Testing the Consistency of Preferences in Discrete Choice Experiments: An Eye Tracking Study

Abstract

A within-subjects experiment with eye tracking was implemented to test for the presence of preference inconsistencies over repeated choice experiments. The empirical results indicate that after changing the position of the alternatives in the same choice set, participants were consistent with their choices only 69% of the time. Moreover, after reverting to the original positions of the alternatives but randomizing the order of the choice sets, individuals' choices were consistent only 67% of the time. The robustness of these results was further demonstrated by using random parameters models with flexible mixing distributions to calculate willingness-to-pay (WTP) for the product attributes. The WTP estimates differed significantly after altering both the order of the choice sets and the position of the alternatives, which again supports the notion of preference inconsistences across repeated choice experiments.

Key words: Choice Experiments, Eye-Tracking, Consistency

JEL codes: C91, C18

1. Introduction

Several experimental methods have been used to elicit consumers' preferences for goods and services. The two methods generally utilized are stated and revealed preference mechanisms. While stated preference methods rely mainly on hypothetical surveys, revealed preference mechanisms are based on incentive compatible methods that parallel real market settings. This incentive compatibility induces individuals to reveal their true preferences (Alfnes and Rickertsen 2010).

In stated preference mechanisms, individual valuations are estimated from ranking, rating, and choice data (Bunch, Louviere, and Anderson 1996). Discrete choice experiments (DCE) are the most commonly used stated preference approach and have been applied to elicit valuations for environmental assets, household appliances, transportation choices, and health services (McNeil et al 1982; Hensher 1994; Revelt and Train 1998; Louviere, Flynn and Carson 2010). One of the main reasons researchers choose to use choice experiments is that they can manipulate the choice sets and design alternatives that maximize the amount of information collected from participants (Lusk and Norwood 2005). The validity and accuracy of this method, however, have been in a longstanding dispute due to its hypothetical nature.

In particular, past evidence has found that choice experiments result in inconsistent choices as consumers tend to overstate their preferences in a hypothetical setting compared to when real money is on the line (List and Gallet 2001; Ding, Grewal, and Liechty 2005; Murphy et al. 2005; Lusk and Schroeder 2006; Sandor and Franses 2009). As a consequence, several methods for reducing hypothetical bias in choice experiments have been proposed, including the use of "cheap talk", certainty adjustment, and "honest priming" task (Cummings and Taylor 1997; De-Magistris, Gracia, and Nayga 2013).

Despite the efforts to diminish hypothetical bias in stated elicitation methods, preference inconsistencies have been constantly observed in applied research. This has driven interest into looking for potential explanations for these inconsistencies by comparing individuals' valuations under different elicitation mechanisms (Kassas, Palma, and Zhang 2016). Specifically, preferences and willingness to pay (WTP) elicited using choice experiments have been compared to those elicited under rankings, ratings, and experimental auctions (Caparros et al., 2008; Corrigan et al., 2009; Su et al. 2011). The results obtained from these comparisons are controversial. For example, while Boyle (2001) found inconsistent estimates between ranking and choice experiments, opposite results were found by Caparros et al. (2008). Preference inconsistencies in choice experiments have been attributed to several causes such as differences in experimental designs, changes in the combination of the attributes, and confusion and cognitive dissonance exhibited by participants (Mellers et al., 1992; Plott and Zeiler 2005).

Although past research has refined stated preferences elicited under DCEs by using the hypothetical bias mitigation methods mentioned earlier, little has been done to explore the consistency of preferences in repeated choice experiments. A key assumption of most DCEs is that individual's preferences are stable across choice sets and remain unchanged throughout the experiment. However, it is possible that even little details in the experimental design, like changing the position of the alternatives within the same choice set, can hold a significant effect on choices. This paper contributes to the related literature by assessing the influence of the position of the alternatives on the consistency of individuals' choices. In doing so, we implement a within-subject experiment to test for the presence of preferences inconsistencies over a sequence of three choice experiments. Moreover, we utilize eye-tracking metrics to aid in a more accurate and extensive analysis of the results.

Our findings show that researchers should pay more attention to DCE design, as the minor changes we implement in the DCE led to preference inconsistencies. In our results, when stating preferences in two sequences of choice sets where the only difference is the position of the alternatives in each choice set, subjects selected the same alternative on both only 69% of the time. As a robustness test we revert the positions of alternatives back to the original setting but show the sequence of choice sets in different order than the original and this time subjects selected the same alternative they had in the first round only 67% of the time. The latter consistency level is concerning, if we consider that subjects were facing identical choice sets, only in different order.

The remainder of this paper is organized as follows. Section 2 describes the experimental setup and design. Section 3 presents the methodology, while Section 4 discusses the main results. Lastly, Section 5 highlights the significance of this study and concludes the paper.

2. Experimental Setup and Design

A within-subject DCE was conducted to test the consistency of choices in repeated choice experiments. A total of 101 participants (39 male, 62 female) were recruited from the general population of the East-Central area of Texas. Subjects ranged in age from 19 to 69, with an average age of 28 years and average income of $45,000.

Individuals who agreed to participate in the experiment were assigned a specific time and date that was convenient for them. Each session lasted approximately 30 minutes and a compensation of $10 was paid to subjects for their participation. Upon arrival at the session, participants signed a consent form and were assigned an identification number to maintain anonymity. Subjects' eye-movements were recorded using a Tobii TX300 eye-tracking device which tracks gaze position using near-infrared recording technology at a rate of 120 Hz.

The experiment was an ABA design that included three conditions and two "distraction tasks" between each treatment (Figure 1). The first condition was the *baseline control*: a standard DCE consisting of twelve hypothetical choice sets for vegetable products. In each choice set, subjects were asked to choose between three vegetable products and a "no-purchase" option, placed in four possible positions on the computer screen: 1) upper-left corner, 2) upper-right corner, 3) lower-left corner, and 4) lower-right corner. The second condition of the design, the *position change treatment*, the same choice sets were presented but the position of the alternatives was randomly changed in each choice set. The third condition, the *baseline treatment,* replicated the original choice sets in the *baseline control*, reverting back to the same positions for each alternative but randomizing the order of the choice sets. This randomization of the order was done to avoid subjects' intent to reduce cognitive dissonance: trying to memorize their choices in the *baseline control* and deliberately trying to match them in the *baseline treatment*. In between each condition two "distraction tasks" were included to evaluate choice preferences after the subject's attention was diverted by manipulating the focus of attention. The first distraction task was a short socio-demographic survey presented between the *baseline control* and the *position change treatment*. The second distraction task was a cognitive function test commonly used to measure fluid intelligence, which was completed between the *position change* and *baseline treatments*[1].

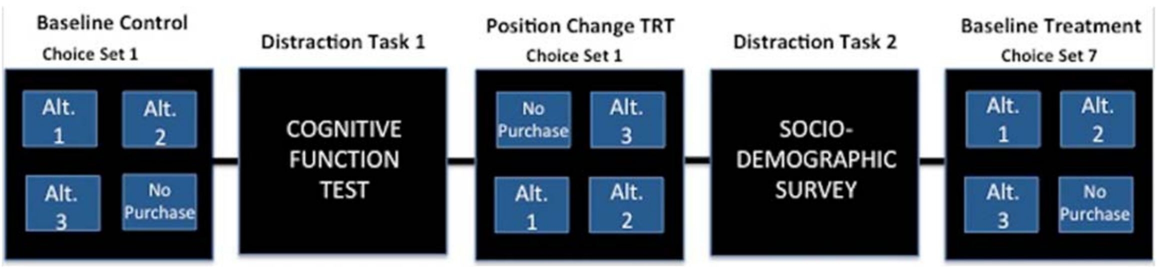

Figure 1. Experimental Procedure.

For this study an orthogonal D-efficient fractional factorial design with no priors was generated using NGENE 1.1.2 (ChoiceMetrics 2014). Five artichoke vegetable attributes with three levels each were used: size (*small, medium, large*), color (*green, purple, mixed*), production method (*conventional, organic, pesticide-free*), presentation form (*fresh, canned, glass*), and price *($1/unit, $2/unit, $3/unit*). In order to ensure that the subject was familiar with the attributes, a review of the definitions of each product attribute and attribute levels was presented prior to the *baseline control* condition.

3. Methodology

To account for unobserved taste heterogeneity, a mixed logit model (Revelt and Train 1998) was developed following a random utility theory framework (McFadden 1974). In this model, the utility of each alternative is specified as a function of the attributes of each of the other alternatives. Let the nth individual's utility of choosing option j in choice situation t be given by $U_{njt} = V_{njt} + \varepsilon_{njt}$, where V_{njt} represents the systematic

[1] All experimental materials are available upon request.

portion of the utility determined by the product attributes and ε_{ijt} is a stochastic component. Assuming V_{njt} is linear in parameters, the utility function can be expressed as $U_{njt} = \beta_n' x_{njt} + \varepsilon_{njt}$, where x_{njt} represents a vector of observed attributes for individual *n* in choice set *t*, β_n is a vector of utility coefficients that vary over people, and ε_{njt} is an extreme-value distributed error term. Under this assumption, the probability that decision-maker *n* makes a sequence of choices, conditional on β_n, can be specified as

$$L_n(\beta_n) = \prod_{t=1}^{T} Q_{nit}(\beta_n) \tag{1}$$

where $Q_{nit}(\beta_n) = \frac{e^{\beta_n' x_{nit}}}{\sum_{j \epsilon J} e^{\beta_n' x_{njt}}}$. Then, the unconditional probability of the sequence of choices takes the form:

$$P_n = \int L_{nt}(\beta) f(\beta|\theta) d\beta, \tag{2}$$

where $f(\beta|\theta)$ corresponds to the specified distribution of the random coefficients, and θ is a vector that describes the distribution of β_n (Train 2009).

3.1. Econometric models in WTP-space using flexible mixing distributions

The standard practice for application of choice models is the "model in preference space", in which the utility parameters are used to calculate WTP. Based on previous work by Cameron and James (1987), Train and Weeks (2005) constructed econometric models where the distributional assumptions and restrictions are placed on the WTP instead of the coefficients and referred to them as "models in WTP space". In these models, convenient distributions are specified for the WTP and price coefficient, the parameters of those distributions are calculated and later used to derive the distribution of utility coefficients. Our model assumes polynomial distribution for WTP, implying that coefficients are the product of polynomial and log-normal functions. Here, the utility is separated into price, p_{njt}, and non-price attributes as follows

$$U_{njt} = -\gamma_n p_{njt} + (\gamma_n WTP_n)' x_{njt} + \varepsilon_{njt} \tag{3}$$

where WTP_n corresponds to a vector of willingness to pay for each non-price attribute, and γ_n is a random scalar. The probability that the decision maker *n* chooses alternative *j* in choice set *t* becomes

$$Q_{nit}(\beta_n) = \frac{e^{-\gamma_n(p_{nit}+WTP_n' x_{nit})}}{\sum_{j\epsilon J} e^{-\gamma_n(p_{njt}+WTP_n' x_{njt})}}. \tag{4}$$

A detailed explanation on the procedures for estimating random parameters with flexible distributions can be found in Train (2015).

4. Results

Theoretically the order of the choice sets and the position of the alternatives should not alter the subject's preferences. We find evidence that both the position in which the alternatives are presented and the choice sets' order influence which attributes the participants pay more attention to and ultimately their choices.

4.1. Eye-Tracking Analysis

To analyze whether the position of the alternatives influenced subjects' choice decisions, specific areas of interest (AOIs) were created for the alternatives in each choice set. Overall the time subjects spent evaluating the different choice sets quickly decayed as they progressed through the experiment (Figure 2). This result goes in line with previous research that found a continuous decrease in visit duration in the course of the choice experiment (Palma et al. 2016). Rasch, Louviere, and Teichert (2015) attributed this outcome to potential learning effects acquired by participants as they view the choice sets.

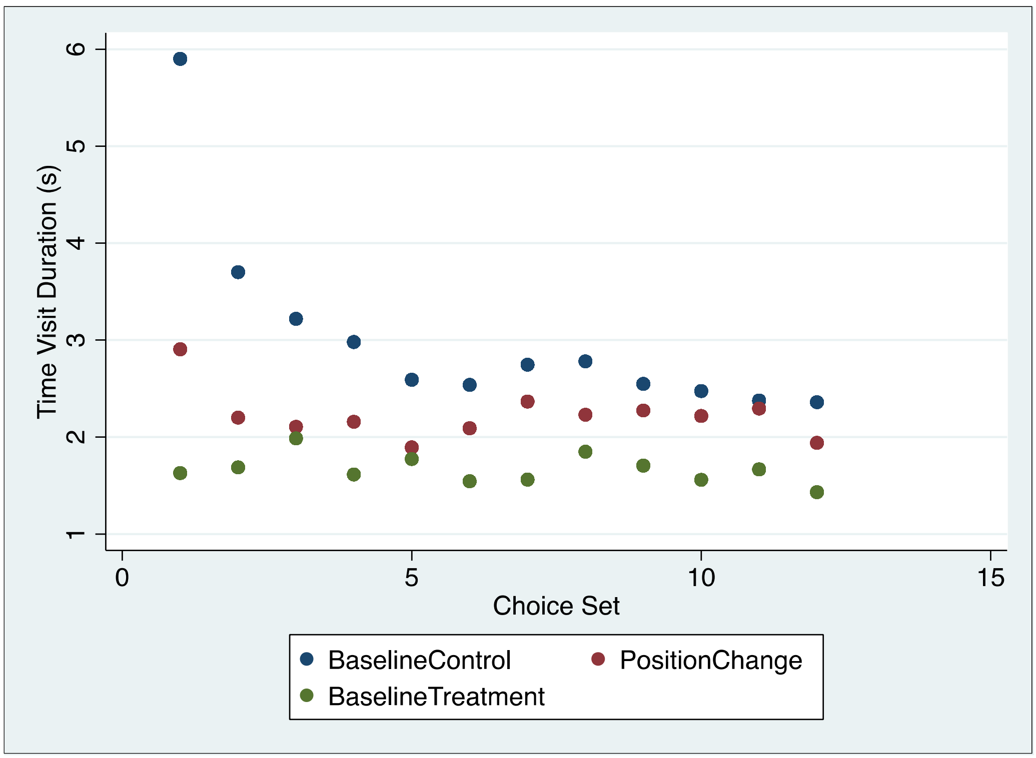

Figure 2. Time Visit Duration for each Choice Set by Treatment.

Figure 3 shows the eye-tracking metrics by treatment and position. The values in orange, green, and blue colors represent estimates for the *baseline control*, *position change treatment*, and *baseline treatment*, respectively. Panel A displays the total amount of time (in seconds) spent on each position by treatment. In all conditions, the longest amount of time was for the upper-left position (4.62 s, 2.71 s, and 2.49 s), followed by the upper-right (3.62, 2.31, and 2.11), lower-left (3.26, 1.99, and 1.80), and the lower-right (0.57, 1.88, 0.27). The alternatives located in the upper positions, especially the upper left position, received the highest attention in terms of how often subjects looked at those alternatives, as shown in Panel B. This result ties into the relationship between the position of the alternatives and the frequency of choices. Panel C shows the proportion of choices made by position. On average, subjects tend to choose the products located at the upper positions more often, with a higher disposition towards the alternative in the upper right position.

To gather a better understanding on the influence of the experimental design on consumer choices, we calculate the inconsistency of choices across treatments. Results show that after changing the position of the alternatives in the choice set, subjects selected the same alternative only 69% of the time. After reverting back to the original positions (*baseline treatment*), subjects consistently selected the same alternative only 67% of the time. We find the latter consistency level more worrisome. Subjects were facing identical choice sets to those in the *baseline control* only in different order and chose differently one third of the time.

Table 1 shows the time (ms) that consistent and inconsistent subjects spent looking at the attributes of the chosen and non-chosen products. In both cases, after changing the position of the alternatives and the order of the choice sets, respondents who were consistent with respect to their choices in the *baseline control* spent significantly more time looking at the chosen product compared to the no-chosen products. There was no difference between the total visit duration between chosen and no-chosen products for inconsistent respondents. Inconsistent subjects are spending less time evaluating the alternatives, which may be due to fatigue effects or lack of engagement in the DCE. This could explain their inconsistency in selections.

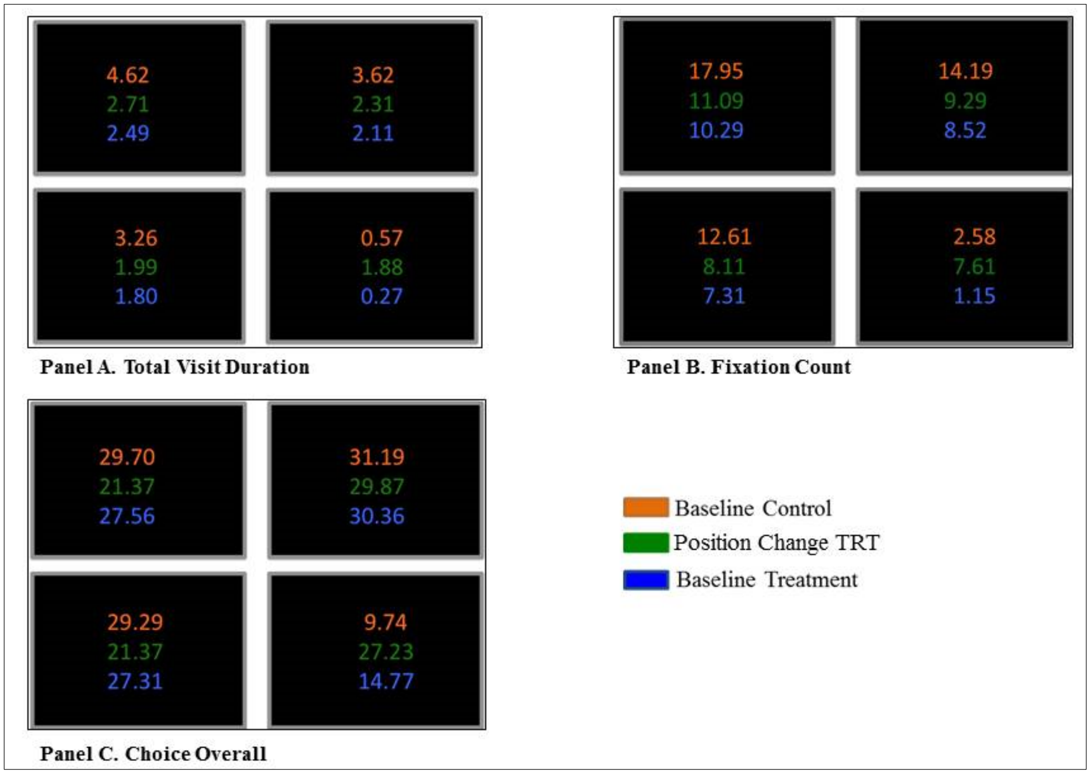

Figure 3. Eye-tracking Metrics by Treatment and Position.

Table 1. Total Visit Duration by consistency and Treatment.

	Position Change Treatment				Baseline Treatment			
	Consistent Subjects		Inconsistent Subjects		Consistent Subjects		Inconsistent Subjects	
Time Visit Duration	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
Chosen Product	3.72	0.19	2.48	0.2	2.83	0.16	2.79	0.22
Not Chosen Products	1.76	0.07	2.66	0.16	2.25	0.09	2.55	0.17

4.2. WTP Estimates

The eye tracking results are used to estimate WTP space parameters. Table 2 displays the mean and standard deviation of WTP space models assuming the coefficients for all attributes follow flexible polynomial distributions[2]. The WTP range with flexible polynomial distributions was set using two standard deviations above and below the mean WTP with normal distribution. The simulation was done using 2000 random draws

[2] The parameter estimates of WTP space models assuming a normal distribution are available upon request.

per individual, with standard errors obtained by replicating the estimation procedure over 20 new samples.

The WTP estimates support the findings described above. In general, the distributions of WTP estimates differed significantly for nearly all attributes after changing the order of the choice sets and the position of the alternatives[3]. Specifically, in the case of the “no product” estimate, both the magnitude and sign of the coefficient changed with respect to the *baseline control*. That is, when keeping the exact same position of the alternatives (*baseline control* and *baseline treatment*), subjects were more likely to choose one of the options over the “no product” option. The opposite effect was found after changing the position of the alternatives in the *position change condition*. Considering that the alternatives and choice sets are identical, this switch from negative to positive WTP in the *position change condition* can be a sign of subjects’ inconsistent behavior. Regarding the specific attributes of the products, preferences for the mixed-color, green, and large artichokes changed as they carried the highest price premiums ($1.33, $1.04, and $1.00, respectively) after the position of the alternatives was modified. In contrast, for the attributes describing fresh, glassed, organic, and pesticide-free artichokes, the mean price premiums significantly decreased after changing both the order of the choice sets and the position of the alternatives. These results strengthen the hypothesis that preferences are not stable with respect to the *baseline control*.

[3] Graphs of the distributions in the appendices of the article.

Table 2. Parameter Estimates of WTP Space Models with Flexible Polynomial Distributions.

	Baseline Control			Position Change Treatment			Baseline Treatment		
				WTP Means					
	Coefficient		S.E	Coefficient		S.E	Coefficient		S.E
Green	1.1426	***	0.2050	1.3328	***	0.1452	0.5466	***	0.1546
Mixed	0.8877	***	0.1815	1.0437	***	0.0113	0.5773	***	0.1376
Fresh	3.4962	***	0.3020	3.1446	***	0.3118	2.5421	***	0.2237
Glassed	1.8707	***	0.2188	1.7218	***	0.2518	1.3879	***	0.1736
Small	-1.3796	***	0.2729	-1.4301	***	0.2697	-1.0583	***	0.1882
Large	0.7660	***	0.2781	1.0010	***	0.2178	0.7922	***	0.0939
Organic	1.9946	***	0.2492	1.9043	***	0.2751	1.2111	***	0.0751
Pest-free	1.7350	***	0.2693	1.6789	***	0.3263	0.9832	***	0.1209
No-prod	-1.4158	***	0.8928	0.3150	***	0.1148	-0.9197	***	0.3466
Price	0.7946	***	0.1045	0.9121	***	0.0700	1.0356	***	0.1023
				WTP Standard Deviations					
Green	1.0833	***	0.1696	0.8625	***	0.1341	0.5781	***	0.1294
Mixed	0.6978	***	0.1090	0.0379	***	0.0054	0.3728	***	0.0698
Fresh	2.8125	***	0.3086	2.9583	***	0.2696	2.2772	***	0.2045
Glassed	1.1545	***	0.1988	1.1436	***	0.1291	1.1823	***	0.1144
Small	1.2988	***	0.2064	1.3635	***	0.2640	0.6379	***	0.1422
Large	1.0940	***	0.1406	1.3412	***	0.2705	0.5189	***	0.0730
Organic	1.5254	***	0.2063	2.4340	***	0.4295	0.1672	***	0.0360
Pest-free	0.9830	***	0.1350	2.2394	***	0.2690	0.5198	***	0.1031
No-prod	2.7665	***	0.5777	0.4377	***	0.0732	2.2503	***	0.2504
Price	0.4006	***	0.0882	0.4192	***	0.0870	0.4049	***	0.0668
NOBS			4848			4848			4848
Log Likelihood			-1062.35			-1098.29			-1092.21

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

The inconsistency in subjects' choices can be further demonstrated by comparing the distributions of WTP for each attribute across treatments. Though none of the attributes' parameters followed a normal distribution, there were substantial differences in the WTP distributions across treatments. The inconsistencies are also present the results shown in Table 3, which presents the WTP correlations between attributes. For the *baseline control*, statistically significant correlations include: Subjects who preferred small artichokes were willing to pay a price premium for mixed-color artichokes (0.51); people who liked glassed products had preference for fresh (0.57) but disliked pesticide-free artichokes (-0.53). In the position change treatment, the same number of significant correlations was found but between different attributes. In this case, individuals who had price premiums for green artichokes preferred large and organic artichokes (0.44 and 0.53 respectively), but disliked glassed products (-0.50). Subjects who preferred mixed-color artichokes expressed a premium for small artichokes, as did subjects in the *baseline control* condition. For the *baseline treatment*, statistically significant and negative correlations were found between large and mixed artichokes (-0.70) and between pesticide-free and green artichokes (-0.66). These results indicate significant changes in preferences for attributes across treatments, which affirms the significance of the influence of minor changes in the experimental design on elicited preferences in DCE.

Table 3. WTP Correlations Between Artichokes Attributes.

Baseline Control									
	green	mixed	fresh	glassed	small	large	organic	pest-free	noprod
green	1.0000	0.2151	0.0228	-0.0541	-0.2952	-0.0751	0.1654	0.2931	-0.1661
mixed	0.2151	1.0000	0.1917	0.0014	0.5111	-0.3016	0.1085	0.1662	-0.0431
fresh	0.0228	0.1917	1.0000	0.5718	0.1964	-0.3965	-0.4461	-0.4304	0.1280
glassed	-0.0541	0.0014	0.5718	1.0000	0.1787	-0.2100	-0.2893	-0.5260	0.5404
small	-0.2952	0.5111	0.1964	0.1787	1.0000	-0.2485	-0.0802	0.1760	-0.1507
large	-0.0751	-0.3016	-0.3965	-0.2100	-0.2485	1.0000	-0.3518	-0.0697	0.0192
organic	0.1654	0.1085	-0.4461	-0.2893	-0.0802	-0.3518	1.0000	0.6735	0.1666
pest-free	0.2931	0.1662	-0.4304	-0.5260	0.1760	-0.0697	0.6735	1.0000	-0.2184
noprod	-0.1661	-0.0431	0.1280	0.5404	-0.1507	0.0192	0.1666	-0.2184	1.0000

Position Change Treatment									
	green	mixed	fresh	glassed	small	large	organic	pest-free	noprod
green	1.0000	-0.0667	-0.2200	-0.4991	0.0825	0.4425	0.5317	0.0807	-0.0109
mixed	-0.0667	1.0000	-0.2343	-0.0321	0.4720	-0.2273	-0.2781	-0.6822	-0.2989
fresh	-0.2200	-0.2343	1.0000	0.3544	-0.0552	0.1045	-0.0393	0.0468	-0.0105
glassed	-0.4991	-0.0321	0.3544	1.0000	0.2601	-0.0789	-0.0790	0.0229	0.3828
small	0.0825	0.4720	-0.0552	0.2601	1.0000	-0.2329	0.1815	-0.1431	0.2888
large	0.4425	-0.2273	0.1045	-0.0789	-0.2329	1.0000	-0.0924	0.1201	-0.2304
organic	0.5317	-0.2781	-0.0393	-0.0790	0.1815	-0.0924	1.0000	0.5492	0.2394
pest-free	0.0807	-0.6822	0.0468	0.0229	-0.1431	0.1201	0.5492	1.0000	0.4418
noprod	-0.0109	-0.2989	-0.0105	0.3828	0.2888	-0.2304	0.2394	0.4418	1.0000

Baseline Treatment									
	green	mixed	fresh	glassed	small	large	organic	pest-free	noprod
green	1.0000	0.2844	0.0576	-0.0094	-0.1395	-0.0787	0.2866	-0.6618	0.3123
mixed	0.2844	1.0000	0.0269	0.1546	0.6630	-0.6983	0.2735	-0.4466	0.5661
fresh	0.0576	0.0269	1.0000	0.6999	0.0251	-0.1066	-0.3387	-0.0081	0.4013
glassed	-0.0094	0.1546	0.6999	1.0000	0.1467	-0.1532	-0.5150	-0.2099	0.4818
small	-0.1395	0.6630	0.0251	0.1467	1.0000	-0.6457	0.4070	0.0866	-0.0011
large	-0.0787	-0.6983	-0.1066	-0.1532	-0.6457	1.0000	-0.3819	0.2467	-0.3151
organic	0.2866	0.2735	-0.3387	-0.5150	0.4070	-0.3819	1.0000	0.0351	-0.3831
pest-free	-0.6618	-0.4466	-0.0081	-0.2099	0.0866	0.2467	0.0351	1.0000	-0.5933
noprod	0.3123	0.5661	0.4013	0.4818	-0.0011	-0.3151	-0.3831	-0.5933	1.0000

5. Conclusions

The objective of this paper is to test for the presence of preference inconsistency over repeated choice experiments in DCE. The results presented here highlight the importance of the position of the alternatives and the order of the choice sets in the experimental design. In particular, it was found that participants were consistent with their choices only 69% after the position of the alternatives within the choice set was altered, and 67% of the time after the order of the choice sets was randomized but the position was reverted back to the original. These findings were supported by discrete choice models estimated in WTP space. The parameters obtained form these models differed for all attributes across treatments indicating choice inconsistencies.

The result that even minor changes in the experimental design significantly affect individuals' stated preferences warrants more attention when designing DCEs to elicit individuals' valuations. With this in mind the position of the alternatives and the order of the choice sets should be considered as part of the experimental design in order to obtain more stable preference parameter estimates.

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Appendix A. Distributions of WTP of artichoke products by treatment.

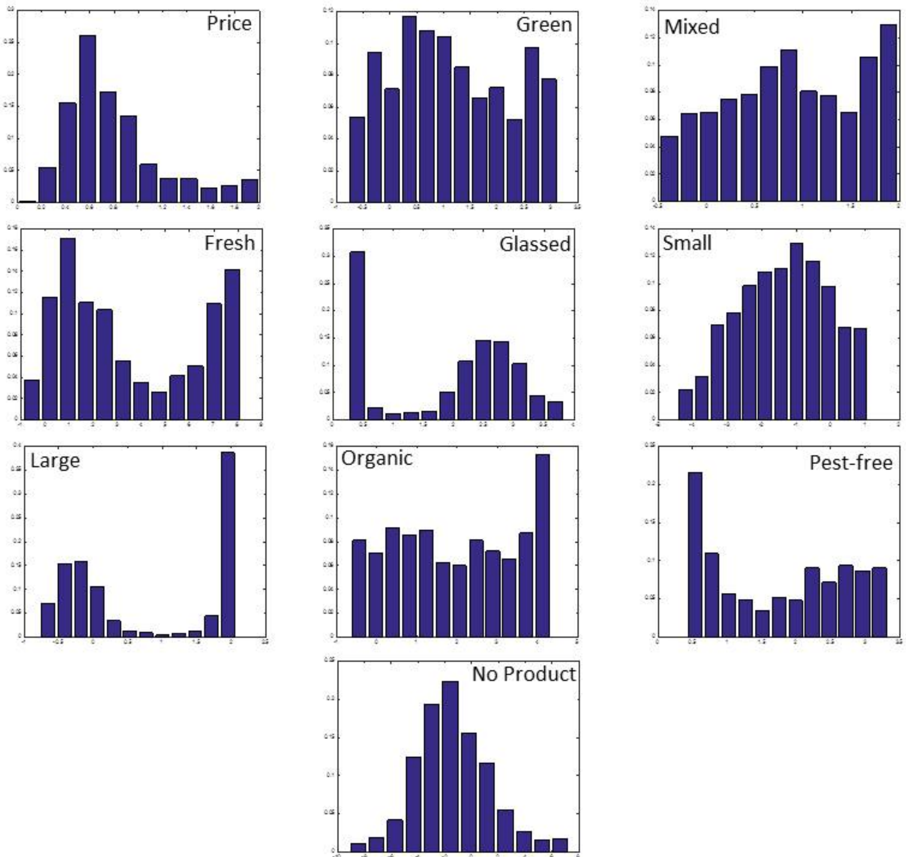

Figure 4. WTP Distributions of Artichoke Attributes for Baseline Control.

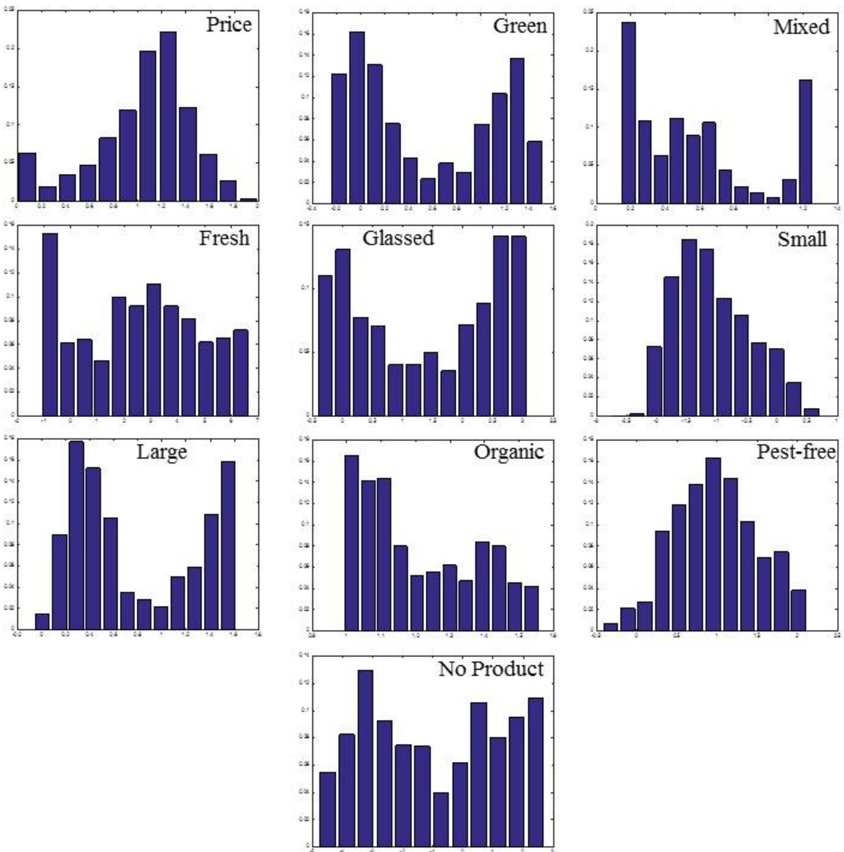

Figure 5. WTP Distributions of Artichoke Attributes for Position Change Treatment.

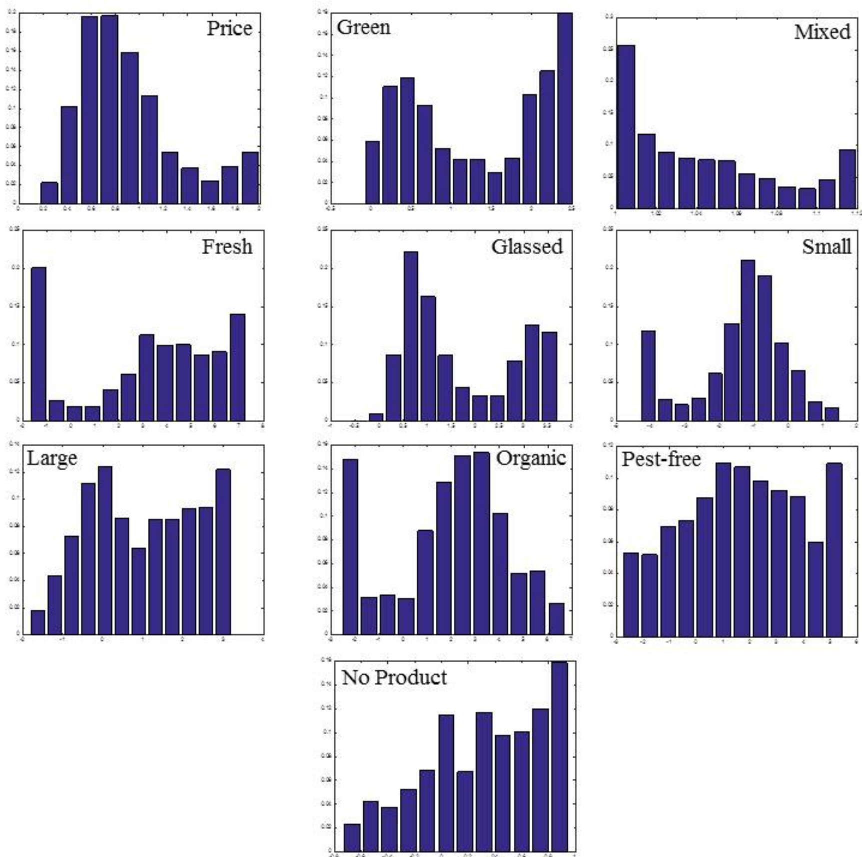

Figure 6. WTP Distributions of Artichoke Attributes for Baseline Treatment.