Trade-Off Aversion as an Explanation for the Attraction Effect: A Functional Magnetic Resonance Imaging Study

WILLIAM HEDGCOCK and AKSHAY R. RAO

Web Appendix A: Sample Preliminary Questionnaire

On the next few pages, you will be asked many questions. In each question, you must make an evaluation of two options. Here is a sample question:

Suppose you had to choose between two offerings of a College Class. One class had a better instructor. What would the quality of materials have to be in the other class to make the two equally attractive? Both instructor quality and materials quality are rated on a 1-100 scale where 1= very poor and 100 = outstanding.

College Class

	Quality of Instructor	**Quality of Materials**
Option #1	70	80
Option #2	80	______

We are interested in your judgment about what score will make these classes equally attractive. For instance, you might enter 65 as a value that makes you equally interested in either section since the instructor for section #2 is better than the instructor in section #1.

Please enter an answer for every question.

Following is a sample question from the indifference questionnaire:

House options:

	Crime Rate	Cost
Option #1	15 per 1,000	$620
Option #2	7 per 1,000	$______

- *Crime rate is a count of moderate to severe physical violence per 1,000 residents.*
- *Cost is the monthly mortgage payments.*

Web Appendix B: Situations and Attributes for Pilot Study

Block	Trial	Task	Attribute 1	Attribute 2	Attribute Value	Decoy Type
1	1	Car	Ride Quality	Lease	Low	Inf
1	2	Cruise	Incidence of Disease	Shore Excursions	Low	Asym
1	3	Car Repair	Odds of Breakdown	Cost	Low	Inf
1	4	Apartment	Building Safety	Commute	High	Inf
1	5	Day Care	Experience	Cost	High	Asym
1	6	Retirement Investment	Quality of Service	Fees	Low	Non
1	7	House	Crime Rate	Cost	High	Asym
1	8	Career	Job Security	Commute	High	Asym
2	9	Day Care	Experience	Cost	Low	Non
2	10	Retirement Investment	Security	Quality of Service	High	Inf
2	11	House	Crime Rate	Cost	Low	Asym
2	12	Hotel	Years Since Last Remodel	Rate	Low	Asym
2	13	Apartment	Building Safety	Commute	Low	Asym
2	14	Car Repair	Distance	Cost	High	Non
2	15	Car	Crash Ranking	Ride Quality	High	Asym
2	16	Health Plan	Participating Doctors	Copay	High	Inf
3	17	Apartment	Building Safety	Rent	High	Non
3	18	Car Repair	Distance	Cost	Low	Asym
3	19	Career	Job Security	Salary	High	Inf
3	20	Day Care	Security	Experience	High	Inf
3	21	House	Number of bedrooms	Cost	High	Inf
3	22	Retirement Investment	Security	Quality of Service	Low	Asym
3	23	Cruise	Incidence of Disease	Price	Low	Non
3	24	Health Plan	Participating Doctors	Copay	Low	Asym
4	25	Cruise	Shore Excursions	Price	High	Asym
4	26	Car Repair	Odds of Breakdown	Distance	High	Inf
4	27	Retirement Investment	Security	Fees	High	Non
4	28	House	Number of bedrooms	Cost	Low	Non
4	29	Apartment	Building Safety	Rent	Low	Asym
4	30	Hotel	Safety of Beach	Years Since Last Remodel	Low	Inf
4	31	Day Care	Security	Experience	Low	Inf
4	32	Career	Job Security	Salary	Low	Asym

Web Appendix C: Situations and Attributes for Main Study

Block	Trial	Task	Attribute 1	Attribute 2	Attribute Value	Decoy Type
1	1	Car	Ride Quality	Lease	Low	Inf
1	2	Hotel	Years Since Last Remodel	Rate	High	Non
1	3	Home Maintenance	Environmental Impact	Work Time	Low	Non
1	4	Cruise	Incidence of Disease	Shore Excursions	Low	Asym
1	5	Car Repair	Odds of Breakdown	Cost	Low	Inf
1	6	Apartment	Building Safety	Commute	High	Inf
1	7	Day Care	Experience	Cost	High	Asym
1	8	Retirement Investment	Quality of Service	Fees	Low	Non
1	9	House	Crime Rate	Cost	High	Asym
1	10	Health Plan	Maximum Coverage	Copay	Low	Non
1	11	Education Policy	Money for Special Needs	Taxes	High	Non
1	12	Career	Job Security	Commute	High	Asym
2	13	Day Care	Experience	Cost	Low	Non
2	14	Retirement Investment	Security	Quality of Service	High	Inf
2	15	House	Crime Rate	Cost	Low	Asym
2	16	Hotel	Years Since Last Remodel	Rate	Low	Asym
2	17	Cruise	Incidence of Disease	Price	High	Inf
2	18	Education Policy	Money for Special Needs	Taxes	Low	Non
2	19	Apartment	Building Safety	Commute	Low	Asym
2	20	Car Repair	Distance	Cost	High	Non
2	21	Car	Crash Ranking	Ride Quality	High	Asym
2	22	Career	Job Security	Commute	Low	Non
2	23	Home Maintenance	Environmental Impact	Cost	High	Inf
2	24	Health Plan	Participating Doctors	Copay	High	Inf
3	25	Apartment	Building Safety	Rent	High	Non
3	26	Hotel	Safety of Beach	Years Since Last Remodel	High	Non
3	27	Home Maintenance	Environmental Impact	Cost	Low	Inf
3	28	Car Repair	Distance	Cost	Low	Asym
3	29	Career	Job Security	Salary	High	Inf
3	30	Day Care	Security	Experience	High	Inf
3	31	House	Number of bedrooms	Cost	High	Inf
3	32	Retirement Investment	Security	Quality of Service	Low	Asym
3	33	Cruise	Incidence of Disease	Price	Low	Non
3	34	Health Plan	Participating Doctors	Copay	Low	Asym
3	35	Car	Crash Ranking	Ride Quality	Low	Inf
3	36	Education Policy	Students per class	Taxes	High	Asym
4	37	Cruise	Shore Excursions	Price	High	Asym
4	38	Health Plan	Maximum Coverage	Participating Doctors	High	Non
4	39	Education Policy	Students per class	Taxes	Low	Inf
4	40	Car Repair	Odds of Breakdown	Distance	High	Inf

4	41	Retirement Investment	Security	Fees	High	Non
4	42	House	Number of bedrooms	Cost	Low	Non
4	43	Apartment	Building Safety	Rent	Low	Asym
4	44	Hotel	Safety of Beach	Years Since Last Remodel	Low	Inf
4	45	Day Care	Security	Experience	Low	Inf
4	46	Career	Job Security	Salary	Low	Asym
4	47	Car	Crash Ranking	Lease	High	Non
4	48	Home Maintenance	Work Time	Cost	High	Asym
5	49	Cruise	Shore Excursions	Price	Low	Inf
5	50	House	Crime Rate	Number of bedrooms	High	Inf
5	51	Car Repair	Odds of Breakdown	Distance	Low	Asym
5	52	Day Care	Security	Cost	High	Asym
5	53	Retirement Investment	Security	Fees	Low	Asym
5	54	Career	Commute	Salary	High	Non
5	55	Home Maintenance	Work Time	Cost	Low	Non
5	56	Hotel	Safety of Beach	Rate	High	Asym
5	57	Health Plan	Maximum Coverage	Participating Doctors	Low	Inf
5	58	Apartment	Commute	Rent	High	Inf
5	59	Car	Crash Ranking	Lease	Low	Non
5	60	Education Policy	Money for Special Needs	Students per class	High	Asym
6	61	Home Maintenance	Environmental Impact	Work Time	High	Asym
6	62	Apartment	Commute	Rent	Low	Non
6	63	Health Plan	Maximum Coverage	Copay	High	Asym
6	64	House	Crime Rate	Number of bedrooms	Low	Non
6	65	Retirement Investment	Quality of Service	Fees	High	Inf
6	66	Career	Commute	Salary	Low	Inf
6	67	Education Policy	Money for Special Needs	Students per class	Low	Inf
6	68	Cruise	Incidence of Disease	Shore Excursions	High	Non
6	69	Day Care	Security	Cost	Low	Non
6	70	Car	Ride Quality	Lease	High	Asym
6	71	Hotel	Safety of Beach	Rate	Low	Inf
6	72	Car Repair	Odds of Breakdown	Cost	High	Non

Web Appendix D: Technical Details

Equipment. The fMRI phase of the study employed a 3 Tesla, Siemens Trio whole body scanner with a standard CP head coil. Functional scans used a relatively standard scan sequence (T2* weighted EPI sequence, voxels = 35 3mm^{2}x2mm slices with a .7mm skip between slices, TR = 2000ms) obtained in the axial plane. Some of the regions of interest are located in the ventral prefrontal cortex, a region susceptible to measurement error because of the presence of cranial sinuses. The 2mm slice thickness and slice angle help minimize these problems. Structural scans for each subject were performed using a T1-weighted MPRAGE sequence (voxels = 1mm^3).

Subjects answered choice questions while lying on their back. Stimuli were projected on a screen outside of the scanner that subjects could see using a mirror that was placed just over their eyes. Subjects responded with their right hand using the first three numbers on a key pad. Total time in the scanner including preparation, instructions, and task time was 75 minutes.

Analyses. Image analyses and preprocessing were performed using BrainVoyager QX 1.8. Functional scans were preprocessed using the following steps: three-dimensional motion correction, slice scan time correction, spatial smoothing, and temporal data smoothing. No subject had greater than one voxel movement in any direction. Spatial smoothing was performed using a 4-mm full-width, half maximum Gaussian kernel. Temporal smoothing used a high-pass filter (cutoff frequency = 3 cycles per functional run) to remove low-frequency drift or oscillations. Subjects' anatomical images were normalized to the Talairach and Tournoux (1988) brain template. Functional volumes were then standardized using the transformation parameters from the anatomical images.

The first five volumes of each functional scan were discarded to minimize problems with T1 saturation effects.

Changes in the BOLD contrast associated with performance of each part of the decision task were assessed for each voxel using the general linear model (GLM) in Brainvoyager QX. Unique predictors were created for each part of the decision task: task description (TaskDesc), choice description (Choice), post-choice grey screen (Post), and fixation (fix). Choice description and post-choice screens were further subdivided between choice sets that included an asymmetric decoy (Asym), inferior decoy (Inf), or no decoy (No) and coded based on the ultimate choice of the target (T) or choice of the other options (C) for asymmetric and inferior decoy choices, or choice of the option that dominated on the first attribute (1) or dominated on the second attribute (2) for non-decoy choices. This resulted in 14 predictors (TaskDesc, ChoiceAsymT, ChoiceAsymC, ChoiceInfT, ChoiceInfC, ChoiceNo1, ChoiceNo2, PostAsymT, PostAsymC, PostInfT, PostInfC, PostNo1, PostNo2, Fix). The onset of each predictor was convolved with a two gamma hemodynamic response function to identify voxels with blood flow that correlated with the predictors. The GLM was corrected for temporal serial correlation using AR(1) modeling.

Analysis continued used a second-level random effects ANOVA to contrast decoy decisions (ChoiceAsymT, ChoiceAsymC, ChoiceInfT, ChoiceInfC) with tradeoff decisions (ChoiceNo1, ChoiceNo2). The results of this contrast are displayed in Figures 3 and 4 of the main text. Voxels in these figures exceeded the probability threshold of $p < .000117$ (uncorrected, which corresponded to a false discovery rate (FDR) $< .001$).

Regions of interest (Table 2, main text and Table WD1) were reported if they had 50 or more contiguous voxels.

TABLE WD1

Complete list of regions showing significant differences in BOLD activation for Decoy - No Decoy in the choice task (n = 16, random effect, p < .00012, q(FDR) < .001)

Regions with significant increases in BOLD activation for contrast of Decoy - No Decoy

Location	Hemi-sphere	Brodmann Area	x	y	z	Significant Voxels	Average t-Stat
Anterior Cingulate/Medial Frontal Gyrus		24/6/32	1.9	13	44	12792	5.08
DLPFC: Middle/Inferior Frontal Gyrus	R	9/46	40	18	20	23817	4.77
DLPFC: Inferior/Middle Frontal Gyrus	L	10/46	-40	43	6.8	3625	4.7
DLPFC: Precentral Gyrus/Middle Frontal Gyrus	L	6/9	-42	5.9	31	6577	4.37
Insula/Claustrum	L		-31	12	5.2	3090	4.96
Cerebellum/Middle Occipital Gyrus/Fusiform Gyrus	R	18/19/37	36	-68	-14	18669	4.81
Cerebellum/Middle Occipital Gyrus/Fusiform Gyrus	L	18/19/37	-31	-75	-16	19316	4.65
Middle Frontal Gyrus	L	6	-27	-7.4	47	125	4.54
Thalamus-Ventral Lateral Nucleus	R/L		0.17	-15	3	23327	4.54
Thalamus	R		22	-30	-0.08	1279	4.31
Cerebellum	R/L		0.14	-70	-29	4758	4.29
Cerebellum	R/L		0.51	-51	-33	1139	4.19

Regions with significant decreases in BOLD activation for contrast of Decoy - No Decoy

Location	Hemi-sphere	Brodmann Area	x	y	z	Significant Voxels	Average t-Stat
Amygdala	L		-20	-7.8	-16	51	-4.11
Amygdala	R		24	-8.3	-16	1894	-4.22
MPFC/Rostral Anterior Cingulate	R/L	10/25/32	-0.69	30	-0.05	14339	-4.55
Inferior Parietal Lobule/Superior Temporal Gyrus	R	40/22	56	-36	20	7377	-4.6
Middle Temporal Gyrus	R	22	49	-38	2.2	468	-4.06
Parahippocampal Gyrus	L		-24	-13	-15	635	-4.1
Inferior Temporal Gyrus	L	21	-57	-6.3	-13	808	-4.1
Temporal Lobe	R	21	42	-6.4	-10	712	-4.11
Parahippocampal Gyrus	L	36	-24	-40	-10	728	-4.15
Superior Temporal Gyrus	L	38	-51	14	-20	129	-4.16
Cingulate Gyrus	R/L	24	-1.5	-18	40	106	-4.19
Middle Temporal Gyrus/Precentral Gyrus	R	21/44	56	-5.9	-6.4	5576	-4.19
Insula	L	13	-42	-5.7	-5.8	1359	-4.19
Superior Temporal Gyrus	L	13	-58	-42	18	3014	-4.2
Posterior Cingulate	L	30	-8.5	-61	16	1682	-4.31
Middle Temporal Gyrus	L	21	-55	-21	-5.5	597	-4.32

Note: All x, y, and z coordinates refer to Talairach coordinates.

Analysis of the high versus low heuristic processors contrast used the same first level GLM described above. Regions in this contrast were defined using a mask from the first decoy versus tradeoff analysis. In other words, "DLPFC" in analysis 1 was defined as a particular set of voxels, so active voxels in analysis 2 only counted if they were in the same region. This assured that defined regions were identical in both analyses and helped increase statistical significance. Yoon et al. (2006) use a similar masking procedure though they use pre-defined anatomical regions.

A second level random effects analysis contrasting high versus low heuristic processors was not significant at acceptable probability levels.[1] This is not surprising as this contrast is a between subjects analysis which has less sensitivity to activation differences because of the low degrees of freedom and high inter-subject variability. We then performed a fixed-effects analysis which increased the degrees of freedom, though the use of a fixed effects analysis limits our ability to generalize the result of this contrast to the population (Friston et al. 1999).

The fixed effects analysis contrasted decoy decisions (ChoiceAsymT, ChoiceAsymC, ChoiceInfT, ChoiceInfC) in high versus low heuristic processors. Regions of interest were reported if they had 50 or more contiguous voxels that exceeded the probability threshold of $p < .000774$ (uncorrected, which corresponded to an FDR < .001).

1. This contrast yielded differences in the predicted direction for the primary regions of interest (amygdala, DLPFC, MPFC, ACC, and right inferior parietal lobule) at $p < .08$ (uncorrected).

Friston, K.J., A.P. Holmes, C.J. Price, C. Buchel, and K.J. Worsley (1999), "Multisubject fMRI Studies and Conjunction Analyses," *NeuroImage*, 10 (4), 385–96.

Yoon, Carolyn, Angela H. Gutchess, Fred Geinberg, and Thad A. Polk (2006), "A Functional Magnetic Resonance Imaging Study of Neural Dissociations Between Brand and Person Judgments," *Journal of Consumer Research*, 33 (1), 31–40.