in reducing Tier 1 disease risks	37	79.0	16.2	34	84.1	11.5	7	82.7	13.1	11	85.5	10.2	16	83.8	12.3
Producer having personally experienced a Tier 1 disease on their operation	37	80.8	25.6	34	83.9	18.6	7	88.4	14.1	11	76.6	26.2	16	87.0	13.0
Producer having a neighbor who personally experienced a Tier 1 disease on their operation	37	78.1	15.6	34	73.0	18.6	7	73.9	21.9	11	75.8	23.1	16	70.6	14.2
Producer having more educational materials available to explain Tier 1 disease risks and the benefits of risk mitigating biosecurity measures	37	60.3	22.4	34	52.8	25.1	7	54.1	22.7	11	52.7	30.7	16	52.3	23.4
Governmental indemnity payment eligibility requiring evidence of implementing Tier 1 disease risk mitigating biosecurity measures	37	68.8	23.6	34	65.0	24.1	7	57.7	20.4	11	68.1	28.7	16	66.1	23.0

Notes: Importance scale (0 = not important; 100 = utmost importance). [a] means statistically different at the 5% level.

Table 1.5. Experts' importance ranking of factors in the decision to adopt and comply with biosecuirty measures aimed at reducing Tier 1 disease risks in the beef cattle industry

Importance Ranking	Implement new, additional biosecurity measures aimed at reducing Tier 1 disease risks			Persistent compliance (e.g. rigorous, ongoing maintenance of effort over time) with biosecurity measures previously implemented for reducing Tier 1 disease risks											
	First year of a large outbreak			Overall 1 to 10 years after initial implementation			Near term 1 to 3 years after initial implementation			Medium term 4 to 6 years after initial implementation			Long term 7 to 10 years after initial implementation		
	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev
Up-front fixed (one-time) monetary costs of implementation	45	65.8[a]	20.2	42	57.0[a]	28.5	11	66.4	21.3	15	52.8	23.8	16	54.6	36.0
Ongoing (recurring) monetary costs of implementation	46	73.7	19.5	42	75.0	20.1	11	75.9	13.0	15	68.6	25.1	16	80.4	18.2
Availability of governmental cost-share to reduce out-of-pocket expense	46	71.9	20.0	42	72.7	18.0	11	75.5	12.1	15	73.9	16.3	16	69.6	22.7
Producer's view on their own likelihood of experiencing a Tier 1 disease given their own situation	46	73.8	22.8	42	76.5	23.4	11	85.0	15.8	15	70.7	27.5	16	76.1	23.3
Producer's view on effectiveness in reducing Tier 1 disease risks	46	73.8	20.0	42	70.6	20.4	11	75.7	15.4	15	67.3	20.4	16	70.1	23.7
Producer having personally experienced a Tier 1 disease on their operation	46	82.6	24.0	42	86.8	15.9	11	89.5	20.7	15	83.7	13.4	16	87.8	14.8
Producer having a neighbor who personally experienced a Tier 1 disease on their operation	46	76.1	19.1	42	72.4	20.7	11	77.8	26.4	15	70.9	17.8	16	70.1	19.5
Producer having more educational materials available to explain Tier 1 disease risks and the benefits of risk mitigating biosecurity measures	46	58.8	23.8	42	48.2	22.7	11	52.2	21.8	15	49.9	19.8	16	43.9	26.4
Governmental indemnity payment eligibility requiring evidence of implementing Tier 1 disease risk mitigating biosecurity measures	46	72.4	21.2	42	72.3	20.3	11	78.9	14.7	15	74.7	19.6	16	65.6	23.1

Notes: Importance scale (0 = not important; 100 = utmost importance). [a] means statistically different at the 10% level.

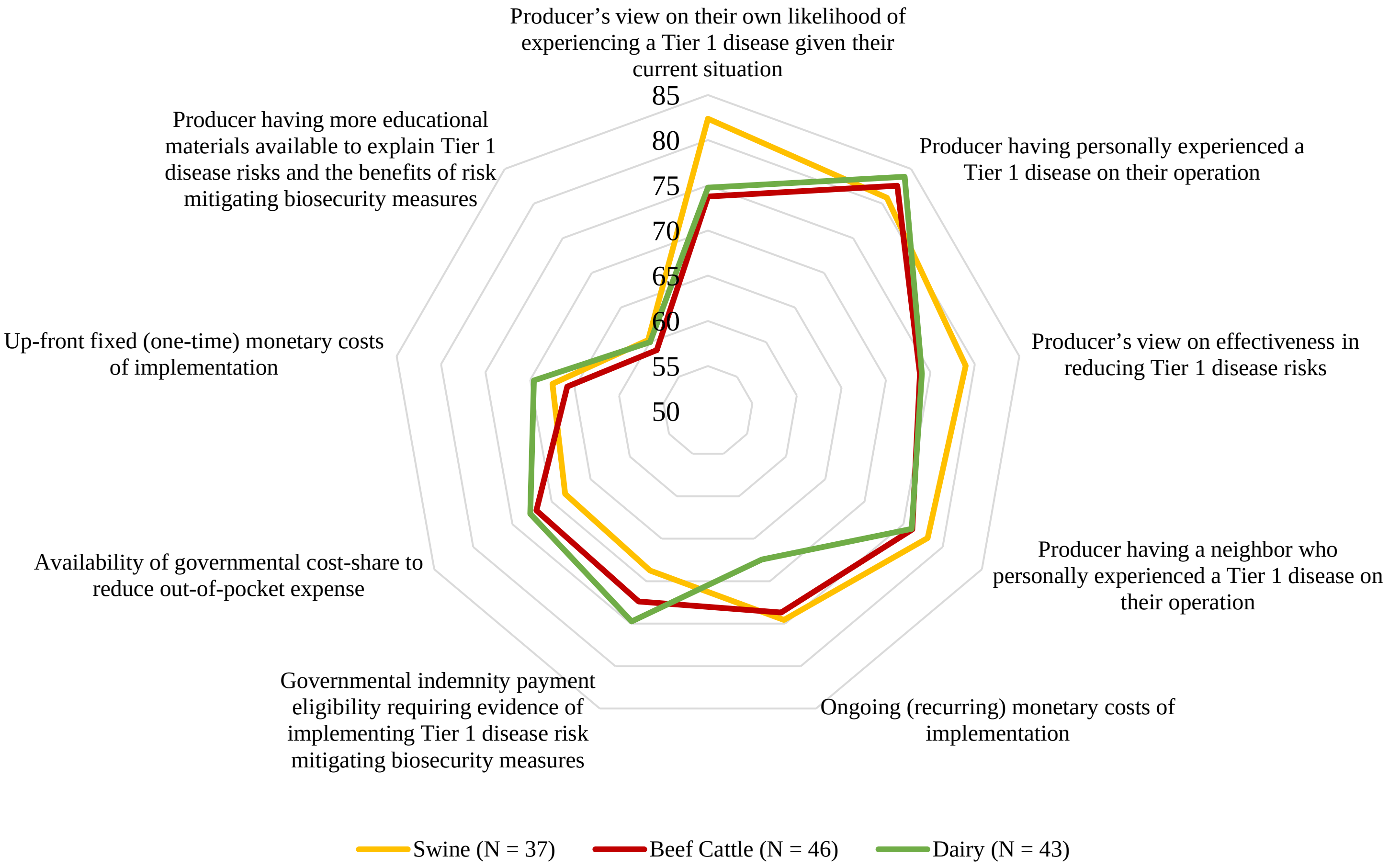
Table 1.6. Experts' importance ranking of factors in the decision to adopt and comply with biosecuirty measures aimed at reducing Tier 1 disease risks in the dairy industry

Importance Ranking	Implement new, additional biosecurity measures aimed at reducing Tier 1 disease risks			Persistent compliance (e.g. rigorous, ongoing maintenance of effort over time) with biosecurity measures previously implemented for reducing Tier 1 disease risks											
	First year of a large outbreak			Overall 1 to 10 years after initial implementation			Near term 1 to 3 years after initial implementation			Medium term 4 to 6 years after initial implementation			Long term 7 to 10 years after initial implementation		
	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev
Up-front fixed (one-time) monetary costs of implementation	43	69.6[a]	19.9	40	57.0[a]	25.5	13	49.0	28.8	14	56.2	22.5	13	65.8	24.2
Ongoing (recurring) monetary costs of implementation	43	67.5	22.7	40	71.9	22.6	13	73.2	21.2	14	74.6	21.7	13	67.7	26.0
Availability of governmental cost-share to reduce out-of-pocket expense	43	72.7	19.3	40	72.6	21.3	13	74.8	23.9	14	69.5	20.3	13	73.7	21.0
Producer's view on their own likelihood of experiencing a Tier 1 disease given their own situation	43	74.7	20.5	40	80.4	16.1	13	85.3	13.6	14	75.3	20.5	13	81.0	12.0
Producer's view on effectiveness in reducing Tier 1 disease risks	43	74.0	19.1	40	79.0	18.2	13	81.5	12.3	14	78.6	21.0	13	76.8	20.8
Producer having personally experienced a Tier 1 disease on their operation	43	83.9	22.5	40	84.8	20.1	13	84.5	18.7	14	83.7	20.6	13	86.3	22.5
Producer having a neighbor who personally experienced a Tier 1 disease on their operation	43	76.0	22.2	40	73.0	22.6	13	62.3	30.0	14	80.6	14.7	13	75.5	17.9
Producer having more educational materials available to explain Tier 1 disease risks and the benefits of risk mitigating biosecurity measures	43	60.0	21.3	40	55.1	22.8	13	54.9	27.5	14	54.3	23.0	13	56.1	19.0
Governmental indemnity payment eligibility requiring evidence of implementing Tier 1 disease risk mitigating biosecurity measures	43	74.7	19.5	40	76.6	18.7	13	75.1	22.5	14	75.0	19.2	13	79.8	14.3

Notes: Importance scale (0 = not important; 100 = utmost importance). [a] means statistically different at the 5% level.

Table 1.7. Summary statistics of expert views on resulting benefits and costs if biosecurity measures aimed at reducing Tier 1 disease risks were put in place industry-wide

Industry	Sector	N	Benefits, %	Costs, %	t	p-value
Swine	Retailers	33	13	4	3.40	0.00
	Processors	33	20	8	4.61	0.00
	Finishing	33	19	23	-2.13	0.04
	Nursery	33	15	21	-3.95	0.00
	Sow/Breeding	33	33	44	-3.72	0.00
Beef Cattle	Retailers	41	17	6	4.64	0.00
	Processors	41	18	11	3.58	0.00
	Feedlot	41	29	31	-0.95	0.35
	Stocker/Backgrounder	41	17	23	-4.93	0.00
	Cow Calf	41	19	29	-4.41	0.00
Dairy	Retailers	38	20	9	4.44	0.00
	Processors	38	26	18	3.74	0.00
	Dairy Producer	38	54	73	-5.52	0.00



Importance scale (0 = not important; 100 = utmost importance)

Figure 1.1. Experts’ importance ranking of factors in a typical producer’s decision to adopt and implement new, additional biosecurity measures aimed at reducing Tier 1 disease risks in the first year of a large outbreak

CHAPTER 2. LEFT BRAIN, RIGHT BRAIN: DIFFERENTIAL BRAIN ACTIVITY BETWEEN DEMOCRATS AND REPUBLICANS WHEN THINKING ABOUT FOOD PURCHASES

Abstract

We studied brain activity using a functional magnetic resonance imaging (fMRI) whole-brain analysis while healthy adult Democrats and Republicans make non-hypothetical food choices. While the food purchase is not significantly different, we find that brain activation in distinct regions differs by a subject's political affiliation during the choice. Republicans exhibit stronger activities in left brain regions while Democrats show more activation in regions of the right hemisphere. Single variable models of partisanship based on left insula or premotor/supplementary motor area activations achieve better accuracy in predicting participants' political views than a political ideology questionnaire.

Introduction

Because political ideology influences day-to-day perceptions of many issues, it follows that it may also influence food perceptions and economic decisions. Specifically, this study examined if adults who self-identify as Democrat or Republican can be predicted based not on the foods they purchase, but on their *brain activity* when making those purchases. While we answer this question in the affirmative, we also show that the food the two groups choose do not differ. In other words, while brain activations differ when the food is considered, and those differences are significant enough to allow us to predict which consumer is a Republican and which a Democrat, the food the subject chose does not allow us to make that distinction. In brief, it is not the food you buy that predicts your politics, but *how you think* about the food when you buy it.

Neuropsychological and neuroimaging research has explored brain differences between Republicans and Democrats in various socio-political experiments including face judgment, partisanship, motivated reasoning, political interest, political attitudes, and automatic processing of political preferences (for a review of the literature see Krastev et al. 2016). Schreiber et al. (2013) show that the evaluation processes in the brain in a non-social, non-political, risk-taking lottery experiment are distinct between Republicans and Democrats. Yet, what about more day-to-day decisions? Will brain differences that can predict political affiliation still exist if the experimental stimulus is something as simple as a single item food purchase?

The brain regions commonly found to be associated with political attitudes and behavior are the amygdala (Knutson et al. 2006; Gozzi et al. 2010; Rule et al. 2010; Kanai et al. 2011; Krosch et al. 2013), the insula (Westen et al. 2006; Kaplan et al. 2007; Krosch et al. 2013; Schreiber et al. 2013), the anterior cingulate cortex (Westen et al. 2006; Amodio et al. 2007; Kaplan et al. 2007; Kanai et al. 2011), the ventromedial prefrontal cortex (vmPFC) (Knutson et al.

2006; Mitchell et al. 2006; Zamboni et al. 2009), the dorsomedial prefrontal cortex (dmPFC) (Mitchell et al. 2006; Zamboni et al. 2009), the dorsolateral prefrontal cortex (dlPFC) (Kaplan et al. 2007; Kato et al. 2009; Zamboni et al. 2009), and the ventral striatum (Westen et al. 2006; Zamboni et al. 2009; Gozzi et al. 2010; Tusche et al. 2013). Tusche et al. (2013) suggest that partisan bias may operate even in the absence of explicit attention to political content, yet few studies have examined the link between political ideology, brain activity, and non-political content in experiments. Of studies related specifically to food, Haidt (2008) and Sayre (2011) indicate that food *preferences* may reveal political preferences, and Lusk (2012) shows that there are strong ideological leanings in support of or opposition to a host of food policies. Our interest is not related to the revealed *preferences* of the food, but, as discussed in Sayre (2011), how the *process* of thinking about food reveals political identity.

For this study, we examined two sets of healthy adult participants in separate experiments. One group made food purchase decisions about milk and the other group made purchase decisions about eggs. The impetus for these food groups was that milk and egg products are so commonly purchased that consumers who purchase them likely have long-established preferences. This study contributes significantly to the area of brain differences between Democrats and Republicans related to a social, but non-political task – food valuation.

Methods

Participants

One hundred healthy, right-handed, English-speaking, non-vegan, non-lactose intolerant adult participants (ages 18-55; mean = 31 years; 49 females) from the Kansas City metropolitan area underwent fMRI scanning at the Hoglund Brain Imaging Center at the University of Kansas

Medical Center on a 3-T Skyra (Siemens, Erlangen, Germany) scanner. The study collected political, demographic, biometric, and psychographic information from all participants. Seven participants dropped out during the fMRI scanning. 28 participants stated their political affiliation as non-affiliated or other party and their data were excluded. In the end, this study analyzed 65 participants, among which 40 were Democrats, and 25 were Republicans.

Experiments

Two separate experiments were performed: a milk-choice experiment and an egg-choice experiment. For the milk experiment, participants underwent fMRI scans and completed 84 non-hypothetical, binary choices between two milk product images labeled with various prices and the production technologies used. Likewise, for the egg experiment, participants underwent fMRI scans and made 84 non-hypothetical, binary choices between two product images of a dozen eggs labeled with prices and production methods. Participants were given $50 and told that they would be given one of the products they chose during the experiment, with the price of the choice deducted from the payment. In both experiments, participants went home with one of their choices (milk or eggs).

We presented participants choices where the images showed either a "conventional" product or a product produced using an "alternative" production practice. The labels on the images differed according to three experimental conditions for the 84 choices: (*a*) 28 choices were in the "price condition," in which two products were produced with the same technology, but the prices varied (between $3 and $7 in $0.50 increments in the milk experiment, and between $0.99 and $4.99 in $0.50 increments in the egg experiment); (*b*) 28 choices were in the "technology/method condition," in which one of the milk products was labeled as either "from a cloned cow" or using "artificial growth hormone," and one of the egg products was labeled as coming from hens that were either “caged hens” or “confined hens.” The other choice was offered at the same price and was produced in the conventional manner. In the case of milk, the label indicated it came from a “non-cloned cow” or with “no added growth hormone.” In the egg choice, this conventional method was either “cage-free” or “free-range;” and, finally, (*c*) the remaining 28 choices were in the “combination condition,” in which the product with a higher price was conventional milk or eggs from hens that were not confined, and the product with a lower price was milk produced using the alternative technology or eggs produced from confined hens.

The pricing used in the combination condition was chosen because non-confinement practices would raise prices for eggs but growth hormone or cloning would lower prices for milk. The combination experiment is the method considered to be the most realistic, as shoppers must decide upon competing products based on a combination of changing factors. Each choice pair remained on the visual monitor until the participant made a decision. Following each choice, participants were presented with a confirmation screen indicating which selection they had made. The time to make a decision varied both across and within participants’ choices. In order to obtain a consistent image, the confirmation screen was presented no less than 0.5 seconds but no more than 3.5 seconds after the participant made a choice. There were two functional runs in which participants made 42 choices (84 total choices). A fixation cross was presented for 3–15 seconds to jitter the inter-trial interval. Optimal timing of trials was estimated using an Analysis of Functional Neuroimage (AFNI) stimulus timing program (make_random_timing.py) to minimize collinearity issues in the fMRI analysis. The order of presentation of choices from the three conditions was randomized in each experiment.

To better simulate shopping behavior, we used images of standard, plastic-gallon jugs for the milk experiment. Milk from cloned cows had been approved by the FDA, but was not on the market at the time of data collection. Milk from cows with artificial growth hormone is available but has proven unpopular (Pollack 2006). In the egg experiment, all of the production practices presented to the participants currently exist in the marketplace. We used images of standard one-dozen sized cartons that differed only in the price or technology/method label. Figure 1 provides an example of the types of images that participants saw in the two experiments.

Along with self-reporting their political party, all participants also answered questions developed to elicit their political ideology indirectly. Specifically, we used 12 questions from the *Political Ideology Questionnaire* (PIQ; Grenier 1998) as shown in the top of Table 1. Participants ranked each of the 12 questions in the PIQ from 1= “Totally disagree” to 10= “Totally agree.” Some questions are more nuanced than others and although no question can be seen as eliciting a strictly liberal or strictly conservative response (Grenier 1998 developed the PIQ to understand ideological leanings, not party affiliation), lower aggregated rankings tend toward more liberal political philosophies and higher aggregated rankings tend toward more conservative philosophies and, in the United States, conservatives tend toward Republican affiliation and liberals tend toward Democrat affiliation.[3] The aggregated rankings were found to show statistically significant differences between Republican and Democrat participants in terms of average scores in each food-choice experiment. The bottom of Table 1 provides the summary statistics for each experiment related to the PIQ.

fMRI data acquisition

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[3] Gallup polls finds between 30% and 44% of Democrats self-identified as liberal between 2001 and 2016 versus 5-8% of Republicans. Conversely, between 57% and 63% of Republicans self-identified as conservative over this period while 15% to 23% of Democrats called themselves conservative (Gallup 2017).

Functional MRI data were analyzed using the BrainVoyager QX statistical package with random effects (Brain Innovation, Maastricht, Netherlands, 2004). Following Martin et al. (2010), preprocessing steps included trilinear 3D motion correction, sinc-interpolated slice scan time correction, 3D spatial smoothing with 4-mm Gaussian filter, and high-pass filter temporal smoothing. Functional images were realigned to the anatomical images obtained within each session and standardized using BrainVoyager Talairach transformation, which conforms to the space defined by Talairach and Tournoux's (1988) stereotaxic atlas. Functional scans were discarded if participants moved more than 4 mm along any axis (x, y, or z). Two runs were discarded due to excess motion, and three participants were unable to complete the task, leaving a total of 92 runs. As in Moll et al. (2002) and Martin et al. (2010), activation maps were analyzed using the parametric statistical methods of Friston et al. (1994).[4] Blood oxygenation level-dependent (BOLD) activations during the choices were conducted using multiple-regression analysis (general linear model). Motion parameters were included as nuisance regressors. For the first-level analysis, regressors representing the decision phase (i.e., stimulus onset time to participant choice with an average duration of 2.7 seconds) for the experimental conditions of interest (e.g., price, technology, and combination) were modeled with a hemodynamic response filter and entered into the multiple-regression analysis using a random-effects model. In addition, the feedback phase (i.e., confirmation of feedback, 0.5 seconds) was included as a regressor of no-interest. Regressors were modulated for the decision duration. However, there was no amplitude modulation or orthogonalization. Mean percent signal change values were extracted for each individual for each condition as described below to examine associations between product choices for each experiment.

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[4] The methods are components of the BrainVoyager QX software.

No studies have examined the influence of political preferences on food choices during a neuroimaging experiment. As such, we had no specific a priori regions of interest related to politics during our food choice experiment. We therefore conducted a whole-brain analysis contrasting differences between self-reported Republicans and Democrats in blood oxygenation level-dependent (BOLD) activations from the price choices, technology choices, and combination choices. In this analysis, we subtracted the BOLD activation in the baseline condition averaged across voxels in the cluster of the whole-brain analysis from the choice (price, production method, or combination) condition. This removes the fixation effect so that the remaining BOLD activation would be consistent across participants. We further used a contrast method of two different tasks for extracting the BOLD activation and used Monte Carlo simulation to determine a threshold for 14 voxels ($k = 14$) at $p < 0.05$ and alpha of 0.01. This family-wise error correction creates a more conservative determination of statistical significance.[5]

Results and Discussion

Summary statistics for behavioral choice data

Table 1 shows Republicans had significantly different PIQ results than Democrats ($p < 0.01$) suggesting the two groups' political ideologies do differ. The summary results of the food choices are given in Table 2. For the milk and egg tradeoff choices, *there is no significant difference* between Republicans and Democrats in the average number of choices for the various milk or egg decisions. Thus, unlike the PIQ, food choice does not reveal political party in these

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[5] Eklund et al. (2016) discuss inference issues in fMRI analyses. Along with our more conservative measures of the BOLD variables, as fMRI studies go, we also have a relatively large sample size in each experiment. To check for spurious BOLD extraction, we further test the significance of our BOLD variables in a regression model of political affiliation.

experiments. Sayre (2011) argues that it is not the food choice that reveals political differences, but *how* one makes decisions about food. A finding of significantly different brain activation by political party during the decision-making process, may suggest that the participants are using different thought processes when presented with the choices.

Whole-brain analysis

Table 3 shows the brain regions (with associated Brodmann areas) where there were significant differences between Republicans and Democrats in each experimental condition ($p < 0.05$). An intriguing finding is that brain areas showing significantly stronger activation for Republicans per experimental condition were *all* located in the left hemisphere of the brain, while those with stronger activities for Democrats were *all* located in the right hemisphere. To see how unusual this pattern is, assume that the probability of activation in the left hemisphere/right hemisphere is 0.5. Then to be able to take one piece of information from each participant, their political affiliation, and correctly predict the side that is activated would be equivalent to predicting the correct outcome from 65 coin tosses. This is 0.5^{65} or 2.71051×10^{-20}. Previous research has shown that areas of the left hemisphere are important for order and reason and self-motivated behavior, such as controlling routines, while the right hemisphere uses regions that specialize in environmentally-motivated behavior processing (Gazzaniga 1998; MacNeilage et al. 2009).

Three of the areas listed in table 3 are of less interest for the present work because of the lack of research linking these areas to issues of self-reflection, rationalization, emotion, politics, food choices, or behavioral or economic valuation. These areas are the middle temporal gyrus, the parahippocampus, and the superior temporal lobe. All three of these were active during the milk experiment only. The parahippocampus cortex is known to be associated with memory, especially encoding and retrieval of visual scene stimuli such as landscapes (Aminoff, Kveraga and Bar

2013). The middle temporal gyrus and the superior temporal lobe are known to be important to the comprehension and recognition of words (Booth et al. 2002). Harpaz et al. (2009) also suggest that the superior temporal lobe plays a role in processing the subordinate meanings of ambiguous words. In the milk experiment, the labels informed participants of the usage of cloning and hormones, which are arguably more ambiguous than the cage/cage-free type labels in the eggs experiment. Because of the lack of related research linking these regions to areas other than word or image recognition, we are inclined toward skepticism as to their usefulness as general indicators of political preferences.

Of the remaining five areas in table 3, we will focus on the ventromedial prefrontal cortex, the insula, the premotor/supplementary motor area, the precuneus, and the superior frontal gyrus. Figures 2 and 3 illustrate examples of two of these five areas. The locations showing significantly different brain activation by political party are in color. Figure 2(a) shows the significant activation observed in the left ventromedial prefrontal cortex (vmPFC) for the milk technology condition relative to the baseline condition. The vmPFC is a region involved in processing and evaluation (Ruff and Fehr 2014), associated with self-reflection and self-referential processing (Kelley et al. 2002; Macrae et al. 2004), as well as an area related to valuation of items, monetary or otherwise (Levy and Glimcher 2012) and has been implicated in previous research on politics (Knutson et al. 2006; Mitchell et al. 2006; Zamboni et al. 2009).

The tradeoff decision-making (the “combination condition”) is the most similar to real-life decisions where labels and prices vary among food choices. As table 3 shows, the left insula (also in Figure 2(b)) shows significantly stronger activity in Republicans than Democrats in the milk combination condition relative to the baseline condition. Bartra et al. (2013) find that the left insula is associated with a person’s subjective valuation of a good. Insula activity has been found to be an experience-value signal, also associated with pain (Ruff and Fehr 2014) and disgust (Wicker et al. 2003). The neuropolitics literature shows that the insula is active during conditions of in-group bias (Westen et al. 2006; Kaplan et al. 2007) and political conservatism (Kanai et al. 2011; Krosch et al. 2013).

In the egg tradeoff choice condition, activity in the precuneus and superior frontal gyrus (Figure 3(a)) is significantly stronger in Democrats than Republicans. The precuneus is involved with episodic memory (Lundstrom et al. 2003) but also reflections upon oneself that involve judging one's personality traits relative to those of other people (Kjaer et al. 2002; Lou et al. 2004). The superior frontal gyrus is used in episodic memory as well, along with working memory and multiple-task coordination (Gilbert et al. 2006). As humans evolved, the superior frontal gyrus expanded relative to the rest of the brain, and it is the largest cytoarchitectonic region in the human brain (Semendeferi et al. 2001). However, it is also "one of the least well-understood regions of the human brain," according to Ramnani and Owen (2004).

Figure 3(b) illustrates significantly greater activation observed in the left premotor area (PMA)/ supplementary motor area (SMA) for Republicans than for Democrats for the egg method condition relative to the baseline condition. Our finding may complement Amodio et al. (2007) who used a habitual-tendency Go/No-Go task, finding greater liberalism associated with more responsiveness to new, unexpected, conflicting information, and stronger anterior cingulate activity.

It is finally worth noting that neither Republicans nor Democrats have statistically significant differences in amygdala activity in our study, even though previous studies had shown differences between liberals and conservatives in this particular brain area (Knutson et al. 2006; Gozzi et al. 2010; Rule et al. 2010; Kanai et al. 2011; Krosch et al. 2013). One reason may be that previous studies used images that provoked stronger emotional reactions such as images of politicians. Our experiment portrayed food images for which only text labels and prices on the images differed. Food labels and prices may serve as cognitive information signals, especially in the milk experiment.[6] The amygdala is not as involved in the higher-level cognitive functions like conceptual associations (Jost et al. 2014), but is involved with emotional responses and subsequent decisions.

Logit model predicting political views

If activity that was significantly associated with Republican-Democrat differences in food decision-making in the whole-brain analysis were correctly identified, then that activity should predict the political views of the subject in the study. To make such predictions, we utilize a logit model:

$$\Pr(Y_i = 1 \mid X_i) = \frac{\exp(\alpha_i + X_i\beta)}{1 + \exp(\alpha_i + X_i\beta)}$$

where, $Y_i = 1$ means that participant i is a Republican and $Y_i = 0$ means that participant i is a Democrat. We test the prediction of party affiliation using the PIQ against the brain data of the five BOLD variables of interest from the whole-brain analysis.[7]

Table 4 displays the results of seven binary logit regression models that predict whether an individual is a Republican or Democrat. We wish to compare political affiliation from brain activity with political affiliation identification from the PIQ. A random model would have a 50%

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[6] Kolodinsky (2008) finds that artificial hormone-free milk labels serve as cognitive information signals instead of feeling signals.

[7] We also tested alternative participant-specific variables against the PIQ. We examined logit regressions using age, gender, IQ, religion, income, education, marital status, food neophobia, and food technology neophobia. None of these alternative models predicted political party better than the PIQ. These results are available from the authors.

chance of predicting political party without knowing the sample distribution. Our models will do better if there is information in the included variables. Models 1-3 use only the PIQ as a predictor (note model 1 is for all 65 participants and models 2 and 3 are the same model using the subjects from the milk or egg experiment), while models 4-7 utilize the whole-brain analysis to predict the subject's political view. Models 4-7 use the five areas of interest from the whole-brain analysis.

In general, we find that all 7 models do better than a random guess and find that it is harder to predict Republicans than it is to predict Democrats. The PIQ model beats a coin flip with an overall correct prediction rate of 77%. The PIQ discerns Republicans at a 62% rate and does much better predicting Democrats (86% of the time). The PIQ models 1 and 3 do slightly better than models 4 and 5 in predicting Democrats, but worse at predicting Republicans. PIQ Model 2 (milk experiment) does worse than all other models in each measure. Models 6 and 7 do better than or just as well as the other models overall. Model 3 and model 7 from the eggs experiment do best in predicting party affiliation (model 3 has the lowest AIC). These findings suggests that political orientation might be partially rooted in basic neurocognitive mechanisms that occur even when the choices are non-political.

Specifically, Model 4, which uses left insula activity in the milk combination condition relative to the baseline condition, achieves a prediction accuracy of 78%. Compared with model 4, model 5 adds the vmPFC activity in the milk technology condition relative to the baseline condition. However, model 5 does not improve the overall rate of correct predictions compared with model 4, even though research commonly finds that the vmPFC is different in liberals and conservatives (Mitchell et al., 2006; Knutson et al., 2006; Zamboni et al., 2009). Model 6 includes as predictors the areas examined in whole-brain analysis in the egg combination condition relative to the baseline condition and identifies 91% of Democrats correctly. Model 7, which uses a single brain activity variable from the egg production experiment, not only achieves the highest rate of correct predictions (85%) for political affiliation, but also a tie (with model 3) for the highest rate for identifying Democrats and the highest rate for identifying Republicans (91% and 73%, respectively).

Conclusion

We found that when making non-hypothetical economic decisions about food, Republicans show greater neural activity than Democrats in regions in the left side of the brain, and Democrats have greater neural activity than Republicans in the right side of the brain. Decisions made by Republicans and Democrats are the same, but the neurofunctional activity differs. How this brain activity differs allows us to predict a person's self-reported political party.

A whole-brain analysis revealed that certain regions of interest showed significant differences between Republicans and Democrats when participants made food decisions concerning milk and eggs. Along with using a very conservative extraction for our BOLD variables, we also used these variables to predict the political affiliation of the participants from whom they were gathered. Not only do our collected BOLD variables correctly predict political affiliation 78-85% of the time, they perform as well as, and in most cases better than, a model using a test of political ideology that was administered to the participants. The finding that political leanings can be gleaned from a brain scan during a food purchase unrelated to politics adds to the study of politics in neuroscience. Economists teach that our choices for any product are guided by our underlying utility. Political ideology may be one dimension of that utility that may not reveal itself in the product that is purchased, but may reveal itself in the brain when choosing that product.

The decisions we studied involved routine economic decision making where participants allocated dollars to purchase milk or eggs. Future research should explore whether these results can be applied to economic decision making more broadly.

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Table 2.1. Political Ideology Questionnaire (PIQ) & Summary Statistics of Democrats and Republicans in Both Experiments.

Political Ideology Questions. Participants Ranked Questions from 1=Strongly Disagree to 10=Strongly Agree.

1. It is better to keep things the way they are.
2. People are essentially selfish and need to be controlled.
3. Individuals have free will and are responsible for their own lives and problems.
4. The traditional family (married father and mother with children) must be preserved at all costs.
5. Government regulations are needed to control monopolies.
6. A free market economy (no business regulations) is the best way to ensure prosperity and fulfillment of individual needs.
7. Sometimes revolutions are necessary.
8. This country would be better off if most government programs were eliminated.
9. People are basically good, but they can be corrupted.
10. The free market economic system is basically exploitive and inherently unfair to working people.
11. Helping the poor encourages laziness.
12. If the rich continue to get richer, and the poor continue to get poorer, I would support a violent revolution to correct the inequality.

PIQ	Obs	Mean	Std. Dev.	t	p
Milk experiment					
Democrats	18	59	12.9	-3.15	0.00
Republicans	14	71	8.6		
Egg experiment					
Democrats	22	56	8.8	-4.32	0.00
Republicans	11	71	9.6		

Table 2.2. Summary Statistics of Choices Made in the Milk and Egg Combination Experiments.

Tradeoff choices	Mean	Std. Dev.	t	p-value
Cloned milk				
Democrats (N=18)	6.2	6.3	-0.40	0.69
Republican (N=14)	7.1	5.7		
Growth-hormone milk				
Democrats (N=18)	5.2	6.5	-1.11	0.28
Republican (N=14)	7.6	5.8		
Cage-free eggs				
Democrats (N=22)	8.1	5.1	0.71	0.48
Republican (N=11)	6.7	6.0		
Free-range eggs				
Democrats (N=22)	8.2	5.0	0.61	0.55
Republican (N=11)	7.0	5.8		

Table 2.3. Results from Whole-brain Analysis: BOLD Responses to Contrasts of Interest (p<0.05).

Brain Region	*Max voxel coordinates*				
	X	*Y*	*Z*	*t*	*Cont. voxels*
Milk price decision vs. Baseline contrast: Republicans > Democrats					
(L) Middle temporal gyrus, BA 21	*-68*	*-50*	*0*	*4.09*	*25*
Milk technology choice vs. Baseline decision contrast: Republicans > Democrats					
(L) Ventromedial PFC, BA 10	*-1*	*55*	*-12*	*3.78*	*14*
(L) Parahippocampus, BA 36	*-31*	*-29*	*-18*	*4.1*	*34*
(L) Superior temporal lobe, BA 13	*-55*	*-41*	*18*	*4.3*	*16*
Milk combination tradeoff decision vs. Baseline contrast: Republicans > Democrats					
(L) Insula, BA 13	*-31*	*19*	*12*	*4.66*	*17*
(L) Superior temporal lobe, BA 22	*-64*	*-38*	*15*	*4.34*	*17*
Egg method choice vs. Baseline decision contrast: Republicans > Democrats					
(L) premotor/supplementary motor area, BA 6	*-1*	*-17*	*60*	*3.79*	*16*
Egg combination tradeoff decision vs. Baseline contrast: Republicans < Democrats					
(R) Precuneus, BA 7	*20*	*-62*	*36*	*-3.98*	*18*
(R) Superior frontal gyrus, BA 10	*20*	*55*	*21*	*-4.9*	*24*

Notes: BA = Brodmann Area.

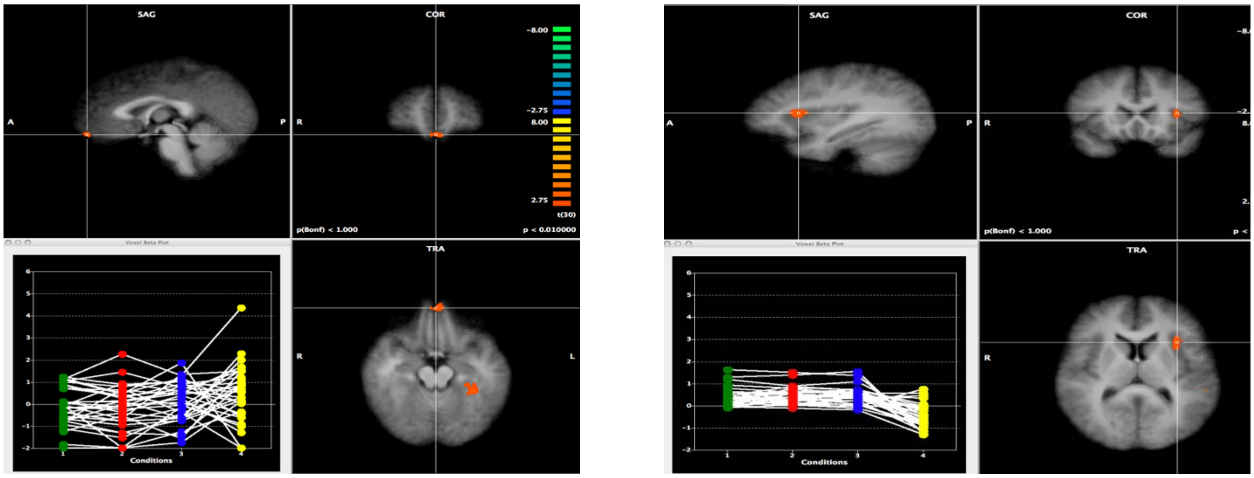
Table 2.4. Logit Models Predicting Political View (Republican = 1).

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
	All PIQ	Milk PIQ	Egg PIQ	Milk fMRI	Milk fMRI	Egg fMRI	Egg fMRI
Intercept	-9.41***	-7.04**	-13.32***	-1.44**	-1.62**	1.23	-1.91***
Political Score	0.14***	0.11**	0.20***				
BOLD activations in tradeoff condition							
L Insula (milk experiment)				5.81**	5.41**		
Superior frontal gyrus (egg experiment)						-5.92	
Precuneus (egg experiment)						-7.96*	
BOLD activations in technology condition							
vmPFC (milk experiment)					2.45*		
premotor/supplementary motor area (egg experiment)							8.09***
N individuals	65	32	33	32	32	33	33
Overall % correctly predicted	75%	69%	85%	78%	78%	82%	85%
Republican % correctly predicted	60%	57%	73%	71%	71%	64%	73%
Democrat % correctly predicted	85%	78%	91%	83%	83%	91%	91%
χ2	23.61	8.48	15.82	8.86	13.61	15.01	13.48
Prob > χ2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Log L	-31.5	-17.7	-13.1	-17.5	-15.1	-13.5	-14.3
AIC	67.0	39.4	30.2	39.0	36.3	33.0	32.5
Area under ROC	0.85	0.80	0.89	0.79	0.85	0.86	0.85

Notes: ***, **, and * indicate significance at the 1%, 5% and 10% levels, respectively.

Figure 2.1. Examples of Images from the Milk and the Egg Experiment.

Figure 2.2. Whole-brain analysis in the milk experiment: Republican-Democrat contrasts.



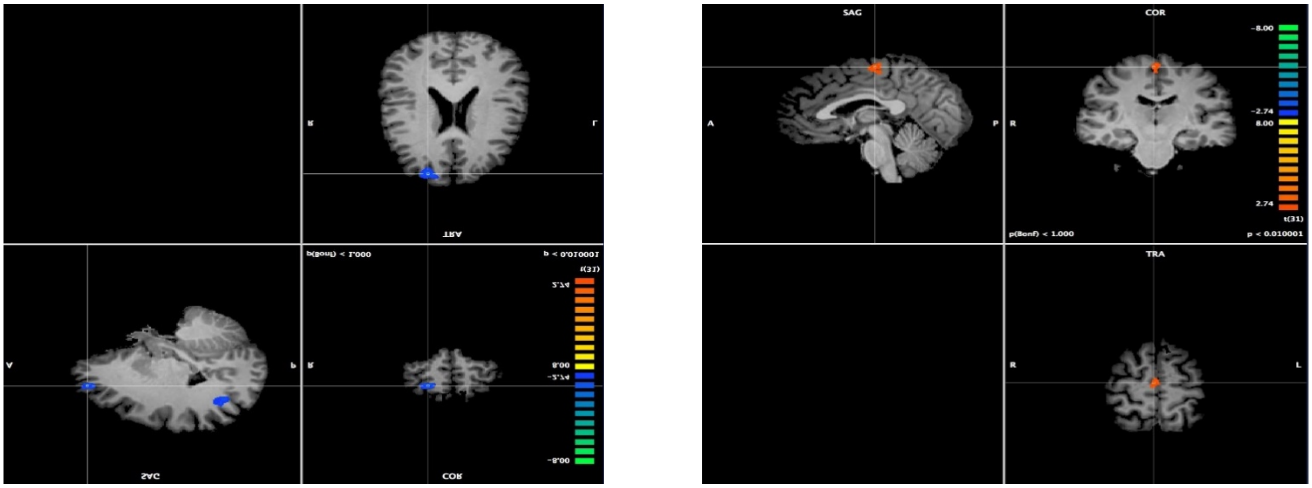
(a) Left vmPFC, BA 10

In milk technology relative to baseline condition.

(b) Left Insula, BA 13

In milk combination relative to baseline condition.

Figure 2.3. Whole-brain analysis in the egg experiment: Republican-Democrat contrasts.



(a) Right Superior frontal gyrus, BA 10

In egg combination relative to baseline condition.

(b) Left premotor/supplementary motor area, BA 6

In egg method relative to baseline condition.

CHAPTER 3. ON GENDER DIFFERENCES, FOOD CHOICES AND BRAIN ACTIVITY

Abstract

We studied behavior and corresponding brain activity when females and males made non-hypothetical food purchases using functional magnetic resonance imaging (fMRI). We found the brain activity difference segmented gender more accurately than their choice differences via a logit model. We also tested the hypothesis that male-female differences were due to differences between primary and non-primary shoppers. Our study has implications for food marketers and food product developers.

Introduction

Do gender differences exist in the human brain? If this question were simple to answer, research on differences between the brains of females and males would not be so lengthy and controversial (Gould 2012). While debate exists as to the physiological differences in human brains (Joel et al. 2015; Glezerman 2016) and whether such differences comport to thinking, that gender differences exist in decision-making is less controversial. For example, the use of simple gender dummy variables in models of economic choice is so common that their absence is more likely to draw a reviewer's criticism than their inclusion.

Neuroeconomic studies are a valuable tool for consumer research because decision-making is driven by different simultaneous systems, such as automatic and controlled processes, and rational and experiential systems. The motives behind shopping behaviors are rational, emotional, and relational in general, and brain activities allow us to observe all three dimensions. Signals that influence choices are not always consciously accessed, yet certainly influence beliefs. In addition, choices require additional cognitive resources, and preferences are not always fixed.

Milk and eggs are ideal to study gender brain differences because consumers are so familiar with these food products that they are likely to already have preference processing systems in the brain. This is useful for an experiment that explores how consumers react to new technology. Supermarket shoppers must choose among foods differentiated by price and technology such as milk labeled as organic, 100% grass-fed, omega-3, homogenized, pasteurized, local, fresh, hormone free, and GMO-free. This paper explores male-female differences in how such choices are made. We also study the hypothesis that male-female differences are due to differences between primary and non-primary shoppers. Primary shoppers are likely have developed systems for making choices that lead to efficiency. Since females are often the primary food shopper in the family, it may be that observed gender differences in food choice experiments are simply due to who does the shopping, something for which researchers may not be controlling. Specifically, this paper uses functional Magnetic Resonance Imaging (fMRI) to explore how males and females and primary and non-primary shoppers make price-technology tradeoff decisions for milk and eggs.

Previous Work

Gender targeting marketing is commonly used for luxury products because luxury consumption is seen as social status/mating signals between or within genders (Han et al. 2010; Wang and Griskevicius, 2014). Skoloda, 2009 and Darroch, 2014 have shown that marketers misunderstand female consumers in many industries. Recent research has shown that organic food shopping is a social status signal (Puska et al. 2016). According to Kraft and Weber (2012), the number of male shoppers has been increasing as more males remain single longer and more parents divide household duties.

In the literature on willingness to pay, a significant number of experiments (see, e.g., the research and discussion of literature in Shogren, Fox, Hayes, and Roosen 1999; Gracia, Magistris, and Nayga 2012; Lusk et al. 2015) find a statistically significant relationship between willingness to pay for food technology and gender. A common finding is that females are more risk-averse than males in such food choices (Davidson and Freudenburg 1996; Bieberstein 2013; Bieberstein and Roosen 2015; Burton et al. 2001; Lusk et al. 2015). Siegrist (2000) indicates that females are less accepting of genetically modified traits than males, but finds no significant difference in perceived risk.

From an evolutionary perspective, the female and male brain developed in response to different needs and problems faced by our hunter-gatherer ancestors (Tooby and Cosmides 2005). Li, Kenrick, Griskevisius, and Neuberg (2012) argue that securing and finding a mate may have reduced loss aversion among males, but not females. Males and females select potential partners by certain characteristics that they interpret as reproductive quality signals (Mafra et al. 2016). According to the selectivity hypothesis, males and females adopt different strategies for processing information and use different thresholds for evaluating information (for reviews, see Meyers-Levy and Loken 2015).

The literature that demonstrates gender brain differences is large. Structurally, male brains have larger volumes than female brains (Filipek et al., 1994; for reviews, see Cahill, 2006). Functionally, gender brain differences have been found in every brain lobe (for reviews, see Luders and Toga 2010). In addition, some studies show that gender differences also exist in the connectivity between brain areas (Shaywitz et al. 1995; Baxter et al. 2003; Braeutigam et al.

2004; Gong, He, and Evans 2011). Tian, Wang, Yan, and He (2011) found that males tend to be more locally efficient in their right hemisphere networks. However, neuroeconomic investigations that seek to explore the reasons behind the gender gap in food decisions are sparse and based mainly on hunger stimuli (Wang et al. 2009; Cornier et al. 2010; Haase et al. 2011). These studies differ from our focus on decision-making in a typical shopping trip where neither hunger nor reaction time are motivating factors.

Methods

Subjects

One hundred healthy participants were recruited from the Kansas City metropolitan area to participate in two experiments. 50 were chosen for an experiment on milk purchasing and 50 were selected for an experiment on egg purchasing. Inclusion criteria were right-handedness and English-speaking, and exclusion criteria were vegan or lactose intolerance. Seven subjects dropped out the experiments, so we obtained 93 observations with complete fMRI data (ages 18-55; mean = 31 years; standard deviation = 10; 47 females). Demographic information was collected from all participants by means of a survey following the fMRI scanning.

Primary shopper subjects in our study were defined by both grocery store shopping frequency and self-identification. The subjects who shopped two or more times a week were defined as primary shoppers, and those who shopped about every two weeks or less were defined as non-primary shoppers. Among those who shopped once a week, we categorized those who self-identified as a primary shopper as such. We excluded the data from individuals who equally divide grocery shopping with their partner. Thus, we obtained 27 primary shoppers and 15 non-primary shoppers in the milk experiment; 21 primary shoppers and 20 non-primary shoppers in the egg experiment.

Stimuli

Half of the subjects were involved with milk choices and the other half with egg choices. Each participant made 84 non-hypothetical binary choices between two products labeled with prices and the production methods used. The screen shown to participants inside the fMRI scanner, was designed to replicate shopping. Two images of white plastic gallon jugs were shown to the milk experiment participants (Figure 1); and two images of a dozen eggs in typical paper cartons were shown to the egg experiment participants (Figure 2) Participants were told at the beginning of each experiment that they would take home one of the choices they made with the price deducted from the participation fee of fifty dollars. The choice was randomly picked by the experimenter at the end of the session.[8]

Participates were randomly presented with 3 different stimuli in each experiment. One condition simulated a trade-off between price and technology. The other two, involved a production method condition with constant prices and a price condition with constant technology as explained below.

Production Method condition

In the method condition, we controlled the price variable in 28 binary choices for each experiment. During the milk experiment, participants were asked to choose between milk "from a cloned cow" and "from a non-cloned cow", or between milk produced with an "artificial growth hormone" and milk produced with "no added growth hormone". For the egg experiment, one of the egg products was labeled as coming from hens that were "caged" or "confined", and "cage-free" or "free-range".

Price condition

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[2] No subject went home with milk from a cloned cow.

The price condition also consists of 28 binary choices in each experiment, in which only the prices were differed. That means two products were produced with the same method, but the prices of the two choices varied. In the milk experiment, the prices were between \$3 to \$7 with \$0.50 increments. In the egg experiment, the prices varied between \$0.99 and \$4.99 in \$0.50 increments.

Combination condition

For the 28 choices in the combination condition, both the price variable and production method variable varied: regular milk or eggs from non-confined hens were priced higher; milk produced from cloned cows or using a growth hormone, or eggs produced from confined hens had lower prices.

After participants made a choice, the visual monitor would present them a confirmation screen for 0.5-3.5 seconds to allow them to avoid errors. Between confirmation screen and next choice pair, a fixation cross was shown for 3-15 seconds to jitter the inter-trial interval. The exact timing of trials was optimized by an Analysis of Functional Neuroimage (AFNI) stimulus timing program in order to minimize fMRI collinearity.

Behavioral choice data analysis

We focus on the 28 choices each participant made in the combination condition. We used t-tests to compare the average choices of females and males and their average response times. We applied logit regressions to predict gender. We evaluated model fitness based on the percent where gender is correctly predicted using the Akaike information criterion (AIC), and the area under the receiver operating characteristic curve (ROC).

fMRI data acquisition

We analyzed activation maps using statistical parametric methods (Friston et al. 1995) contained within the BrainVoyager QX software. Blood oxygenation level-dependent (BOLD) activations during the choices were obtained using multiple-regression analysis with the general linear model, with motion parameters included as nuisance regressors. For the first-level analysis, we modeled regressors representing the decision phase (i.e., stimulus onset time to participant choice, average duration = 2.7 seconds) for the experimental conditions of interest (e.g., price, technology, and combination) using a hemodynamic response filter; we entered these into the multiple-regression analysis using a random-effects model. In addition, we included the feedback phase (i.e., confirmation of feedback, 0.5 seconds) as a regressor of no interest. Regressors were modulated for the decision duration, but there was no amplitude modulation or orthogonalization. We extracted mean percent signal change values for each individual for each condition from regions of interest (ROIs) described below to examine associations between brain response, decision time, and milk/egg choices.

fMRI data analysis

First, we conducted a whole-brain analysis contrasting gender difference in BOLD activations from price, production method, and combination effects. We subtracted the BOLD activation in the baseline condition in each voxel of the whole-brain analysis from the choice (price, or production method, or combination) condition to net out the fixation effect so that the remaining BOLD activation would be comparable across participants.

In order to be as conservative as possible, significant activation must be detected in each of the parenthetical elements in the above equation, as well as the difference between males and females. This experimental design compares signals during a task with not only the signals from the baseline condition but also against signals from a different task. It is this difference in difference on top of setting a conservative p-value (less than 0.05), and group analysis for nearly 50 subjects making 84 decisions each experiment that make our results extremely conservative. With this approach we avoid reporting signals that we know from other research would have been considered significant (Eklund, Nichols, and Knutsson 2016).

Along with the whole-brain analysis, we were interested in specific regions of interest (ROI) that prior research has shown to be related to economic and/or food decisions. We chose eleven ROI BOLD activations and named them according to the area in which they are found: left ventral striatum (LVS), right ventral striatum (RVS), left anterior insula (LINS), right anterior insula (RINS), ventromedial prefrontal cortex (VMPFC), dorsomedial prefrontal cortex/anterior cingulate cortex (DMPFC), left thalamus (LTHA), right thalamus (RTHA), posterior cingulate cortex (PCC), right amygdala (RAMYG), right dorsolateral prefrontal cortex (RDLPFC).

We chose the striatum and medial prefrontal cortex (MPFC) since converging evidence has suggested that they are active in the formation of so-called subjective values (Peter and Büchel 2009; Kable and Glimcher 2007; Levy and Glimcher 2011; Levy, Lazzaro, Rutledge, and Glimcher 2011; Enax et al. 2015). The dorsolateral prefrontal cortex (DLPFC) has been shown to relate to willingness to pay for food (Plassmalen, O'Doherty, and Rangel 2010) and processing of health information in food choices (Hare, Malmaud, and Rangel 2011). We chose the insula, posterior cingulate cortex (PCC), dorsomedial prefrontal cortex/anterior cingulate cortex (DMPFC), thalamus, and amygdala because they have been implicated in economic decision-making generally (Bartra 2013) and in economic decisions related to food choices (Lusk et al. 2015; Crespi et al. 2016).

Test of equality of correlation matrices

How to compare brains has always been an interesting question in neuroeconomics, since decision-making involves multiple simultaneously active systems in the brain, and the processing of different types of information often relies on shared pathways in the brain (Schultz 2000; Sanfey and Chang 2008; Delgado and Dickerson 2012). The whole-brain analysis is necessary for detecting physiological differences in specific areas of activation. Activation alone is telling, but joint activation is likely of more importance for decision-making. What whole-brain analysis does not show, however, is whether correlated activations in multiple areas are related and, importantly for this study, whether those areas are activating in different ways by gender. Finding the difference between, say, the DLPFC in males and females when making choices is interesting from a single-voxel analysis. However, it does not tell us whether, say, the connection between the DLPFC and another area differs when examining gender or shopping experience. fMRI does not lend itself to connectivity tasks directly.

However, correlation analysis of the distributions of the BOLD variables is suggestive and statistically justifiable (Wink and Roerdink 2006). We applied a statistical χ^2-test (Jennrich 1970; Wink and Roerdink 2006) of the significance of the difference between genders to the ROIs related to economic and food decision through their BOLD correlation matrices. The Jennrich (1970) test allowed us to depart from single-voxel analysis and specifically examine *joint* correlation among several variables. We examined permutations of ROIs to determine whether there were groups of activity that were joint, statistically significantly different between males and females and primary and non-primary shoppers.

As discussed, we want to contrast competing hypotheses in this study: gender and shopping frequency, namely, that differences between males and females result from the frequency of shopping. If more females self-report as the primary shopper, females may have developed a decision-making heuristic when it comes to buying milk and eggs, and what we observed is the impact of that heuristic. To net out the primary shopper effect, we applied the same joint-correlation tests to compare primary shoppers (27 in the milk experiment, and 21 in the egg experiment) versus non-primary shoppers (15 in the milk experiment, and 20 in the egg experiment).

Results

Summary statistics for the behavioral choice data

In the 28 choices in which only prices varied across the same production method, participants chose the less expensive milk and the less expensive eggs 97% and 99% of the time, respectively. In the technology condition, participants chose the conventional milk 94% of the time and the non-confinement option for eggs 100% of the time. These high percentages are what we expected and show that participants took the questions seriously and made deliberate decisions, thereby allowing us to focus on the combination condition that involved a price and technologies tradeoff.

In the combination condition, participants chose the more expensive conventional milk over the less expensive option produced using cloning or hormones 58% of the time. They chose the eggs produced through the higher-priced non confinement method over those produced using the less expensive confinement method 50% of the time. As Table 1 demonstrates, gender is significantly different ($p < 0.1$) in each of the experiments.

Overall, more than 60% of the participants in this study were willing to buy milk from cloned cows. This percentage is consistent with the result of 57% from a web-based survey of 2,256 individuals in Brooks and Lusk (2011). However, we find gender difference when we examine the results more closely. Figure 3 shows the percentage of participants by gender who exclusively chose conventional milk or non-confined production eggs. In the milk experiment, 13 (56.5%) females always avoided buying the hormone or cloned milk, while only three (12.5%) males adopted the same strategy. More males (21, or 87.5%) than females (10, or 43.5%) chose the cheaper hormone or cloned milk technology option over the conventional production option at least once. We found similar results in the egg combination experiment, in which seven (29.2%) females always avoided choosing the caged or confined production eggs, while the corresponding observation for the number of males was three (13.6%).

Table 2 shows statistics for decision time. There was no significant difference in mean decision times between genders in the price experiments or combination experiments. However, females on average made slightly faster decisions in the technology and method experiments.

Whole-brain analysis

Table 3 shows brain regions in which there were significant differences between genders in each condition. This analysis shows that, when participants made combination choices (involving both technology and price) in the milk experiment, we observed significantly greater activation in males in the left middle prefrontal gyrus (Table 3), whereas when making price and technology choices, females exhibited greater activity than males in the right temporal lobe. Table 3 also demonstrates that males show greater brain activity than females in the egg experiment, common brain regions include Cuneus, Precuneus, and middle temporal gyrus.

To illustrate some of these brain regions, Figure 4 shows in red the significant activation observed across genders in the left middle frontal gyrus for the combination relative to the baseline condition in the milk experiment, in the superior temporal gyrus for the price relative to baseline condition in the egg experiment, and in the superior/medial frontal for the combination relative to baseline condition in the egg experiment.

Jennrich test analysis: gender versus primary shopper

As Table 4 shows, in the milk price and combination conditions, the Jennrich tests revealed that females and males differ from one another significantly ($p<0.05$) in the correlation matrices consisting of BOLDs from VMPFC, RVS, RDLPFC, and PCC. At the same time, we found no significant difference in these areas when examining the alternative hypothesis of primary versus non-primary shoppers. As Table 4 shows, gender difference exists in the correlations of all eleven economic decision-related ROIs in the egg method and combination conditions, while we find no significant difference between primary shoppers and non-primary shoppers.

The results of the whole-brain analysis show significant voxel differences between males and females in the superior temporal gyrus (price experiment) and the middle frontal gyrus (combination experiment), while the joint correlation tests showed that females and males have, additionally, different joint correlations among the VMPFC, RVS, RDLPFC, and PCC, important decision-related brain regions.

Predicting gender

If the aforementioned areas are important determinants of marketing gender in food decision-making, then the areas ought to be able to predict the gender of the subject in the study. Table 6 and Table 7 present the results of binary logistic regression models designed to predict whether an individual is a female or male.

In all seven models in Table 5, the data were from the milk combination experiment, in which the less expensive milk was produced with cloned/hormone technology. We wanted to compare gender identification from brain activity with gender identification from some other non-brain-related variable. The number of times a subject chose the growth-hormone milk (Model 1) and the number of times s/he chose the cloned milk (Model 2), but not the two numbers together (Model 3), was significantly related to gender and could better predict the gender of the subject. Thus, the two choice models serve as our baseline and include a variable of the total cloned/growth-hormone-added milk choices by subject in the combination experiment. The dependent variable is gender (0=male; 1=female). The results indicate that those who chose less expensive milk were more likely to be males, and the simple model predicts gender correctly 70 % of the time.

In contrast to Models 1-3, Model 4 brings in the result of the whole-brain analysis using the BOLD activation in the left middle frontal gyrus (LMFG) from the combination experiment to predict gender in the combination experiment. As expected, this variable is significantly related to whether the participant is a female or male. The correctly predicted ratio of Model 4, however, is the same as Model 1 and Model 2 (70 %), showing that the number of times a subject chooses cloned milk is a good proxy for BOLD activation in the LMFG and vice versa. The AIC and ROC when using LMFG slightly outperform Model 1 and Model 2 in explaining gender difference, but neither Model 2 nor Model 4 outperforms the other in the correct prediction of either males or females (Table 6).

Model 5 adds to Model 3 the fMRI data (contrast relative to baseline fixation condition) from the price experiment and technology experiment. Although the gender of the subjects is taken from the combination experiment, brain activity in the other experiments may have “primed” the brain for the more realistic choices of the combination experiment. That is, one’s reaction to prices and the novel food technology might impact one’s decisions in a shopping trip that takes both prices and technology into account. Model 5 can explain gender difference from both single-task (price and technology) and multiple-task (combination) brain activity. Model 5 fits the data better than the previous models according to the AIC, and ROC scores and predictive power increases to 74%. The likelihood of being female is significantly related to greater activation in RSTG in the price condition relative to the baseline condition, decreased activation LMFG in the combination condition relative to the baseline condition, and increased activation in RSTG in the technology condition relative to the baseline condition.

Model 6 utilizes the significantly different joint correlations for genders but not for primary shoppers from the Jennrich tests in the price and combination experiments: VMPFC, RVS, RDLPFC, and PCC. The results imply that the BOLD activation in RVS is a significant predictor of gender, and Model 6 slightly outperforms Model 4 in correct predictions and ROC.

In all three models (Models 4, 5, and 7) that include LMFG, this brain region makes a crucial addition to the model's power to classify genders. Model 7, which combines the brain activity results from both the whole-brain analysis and the Jennrich tests, is the best overall predictor, predicting overall gender correctly 81% of the time and female correctly 83% of the time. Joint ($\chi 2$) tests of the coefficients revealed that the BOLD variables were jointly significant, as well.

As Table 6 shows, for Model 8-13, the data were from the egg combination experiment. Model 8-10 are logit models using the number of open-method produced choices as independent variables, Model 11-12 predict gender with BOLD variable(s) from the whole brain analysis, and Model 13 utilizes the BOLD variables from the seven brain regions across all three conditions in Jennrich tests. All fMRI models in the egg experiment outperform the choice models, and Model 13 predicts both females and males more than 80% of the time.

Discussion

It has been well documented in economic studies of food choices that females and males make significantly different choices when it comes to unconventional food while controlling for other factors. Foods produced using non-traditional technological processes lead to different decisions between males and females. This paper examined the brains of 93 participants in an fMRI study of food choices. 47 subjects (23=female) made choices between conventional gallon jugs of milk and jugs of milk that had been labeled as either coming from a cloned cow or from a cow that had been given growth hormones. 46 participants chose between eggs labeled as being from hens in either confined or non-confined environments.

An examination of the brains using fMRI during the decision-making revealed statistically significant differences between the brains of males and females in the superior frontal gyrus in decisions involving price alone and in the middle frontal gyrus in decisions involving both price and technology. Further testing of an array of areas related to economic decision-making found significant joint-correlation differences between females and males in the right dorsolateral prefrontal cortex, the ventromedial prefrontal cortex, the right ventral striatum, and the posterior cingulate cortex. We compared the activations from females versus males with activations from primary versus non-primary shoppers. Activations were not statistically significantly different from each other for this latter hypothesis, providing evidence that gender differences exist in food decisions. Further establishing the link between these areas and gender-specific decision-making, we included the BOLD activations for these areas in a discrete choice regression model and showed that the inclusion of these activations resulted in significantly greater ability of the model to predict gender than a model that took into account the technology choices alone. Further research is needed, but the results here suggest that brain activation differences can account for gender differences when it comes to food choices. Further establishing the link between these specific areas and gender-specific decision-making, we included the BOLD activations for these areas in a discrete choice regression model and showed that the inclusion resulted in significantly greater ability of the model to predict gender.

Our milk experiment results confirmed previous findings showing that females were more risk-averse towards food technology in that more females than males avoided the novel-technology- in making milk choices. Blough and Slavin 1987 found that females were slower in choice tasks, but in our study, we found no such evidence. Again, our task was not a standard reaction time study in which subjects were told to make decisions quickly and, consistent with how food shopping decisions are made, one possible explanation for the faster decision times by females is that females and males used different strategies in the combination experiment. This gender difference in strategy is further supported by the finding that more females than males (56.5% versus 12.5%) always avoided purchasing the novel technology.

Among all the brain regions in the whole brain analysis only one brain region exhibits greater activation for females than males. This is the right superior temporal gyrus (BA 38). Past gender difference studies on brain structure have indicated that females have greater sizes or greater gray matter in the superior temporal gyrus (Schlaepfer et al., 1995; Harasty et al., 1997). Haase et al., 2011 also found more brain activation in the right superior temporal gyrus in females than males in response to sour taste and hunger. In a broader neuroscientific literatures, activation in this brain region has been found in emotional memory retrieval, and in response to fear and anxiety stimuli (Dolan et al., 2000; Maguire et al., 2000; Grezes et al., 2007; Takashima et al., 2007; Schunck et al., 2008; Gupta and Tranel, 2012).

In the milk combination condition (a decision-making task involving tradeoffs between a novel food technology and price), we find greater activation in the left middle frontal gyrus (BA46) for males than females. Activation in this brain area has been observed in tasks involving calculation (Burbaud et al., 1995; Xie et al., 2003). This finding suggests that during a food purchase decision, males focus more on the value calculations.

Considering that our egg experiment task is associated with animal welfare. It is interesting to notice that we find no gender difference in amygdala even though neuroscience research has shown gender differences exist in this (for reviews, see Hamann, 2005). This finding may suggests that there is no significant gender difference in thinking about animal welfare.

Interestingly, in our egg experiment, all brain regions were more activated in males than females.

We also found that common brain regions exhibit different correlations between genders, but not between primary shoppers and non-primary shoppers.

Conclusion

The present study investigated the difference between females and males when they made food choices. We found statistically significant gender differences in both economic choices and brain activities. Our findings suggest that females are willing to pay more for the products that embed altruism, happiness, and health, and which are low risk in the sense that they are produced with familiar technologies. Males focus on price. The result that brain activity predicts gender better than food choices suggest that males and females make purchase decisions in a fundamentally different way.

Whole Foods succeeded by offering foods produced using traditional and environmentally friendly production practices at premium prices along with a pleasant shopping experience (Whole Foods Market, 2010). Our research demonstrates that when thinking about unconventional food production methods, females showed greater activation than males in their right superior temporal gyrus (BA 38). Activation in this brain region was found when subjects were watching sad faces (Blair et al. 1999), watching fearful pictures (Grezes et al. 2007), watching sad movies (Lévesque et al. 2003), and anticipating anxiety (Schunck et al. 2008). These previous findings also suggest females are more aware of emotions from others than males. The activation in BA38 in females coupled with data showing that females prefer milk produced using traditional technology and eggs from non-confined hens suggests that Whole Foods' focus on social wellbeing and avoidance of unconventional technologies may elicit a more positive reaction in females than in males.

The three brain regions found to be highly active during our trade-off tasks in males, including the left middle temporal gyrus (BA 46), the left superior/medial frontal (BA 6/32), and the right Precuneus (BA 31), are commonly associated with the evaluative processes. Activation in BA 46 was found in evaluating value (Miyamoto and Kikuchi, 2012), and when performing numerical calculations (Burbaud et al., 1995; Xie et al., 2003). BA 6 activated differently in females and males in a decision-making experiment involving monetary rewards (Lighthall et al. 2012). Costco and Sam's Club are attractive to value shoppers (Grewal et al. 2010). The activation in BA 46, BA 6/32, and BA 31 coupled with the price conscious choices made by males in the experiments suggest that warehouse companies are focusing on a characteristic, price that is of greater relevance to males.

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Figure 3.1. Example image from the milk choice experiment.

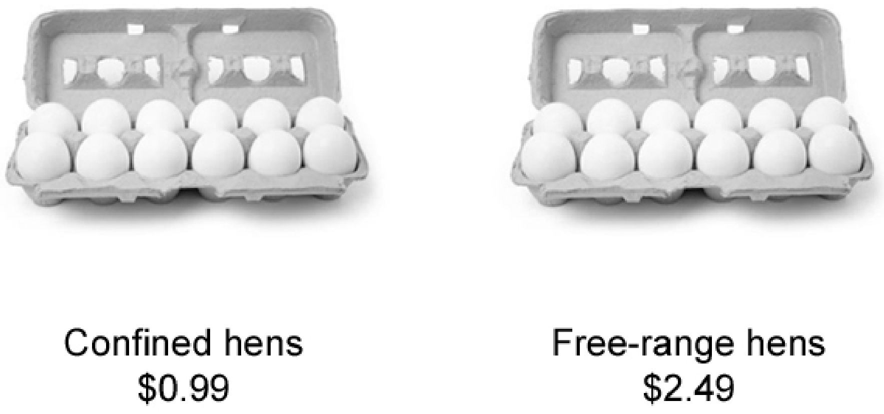


Figure 3.2. Example image from the egg choice experiment.

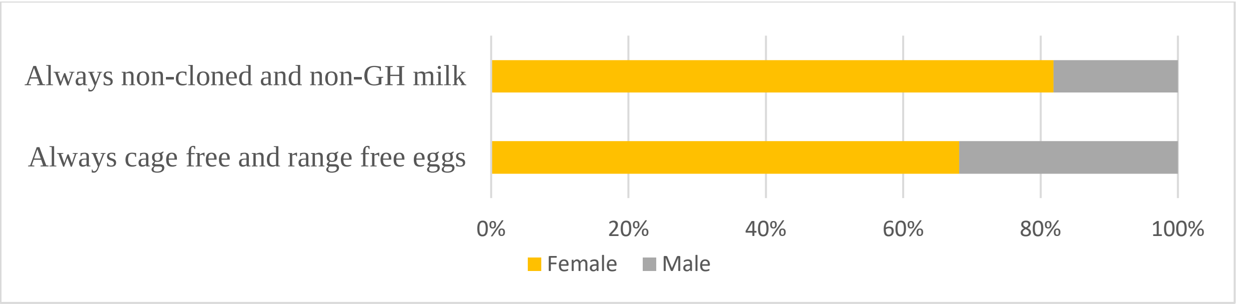
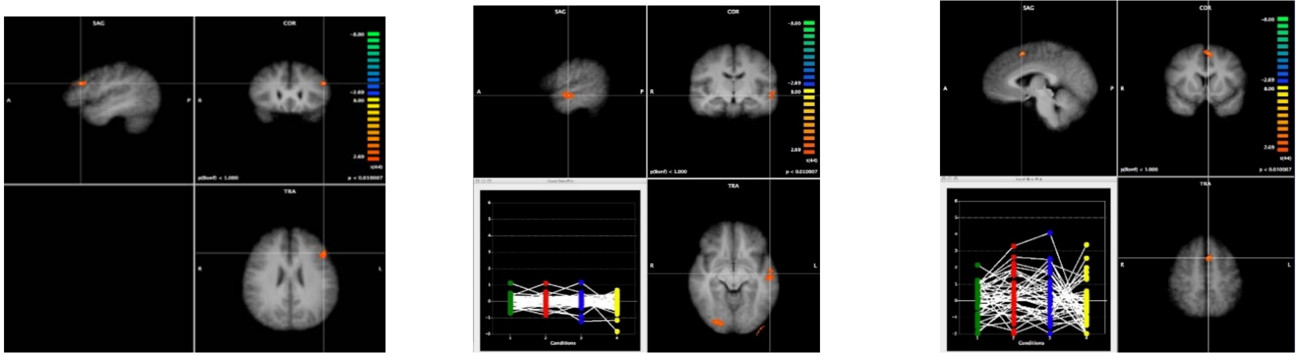


Figure 3.3. Gender-related percentage of participants who only made regular milk and non-confined production egg purchases.



A. Middle frontal gyrus activation

B. Superior temporal gyrus

C. Superior/medial frontal

Figure 3.4. Whole-brain analysis of males versus females in milk combination decisions (left), egg price decisions (middle), and egg combination (right) decisions each compared to the passive viewing of a fixation cross in three views as sagittal (SAG), coronal (COR), and axial/transverse (TRA).

Table 3.1. Summary statistics of choices made in the combination condition. The total number of choices is 14.

Tradeoff choices	Mean	Std. Dev.	t	p-value
Cloned milk				
Female (N=23)	3.70	5.43	-2.68	0.01
Male (N=24)	8.17	5.96		
Growth-hormone milk				
Female (N=23)	3.13	5.27	-3.19	0.00
Male (N=24)	8.42	6.04		
Cage-free eggs				
Female (N=24)	8.38	5.33	*1.94*	*0.06*
Male (N=22)	5.41	4.99		
Free-range eggs				
Female (N=24)	8.54	5.21	*1.98*	*0.05*
Male (N=22)	5.59	4.88		

Note: The total number of cloned milk, growth-hormone milk, cage-free egg, free-range egg choices is 14 each.

Table 3.2. Decision Time.

Response time	Obs	Mean	Std. Dev.	t	p-value
Milk experiment, price condition					
Female (N=23)	644	2659.58	988.98	0.10	0.92
Male (N=24)	672	2653.89	1078.34		
Milk experiment, technology condition					
Female (N=23)	644	2515.01	1173.85	-2.71	0.01
Male (N=24)	672	2681.10	1049.78		
Milk experiment, combination condition					
Female (N=23)	644	2643.27	1491.77	-0.89	0.37
Male (N=24)	672	2712.75	1328.58		
Egg experiment, price condition					
Female (N=24)	672	2404.78	1015.95	-0.92	0.36
Male (N=22)	616	2459.62	1133.46		
Egg experiment, method condition					
Female (N=24)	672	2234.23	962.30	-5.05	0.00
Male (N=22)	616	2531.27	1148.52		
Egg experiment, combination condition					
Female (N=24)	672	2563.59	1501.83	-1.73	0.08
Male (N=22)	616	2708.96	1504.62		

Notes: time in milliseconds.

Table 3.3 Results from the whole-brain analysis; BOLD responses to contrasts of interest ($p<0.05$).
Positive t statistic indicates more activation in males.

Brain regions	*Max voxel coordinates*				
	X	*Y*	*Z*	*t*	*Cont. voxels*
Milk price decision vs. Baseline contrast: Males > Females					
(R) Superior temporal gyrus, BA 38	*26*	*13*	*-15*	*-4.32*	*17*
Milk technology decision vs. Baseline contrast: Males >Females					
(R) Superior temporal gyrus, BA 38	*38*	*22*	*-27*	*-3.79*	*14*
Milk combined tradeoff decision vs. Baseline contrast: Males > Females					
(L) Middle frontal gyrus, BA 46	*-43*	*22*	*27*	*4.53*	*19*
Egg price decision vs. Baseline contrast: Males > Females					
(R) Middle occipital lobe, BA 19	*35*	*-86*	*21*	*4.14*	*103*
(R) Cuneus, BA, 17	*11*	*-95*	*6*	*5.58*	*22*
(L) Cuneus, BA 19	*-7*	*-86*	*39*	*3.88*	*59*
(L) Middle temporal gyrus, BA 21	*-46*	*10*	*-30*	*4.34*	*18*
(L) Superior temporal gyrus, BA 21	*-58*	*-14*	*-3*	*4.19*	*35*
Egg method decision vs. Baseline decision contrast: Males > Females					
(R) Middle temporal gyrus, BA 21	*47*	*1*	*-21*	*5.14*	*17*
(R) Precuneus, BA 31	*29*	*-65*	*27*	*3.82*	*38*
(R) Uncus, BA 36	*26*	*-5*	*-33*	*3.75*	*18*
(L) Cuneus, BA 19	*-7*	*-86*	*39*	*3.38*	*20*
Egg combination tradeoff decision vs. Baseline contrast: Males > Females					
(L) Superior/medial frontal, BA 6/32	*-4*	*10*	*51*	*4.29*	*14*
(R) Precuneus, BA 31	*29*	*-68*	*24*	*3.7*	*16*

Table 3.4. Jennrich test results.

Activations (BOLD)	Females v. males		Primary v. non primary shoppers	
Milk experiment price condition:	*Jennrich $\chi 2$*	*p-value*	*Jennrich $\chi 2$*	*p-value*
VMPFC, RVS, RDLPFC, PCC	20.48	0	5.31	0.51
Milk experiment combination condition:				
VMPFC, RVS, RDLPFC, PCC	14.4	0.03	9.06	0.17
Egg experiment price condition:				
DMPFC, LINS, LVS, AMYG, RDLPFC, RINS, VMPFC	33.06	0.05	20.72	0.48
Egg experiment method condition:				
All 11 ROIs	75.54	0.03	36.24	0.98
Egg experiment combination condition:				
All 11 ROIs	86.73	0	67.48	0.12

ROIs	label	*Max voxel coordinates*		
		X	Y	Z
1. Left Ventral Striatum	LVS	-12	9	-2
2. Right Ventral Striatum	RVS	11	7	-2
3. Left Insula	LINS	-28	18	-2
4. Right Insula	RINS	30	16	-1
5. Ventromedial Prefrontal Cortex	VMPFC	1	41	-8
6. Left Dorsomedial prefrontal cortex/anterior cingulate cortex	DMPFC	4	23	40
7. Left Thalamus	LTHA	-5	-9	8
8. Right Thalamus	RTHA	5	-9	8
9. Posterior Cingulate Cortex	PCC	-3	-28	-34
10. Right Amygdala	AMYG	26	-11	-12
11. Right Dorsolateral Prefrontal Cortex	RDLPFC			

Table 3.5. Logit models predicting gender in milk combination experiment (1= female).

	Model 1 choices 1	Model 2 choices 2	Model 3 choices 3	Model 4 fMRI 1	Model 5 fMRI 2	Model 6 fMRI 3	Model 7 fMRI 4
Intercept	0.82*	0.73*	0.90*	0.81*	0.85*	-0.06	1.41*
Number of milk choices							
Cloning use		-0.13**	-0.04				
Growth hormone use	-0.15***		-0.12				
BOLD activations in tradeoff condition							
VMPFC						1.33	2.76
R VS						-2.48**	-2.95*
R dlPFC						-1.91	-0.63
PCC						0.83	2.89**
L MFG				-5.21***	-4.06**		-7.10*
BOLD activations in price condition							
VMPFC						0.07	-0.45
R VS						2.15*	2.35
R dlPFC						3.88	0.7
PCC						-0.98	-3.22**
R STG					3.70*		4.58*
BOLD activations in technology condition							
R STG					0 .66		2.11
N individuals	47	47	47	47	47	47	47
Overall % correctly predicted	70%	70%	70%	70%	74%	72%	81%
Females % correctly predicted	78%	74%	78%	74%	74%	70%	83%
Males % correctly predicted	63%	67%	63%	67%	75%	75%	79%
χ2	9.06	6.7	9.38	11.42	18.92	14.99	31.83
Prob > χ2	0.00	0.01	0.01	0.00	0.00	0.06	0.00
Log L	-28.04	-29.20	-27.88	-26.90	-23.10	-25.10	-16.70
AIC	60.07	62.4	61.75	57.7	54.2	68.1	57.3
Area under ROC	0.75	0.74	0.77	0.78	0.84	0.81	0.92

Notes: *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.

Table 3.6. Logit models predicting gender in egg combination experiment.

	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13
	choices 4	choices 5	choices 6	fMRI 5	fMRI 6	fMRI 7
Intercept	-0.68	-0.73	-0.73	1.52***	1.86***	2.71
Number of cage free choices	0.11*		-0.01			
Number of free range choices		0.12*	0.13			
BOLD activations in tradeoff condition						
DMPFC						3.41
Linsula						-11.9
Lvs						-32.93
Ramygdala						20.27
RdlPFC						-8.05
Rinsula						0.48
VMPFC						9.84
Superior/medial frontal				-5.88***	-4.72**	
BOLD activations in price condition						
DMPFC						-10.25
Linsula						7.77
Lvs						21.67
Ramygdala						-17.98
RdlPFC						-10.93
Rinsula						10.84
VMPFC						-1.3
Superior temporal gyrus					-0.52	
BOLD activations in method condition						
DMPFC						-6.16
Linsula						-1.78
Lvs						29.54*
Ramygdala						-11.76
RdlPFC						8.92
Rinsula						12.45
VMPFC						-22.46**
N individuals	46	46	46	46	46	46
Overall % correctly predicted	63%	63%	63%	74%	76%	83%
Females % correctly predicted	54%	58%	58%	83%	83%	83%
Males % correctly predicted	73%	68%	68%	64%	68%	82%
$\chi2$	3.71	3.84	3.84	12.61	13.42	35.42
Prob > $\chi2$	0.05	0.05	0.15	0.00	0.00	0.03
Log L	-30.0	-29.9	-29.9	-25.5	-25.1	-14.1
AIC	64	63.8	65.8	55.1	56.3	72.3
Area under ROC	0.65	0.66	0.66	0.8	0.81	0.94

Notes: *, **, *** denote significance at the 10%, 5%, and 1% levels, respectively.