科技部補助專題研究計畫成果報告

（期末報告）

動機與快樂的腦神經研究

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摘要

人們如何評價選擇的結果? 根據 Kőszegi and Rabin (2006) 的參考點相依之效用理論,選擇結果的全面效用包括消費本質的效用與因參考點而生之利得—損失效用。本研究利用功能性磁振造影 (fMRI) 檢視人們在評價結果時,權衡消費效用與利得—損失效用的方法。第一階段實驗監測腦神經對多種類型的貨幣—食物報酬組合之反應。第二階段的每一個實驗都是由預測期與實現期所組成;前一期中各組合之報酬部分或完全未揭露,必須自行猜測,後一期則揭曉前一期的組合之報酬。本研究發現
MPFC 與 OFC 隨著貨幣—食物報酬所帶來的預期消費效用而活化。而當人們體驗參考點相依的全面效用時,一般情況下大腦也在相同區域活化。MPFC 同時也負責編碼損失與利得的反應。

關鍵詞:消費效用、利得—損失效用、體驗效用、參考點依賴、功能性磁振造影

Abstract

How does a person assess the outcome of a choice? Kőszegi and Rabin (2006) proposed a reference-dependent utility theory in which the overall utility of an outcome is composed of two components: an intrinsic consumption utility attached to the choice itself and a gain-loss utility which is reference dependent. Using functional magnetic resonance imaging, we investigated the way people weigh consumption utility and gain-loss utility to assess an outcome. Trials in Session 1 were to monitor neural responses to multiple types of money-food reward bundles. Trials in Session 2 comprised an initial expectancy phase, when rewards in each bundle were not fully disclosed and needed to be predicted, and a subsequent outcome phase, when actual amounts of rewards were revealed. We found that MPFC and OFC track expected consumption utility for money-food rewards bundles. Generally, reference-dependent experienced utility was also observed in the same regions. MPFC also encodes gain or loss signals that were computed during experience of actual rewards.

Keywords: consumption utility, gain-loss utility, experienced utility, reference-dependent, fMRI

Neuronal Representations of Reference-dependent Value

Introduction

People make decisions to maximize outcome utility. Based on Kahneman's conception, outcome utility is a hedonic experience generated by the outcome when eventually gained (Kahneman, et al., 1997), which is distinguished from choice-based or decision utility. How a person assesses the outcome of a choice? Mellers et al. (1997) have shown that the emotional response to an outcome depends on the perceived value and the presence of alternatives. Kőszegi and Rabin (2006) construct a reference-dependent utility theory in which a person's utility depends not only on his consumption bundle but also on a reference bundle. They assume that while evaluating an outcome under uncertain environments, a person sets a reference point based on his recent beliefs about outcomes, and the resulting departure from the posited reference point evokes an emotional response which is called gain-loss utility. Hence, the overall utility of an outcome is composed of two components: an intrinsic consumption utility attached to the choice itself and a gain-loss utility which is reference dependent. If the reference-dependent property of preference is true or counterfactual influences exist, then the selection of utility as a welfare index for public policy is relevant to the desirability of alternative policies.

How do consumption utility and gain-loss utility actually interact within a brain? Is it possible to disentangle the two neural representations of value during evaluation? Is the activation of brain region in the representation of gain-loss utility significant? Kőszegi and Rabin (2006) propose reference-dependent preference, yet claim that gains and losses are not all that people care about. By contrast, Kahneman and Tversky (1979) assert that the evaluation of a risky prospect depends little on the "asset" position (i.e. absolute value) but is framed instead as a gain or loss with respect to a reference (neutral) point. Kőszegi and Rabin show that if consumption utility is linear separately in each dimension of characteristics and gain-loss utility, satisfying the assumptions Kahneman and Tversky (1979) make about their value function defined on gain-loss, is also additively separable across dimensions, then for small changes in a consumption outcome there exists equivalence of properties between overall utility and gain-loss utility. That means insofar as the deviation from the reference level of an outcome is small, the reference-dependent theory has good prediction power as the prospect theory in gain-loss sensation.

If reference-dependent preference is true, then the prediction of behavior is changeable with subjective belief about outcomes, instead of relying solely on absolute assessment. Is self-report value in this circumstance a feasible and cogent

measure of pleasure? The evidence of the credentials of self-reported overall utility would strengthen its practical applicability in the evaluation of welfare.

The goal of this study includes (a) to show the existence of the reference-dependency of preference, (b) to determine the way people weigh consumption utility and gain-loss utility to assess an outcome, (c) to explore the difference between overall utility and anticipated utility which is based on the posited reference outcome, and (4) to examine whether the value eventually self-reported after rational expectation is consistent with the activation of brain regions related to the actual outcome.

Materials and Methods

Subjects

Thirty-two participants were enrolled in the study presented here, but only thirty subjects (12 female; age range, 21-36 years) completed all sessions of the study. All participants gave written informed consent, and all procedures were in compliance with the safety guidelines for MRI research and were approved by the Research Ethics Committee of National Taiwan University.

General procedure

All subjects were asked to participate one behavioral session and two sessions of fMRI study. The interval between the two fMRI experiments ranges from 4 to 41 days. In the first fMRI session, multimodal reward tasks were undertaken. Participants were presented with a succession of images; each image showed a bundle of rewards (money and food). There were three types of food reward: one cup of coffee (350 ml), small milk snacks (Lotte), and a pack of chocolate (Kinder Bueno). Each food reward type combined with money formed a bundle of mixed-type rewards which was rated for intrinsic utility by each subject. There were seven values for money (TWD 0, TWD30, TWD 60, TWD 90, TWD 120, TWD 150, and TWD 180), and seven amounts for each food type (0, 1, 2, 3, 4, 5, and 6). These resulted in 49 bundles per food reward type. During the first scanning session, the subjects were asked to report expected consumption utility with respect to each bundle of rewards, which they might obtain.[1] During the second session, the amounts of all bundles of rewards were partially or completely uninformed to the subjects. They first predicted the unknown reward(s) and reported corresponding anticipated utility derived from this bundle.

[1] The notion of utility in this study is referred to the pleasure of obtaining a rewards bundle. The original, hedonic utility is called consumption utility, and the utility eventually experienced after an outcome realized is called overall utility.

Afterwards, the actual bundle in each trial was revealed, and the subjects, having received the new information about the amount(s) of rewards, reported overall utility associated with the experience of outcomes.

Scanning session I

In the first fMRI study, 49 unique bundles for money and a specific type of food constructed one block of the session, and three types of food with money (money-coffee, money-snack, and money-chocolate) put together resulted in three separate blocks in this session. Each bundle was presented in a randomized order. The subjects were asked to perform 147 trials in three blocks. The task was to rate the degree of happiness (on a 7-point scale) for each bundle of rewards if obtained. Subjects received TWD 500 for completing the scanning which lasted 0.5 h. Besides, subjects were informed in advance that after completing the experiment they would draw a bundle of rewards from 147 totals as a bonus. This meant that before fMRI scanning, a subject knew that he (she) had equal chance to win each bundle.

On each trial, an image of a reward bundle was presented to the subjects for 3 s, followed by the appearance of a white cross in the middle of the screen for a variable anticipation interval of 2-6 s. Thereafter, a reminding screen with a red dot in the middle was presented for 0.5 s, followed immediately by a 2 s rating window in which a rating ruler with 7-point scale appeared. Each subject pressed a button to report his (her) subjective value for the bundle of rewards. The intertrial interval ranged from 2 to 6 s. Participants made 147 evaluations during the multimodal reward task.

Behavioral session

Before the second fMRI session, the subjects participated a behavioral session, which lasted 0.25 h. The three types of the bundles of money-food were constructed approximately as different probability distributions: a normal distribution for money-coffee bundles, a right-skewed Weibull distribution for money-snacks bundles, and a left-skewed Weibull distribution for money-chocolate bundles. A succession of 49 images drawn from the distribution of each type of reward bundles was presented to the subjects on a computer screen. To ensure attention to the experimental stimuli, the subjects had to press a button to the occurrence of the succeeding image. Through viewing the stimuli, each subject formed his (her) own expectation about the distribution of each type of reward bundles.

Scanning session II

After completing the behavioral session, the subjects started the second fMRI study

immediately. According to the revelation (yes/no) of the amounts of rewards, the experimental trials in this session were divided into six blocks. During the first block, in each reward bundle only the amount of money was disclosed; during the second block, only the amount of food was disclosed; during the third block, both amounts of money and food were unrevealed. The revelation of the amounts of rewards in Blocks 4-6 was just the same as in Blocks 1-3. The 18 bundles used in each block were randomly sampled from the pool (147 bundles) presented in the behavior session.

The subjects were informed that they would be going through a prospect phase and an outcome phase during an experimental trial. During the initial prospect phase, a partially or completely unrevealed bundle was presented and the subjects were asked first to predict the amount based on the belief about the bundle he (she) might face and then rated the anticipated utility with respect to this expected bundle. Then the outcome of the combination of rewards was presented, and the subjects perceived gain or/and loss of monetary and food rewards. They were asked to rates the utility with respect to the revealed bundle of rewards at that moment (which we call overall utility).

The experiment consisted of six blocks, with 18 trials per block. In blocks 1, 2, 4, and 5, each bundle's rewards were partially disclosed; in bundles of 3 and 6, neither reward was revealed. Trials were subdivided into a prospect phase and an outcome phase. During the prospect phase of the blocks with incomplete information, the subjects, viewing an incomplete bundle, were instructed to press a button to indicate the amount of reward predicted on a ruler presented on the screen within 4 s. Following an evaluation period ranged from 2 s to 4 s and a reminding (represented by a red dot) for 0.5 s, the subjects gave their rating of anticipated utility from the reward bundle within 2 s. The screen showed consecutively a crosshair (2 s) and a red dot (0.5 s) before the outcome phase occurred. During the outcome phase, the outcome of rewards was shown for 2 s. A randomized period of evaluation (ranged from 2s to 4 s) and a red dot (0.5 s) were presented, followed by a period of rating overall utility lasting 2 s. After randomly fixating on a red dot (2 s – 6 s), there started the onset of the next trial. The time course for the blocks with no information was different in the prospect phase in which a second prediction period (2 s) was included, following a 2 s fixation interval after the first prediction.

The subjects received TWD 750 after completing 108 trials, which lasted 1 h. As in Session 1, each subject randomly selected one completed trial and received those amounts of money and food as a bonus.

Results

Session I

Psychometric results

The analysis focuses on the determination of the consumption utility of multimodal reward bundles. After deleting missing values of rating, data for 30 subjects range from 139-147. The descriptive statistics of variables are reported in Table A1.

GLS (the generalized least squares) random-effects models are performed, with the self-report degree of happiness as the dependent variable and the size of two types of rewards as main independent variables. Table 1 presents the results of consumption utility for seven models allowing for different functional forms or different control variables. Model 1 shows that after controlling the block effects on ratings, the two types of reward (money and food) have significantly positive influence on consumption utility. Different from Model 1, the relationship between reward and utility is quadratic in Model 2. The results show that this nonlinear relationship is not statistically significant.

In Model 3 the variables of relative reward – the reward in current trial relative to that of the previous trial – are added to test for the dependency of utility on consumption experience. The nonsignificant influence of relative rewards fails to reject the null hypothesis that consumption utility of a reward bundle is independent of the previous reward bundle provided. In Model 4 the reaction time to assess each reward bundle is included to control the influence of difficulties in making an assessment. We observe that the more difficult to assess a reward bundle, the less consumption utility a subject expects. Meanwhile, the marginal effect of money or food reward on consumption utility remains significantly positive. From Model 5 to Model 7, we treat three kinds of food appeared in different blocks as a distinct independent variable and replicate the estimations of linear model, nonlinear model, and linear model with the control difficulty, respectively.

Based on the estimates of the coefficients of rewards, we compute the weight of each reward type that the subjects attached to consumption utility, which yields 0.5976 for money and 0.4114 for food. To examine the divergence among the subjects' preference for both types of reward, we estimate Model 4 separately for each subject and find that the value of weights placed on money ranges between 0.2054 – 0.9261, while that placed on food ranges between 0.1296 – 0.8360.[2] We further make use of these individual weights to compute the subjective value of money and food, respectively, and to investigate the associated activation of neural circuits.

[2] There is one subject for whom the amount of food had significantly negative influence on his expected consumption utility, while for another subject food marginally contributed nothing in terms of expected consumption utility.

Table 1: Estimates of consumption utility: GLS random-effects model

	Model 1	**Model 2**	**Model 3**	**Model 4**
Money (TWD)	0.0170	0.0159	0.0171	0.0170
	(0.0002)***	(0.0009)***	(0.0004)***	(0.0002)***
Money^2	−	0.0000	−	−
		(0.0000)		
Food (unit)	0.3516	0.3905	0.3517	0.3506
	(0.0074)***	(0.0266)***	(0.0110)***	(0.0074)***
Food^2	−	-0.0065	−	−
		(0.0043)		
Relative value of money	−	−	0.0188	−
			(0.0167)	
Relative amount of food	−	−	0.0153	−
			(0.0169)	
Food1:	−	−	−	−
Food1^2	−	−	−	−
Food2	−	−	−	−
Food2^2	−	−	−	−
Food3	−	−	−	−
Food3^2	−	−	−	−
Reaction time	−	−	−	-0.2829
				(0.0560)***
Block 2 dummy	0.3735	0.3737	0.3453	0.3524
	(0.0362)***	(0.0362)***	(0.0423)***	(0.0363)***
Block 3 dummy	0.4051	0.4053	0.3615	0.3690
	(0.0362)***	(0.0362)***	(0.0423)***	(0.0368)***
Constant	0.4949	0.4913	0.4639	0.6852
	(0.1275)***	(0.1356)***	(0.1344)***	(0.1337)***
Overall R^2	0.5419	0.5422	0.5484	0.5458
Observations	4374	4374	3161	4374

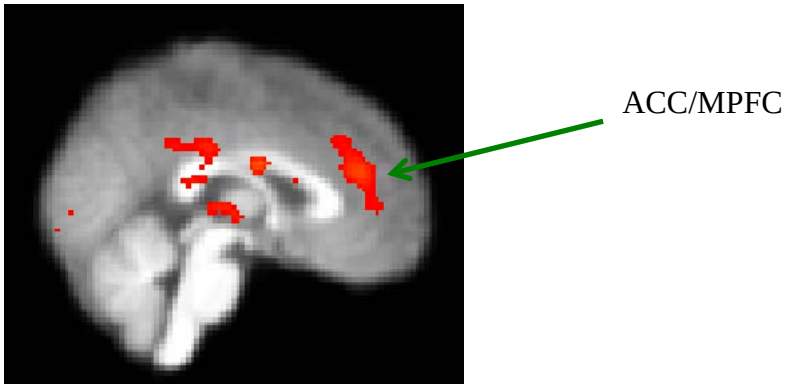
(Continued)

	Model 5	Model 6	Model 7
Money (TWD)	0.0170 (0.0002)***	0.0159	0.0170
		(0.0009)***	(0.0002)***
Money^2	−	0.0000	−
		(0.0000)	
Food (unit)	−	−	−
Food^2	−	−	−
Relative value of money	−	−	−
Relative amount of food	−	−	−
Food1	0.3088	0.3763	0.3096
	(0.0128)***	(0.0461)***	(0.0128)***
Food1^2	−	-0.0112	−
		(0.0074)	
Food2	0.3761	0.4271	0.3748
	(0.0128)***	(0.0460)***	(0.0127)***
Food2^2	−	-0.0085	−
		(0.0074)	
Food3	0.3696	0.3677	0.3674
	(0.0127)***	(0.0460)***	(0.0127)***
Food3^2	−	0.0003	−
		(0.0074)	
Reaction time	−	−	-0.2757
			(0.0560)***
Block 2 dummy	0.1716	0.1856	0.1573
	(0.0652)***	(0.0835)**	(0.0650)**
Block 3 dummy	0.2224	0.2804	0.1964
	(0.0651)***	(0.0834)***	(0.0652)***
Constant	0.6234	0.5959	0.8037
	(0.1307)***	(0.1420)***	(0.1368)***
Overall R^2	0.5432	0.5436	0.5469
Observations	4374	4374	4374

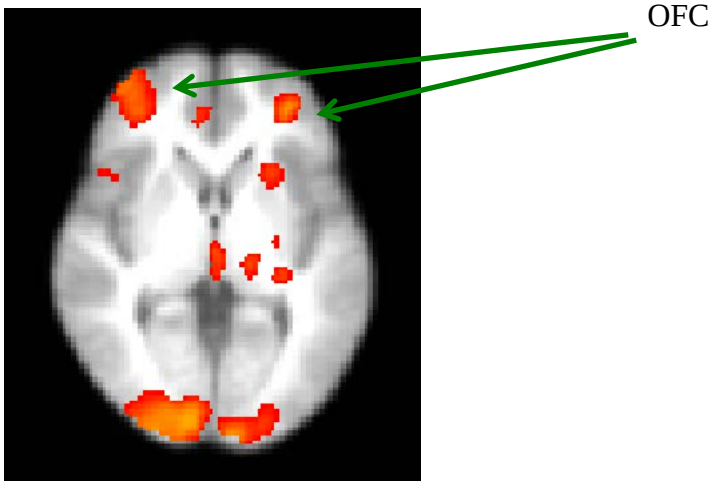
Neurometric results

The primary goal of scanning was to identify brain areas that represent the expected consumption utility of the different types of reward bundles for each subject. It shows that ACC/MPFC and OFC track the expected consumption utility. Like previous studies (Breiter, et al., 2001; Knutson et al., 2007), this study also demonstrates that preference increases MPFC activation, and expected monetary rewards increase OFC activation.

$z > 1.64$ ($p < .05$, uncorrected), $x = 2$

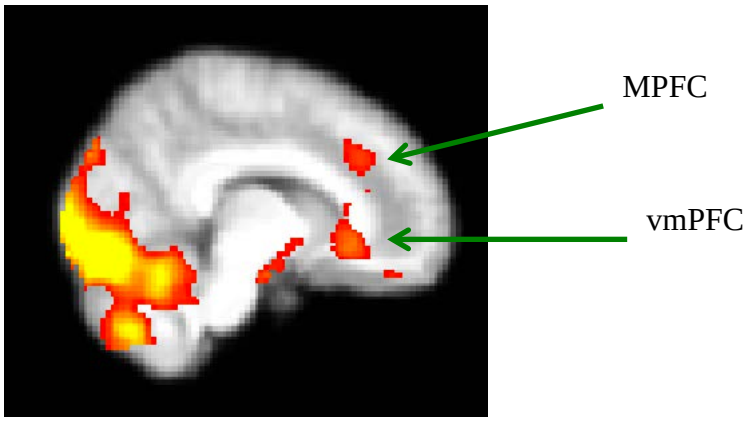


$z > 1.64$ ($p < .05$, uncorrected), $z = 2$



We further use the marginal value of each reward, which was estimated in the Model 4 of consumption utility, to impute subjective value of each bundle of rewards. That is, the subjective value of a reward bundle = the weighted sum of the subject values of money and food. It is shown that the subjective value is represented on MPFC and vmPFC. The result of the vmPFC response to subjective value is in line with Levy and Glimcher (2011), which demonstrated that subregions of the vmPFC represent the expected subjective value.

z > 1.64 (p < .05, uncorrected), x = 10



Session II

Psychometric results

All 30 subjects in the first session returned for a second fMRI scanning session. Each subject predicted the bundle of rewards in the trials of the prospect phase, based on his own belief about the probability distribution which was formed before the scanning, and reported his anticipated utility accordingly. In the trials of the following outcome phase, each subject realized the actual outcome of a reward bundle and reported his momentary utility, called overall utility. Of the 30 subjects, one subject failed to follow the rule of the experiments. The remaining 29 subjects yielded analyzable data in this session.

For the purpose of testing Kőszegi and Rabin's theory of reference-dependent preference, we perform a regression analysis to examine the relationship between consumption utility and overall utility. We merge the data of the two sessions and model overall utility as a function of consumption utility, as well as the associated gains and losses of each reward bundle. As before, we introduce the reaction time of reporting overall utility as a variable representing the difficulty of evaluation, and a dummy variable for each block.

The results of group random-effects estimation are presented in Table 2. The estimates of the generalized least squares (GLS) are shown in the first two columns. Accounting for the endogeneity problem of consumption utility, we also use the instrumental variables estimation and undertake Hausman test. The results are presented in the last two columns. Based on the estimates of β coefficients, we compute the weight the subjects averagely attached on each factor variable. For example, according to the GLS results of Model 1, the weight consumption utility carries is 0.6812, while the weights carried by the gain of money reward, the loss of

money reward, the gain of food reward, and the loss of food reward are respectively 0.0764, 0.1257, 0.0852, and 0.1269. Even though consumption utility has great influence in the determination of overall utility, the importance of gains and losses cannot be ignored. This implies that subjective values of rewards might be reference-dependent such that there are distinctions between overall utility and consumption utility. We further compute a measure of behavioral loss aversion as the ratio of loss weight to gain weight, which yields 1.6453 for money reward and 1.4892 for food reward; that is, the sensation of loss is around 1.5 times the scale of gain.

Table 2 Estimates of overall utility: random-effects model

	GLS		**IV (G2LS)**	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Consumption	0.6876	0.6457	1.0351	1.0527
utility	(0.0132)***	(0.0142)***	(0.0190)***	(0.0221)***
Gain_money	0.0053	0.0052	0.0027	0.0028
	(0.0009)***	(0.0009)***	(0.0010)***	(0.0010)***
Loss_money	-0.0068	-0.0063	-0.0032	-0.0033
	(0.0008)***	(0.0008)***	(0.0009)***	(0.0009)***
Gain_food	0.1869	−	0.1317	−
	(0.0294)***		(0.0327)***	
Loss_food	-0.2171	−	-0.1271	−
	(0.0240)***		(0.0268)***	
Gain_food1	−	0.2549	−	0.3230
		(0.0478)***		(0.0541)***
Loss_food1	−	-0.1377	−	-0.1177
		(0.0412)***		(0.0466)**
Gain_food2	−	-0.0210	−	0.1539
		(0.0603)		(0.0684)**
Loss_food2	−	−-0.3099	−	-0.0900
		(0.0276)***		(0.0323)***
Gain_food3	−	0.2548	−	0.0238
		(0.0360)***		(0.0415)
Loss_food3	−	0.0362	−	-0.2264
		(0.0482)		(0.0553)***
Reaction time of	-0.1684	-0.1878	-0.0397	-0.0561
overall utility	(0.0875)*	(0.0868)**	(0.0973)	(0.0982)

(Continued)

	GLS		IV (G2LS)	
	Model 1	**Model 2**	**Model 1**	**Model 2**
Block 3 dummy	0.2274	0.2090	0.1568	0.1467
	(0.0717)***	(0.0714)***	(0.0796)**	(0.0807)*
Block 4 dummy	-0.0831	-0.0920	-0.0805	-0.0820
	(0.0650)	(0.0646)	(0.0721)	(0.0730)
Block 5 dummy	-0.0196	-0.0022	0.0016	0.0021
	(0.0759)	(0.0755)	(0.0841)	(0.0854)
Constant	1.1743	1.2878	-0.0330	-0.0804
	(0.0986)***	(0.0951)***	(0.1204)	(0.1176)
Overall R^2	0.5541	0.5657	0.5359	0.5290
Observations	3003	3003	3003	3003
Chi2 (11)			647.04	582.37

Setting each expected rewards bundle as a reference point, the subjects experienced sensation of the deviation from the actual outcome. The difference in emotional responses to predicted and actual rewards bundle, which is called value function in the prospect theory, is thus expected to be determined by the magnitude(s) of gain or (and) loss. To test this hypothesis, we estimate two random-effects models of difference in overall utility using the GLS method. The results of estimation are presented in Table 3. As expected, the gain and loss of either type of reward all have significant influences on the difference between overall utility and anticipated utility of the associated reference point. In Model 1, for example, the weights carried by the gain of money and the loss of money are respectively 0.2766 and 0.3841. In contrast to money, the weights carried by the gain of food and the loss of food are a little lower (0.2460 and 0.3261, respectively). The degrees of loss aversion with respect to money and food, computed as 1.3886 and 1.3255, respectively, are less than the degrees observed in the overall utility, which is consistent with the Kőszegi and Rabin's inference.

Table 3 Estimates of difference in overall utility: GLS random-effects model

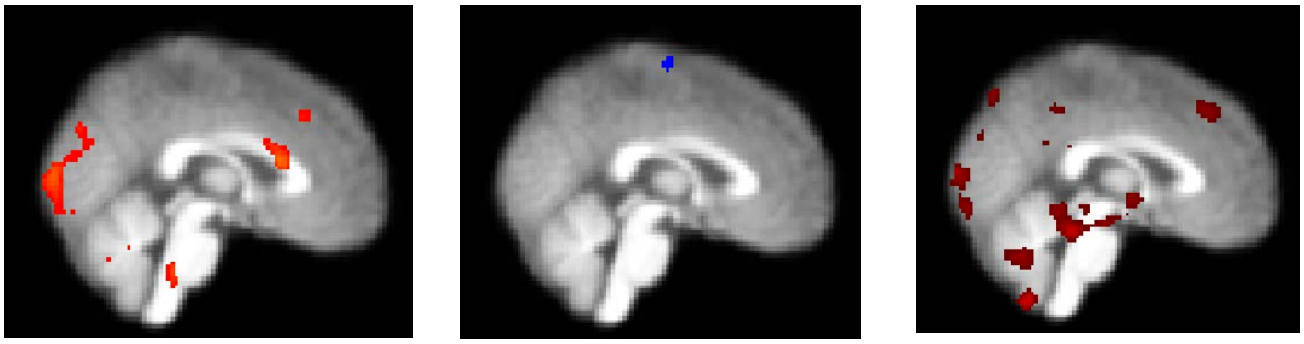
	Model 1		**Model 2**	
Gain_money	0.0191	(0.0008)***	0.0191	(0.0008)***
Loss_money	-0.0207	(0.0007)***	-0.0205	(0.0007)***
Gain_food	0.5398	(0.0255)***	–	
Loss_food	-0.5580	(0.0206)***	–	
Gain_food1	–		0.4414	(0.0418)***
Loss_food1	–		-0.5182	(0.0360)***
Gain_food2	–		0.7120	(0.0526)***
Loss_food2	–		-0.5931	(0.0232)***
Gain_food3	–		0.5506	(0.0306)***
Loss_food3	–		-0.4559	(0.0413)***
Reaction time of overall utility	0.1142	(0.0747)	0.1324	(0.0747)*
Block 2 dummy	0.0259	(0.0660)	0.0463	(0.0659)
Block 3 dummy	0.1383	(0.0627)**	0.1518	(0.0626)**
Block 4 dummy	-0.0625	(0.0569)	-0.0614	(0.0568)
Block 5 dummy	0.0272	(0.0664)	0.0480	(0.0663)
Block 6 dummy	0.1521	(0.0624)**	0.1754	(0.0624)***
Constant	-0.0127	(0.0611)	-0.0461	(0.0616)
Overall R^2	0.6411		0.6451	
No of observations	3003		3003	

Neurometric results

In this session, we explore the activation of the brain region with respect to different concepts of utility, including anticipated utility, gain-loss utility, and overall utility. First, the reference-dependent utility (overall utility) is represented on MPFC and OFC except for Block 2 and Block 5 (denoted by F2_F5 in the following figures). In both blocks, the value of money in each bundle was disclosed after a subject made a prediction of the amount based on his or her own belief. Generally speaking, the regions for overall utility are similar to those for consumption utility.

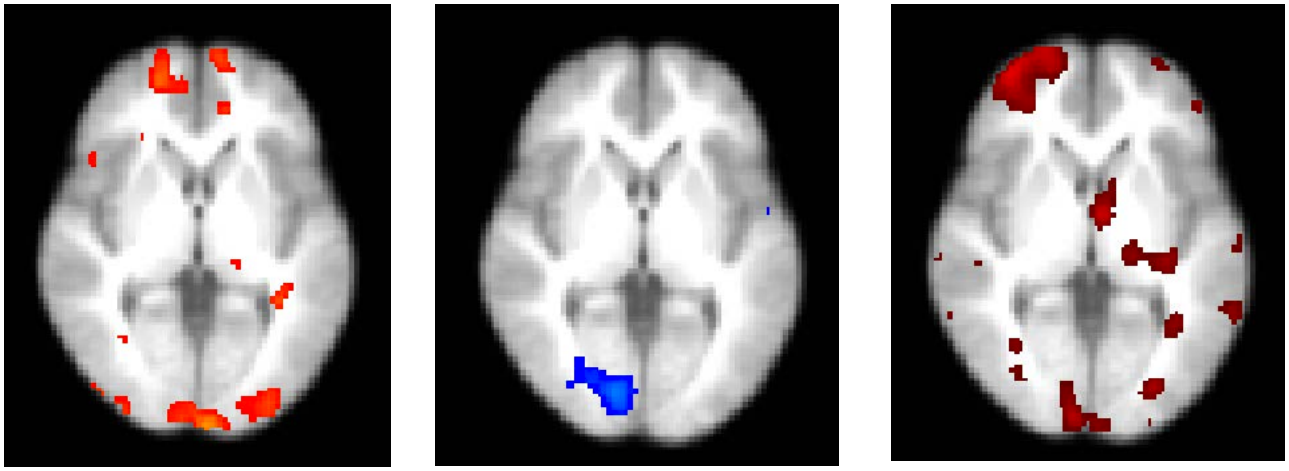
z > 1.64 (p < .05, uncorrected), x = 2
MPFC

F1_F4 F2_F5 F3_F6



z > 1.64 (p < .05, uncorrected), z = 2
OFC

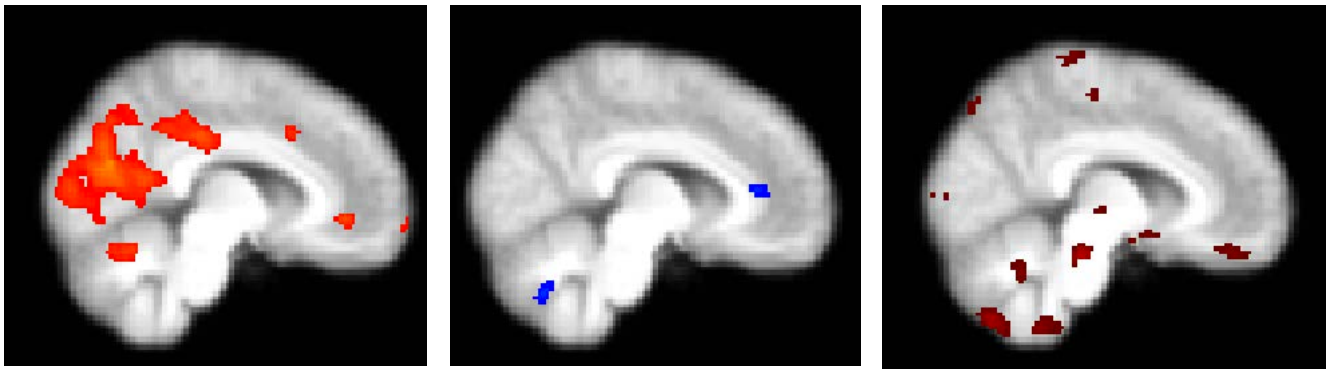
F1_F4 F2_F5 F3_F6



Second, in contrast, anticipated utility which was derived from the predicted bundle rewards seems to be represented on ACC or vmPFC, but the effects are not as strong as the effects for overall utility which experienced after the actual outcome is disclosed. The hemodynamic responses to prospects in the ACC track the expected value(s) of each bundle reward. This finding is consistent with the previous studies (Breiter, et al., 2001; Knutson, et al., 2001; Tom, et al., 2007).

z > 1.64 (p < .05, uncorrected), x = 2
ACC, vmPFC

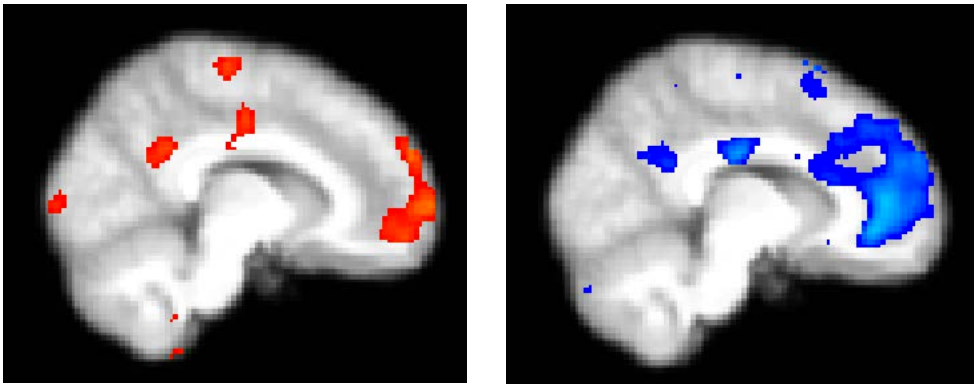
F1_F4 F2_F5 F3_F6



Finally, for both money and food, differences between predicted and actual value (either gains or losses) are represented on MPFC. However, the effect for food, which shows only in Block 1 and Block 4, is weaker than the effect for money. It is possible due to the reason that the subjects weigh less on food.

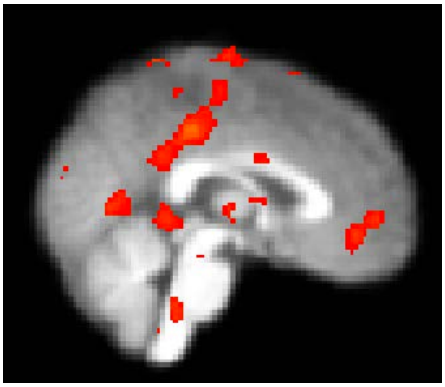
z > 1.64 (p < .05, uncorrected), x = 10
ACC/MPFC

F2_F5 F3_F6

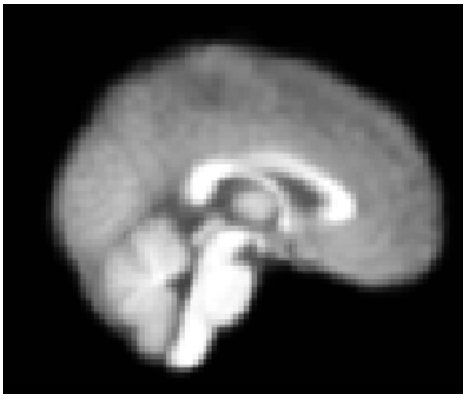


Z > 1.64 (p < .05, uncorrected), x = 2
ACC/MPFC

F1_F4



F3_F6



In sum, we found that ACC/MPFC and OFC track expected consumption utility for money-food reward bundles. In most cases, reference-dependent experienced utility was also observed in MPFC and OFC. MPFC also encodes gain or loss signals that were computed during experience of actual rewards.

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Appendix

Table A1: Summary Statistics: Session 1

Variable	Obs	Mean	Std. Dev.	Min	Max
Rating of consumption utility	4374	3.3423	1.7064	0	6
Money (TWD)	4374	89.8903	60.0102	0	180
Food (unit)	4374	2.9995	2.0018	0	6
Food 1: coffee (cup)	4374	.9998	1.8254	0	6
Food 2: snacks (pack)	4374	.9993	1.8259	0	6
Food 3: chocolate (pack)	4374	1.0005	1.8278	0	6
Reaction time of consumption utility	4374	.5790	.2915	0	1.98
Relative value of money	3691	1.2285	1.3234	0	6
Relative amount of food	3692	1.2131	1.3108	0	6
Block 2 dummy	4374	.3333	.4715	0	1
Block 3 dummy	4374	.3336	.4715	0	1

Table A2: Summary Statistics: Session 2

Variable	Obs	Mean	Std. Dev.	Min	Max
Rating of CU	3003	3.2035	1.6333	0	6
Rating of OU	3003	3.2637	1.6488	0	6
Rating of AU	3003	3.4023	1.4649	0	6
Gain_money	3003	10.6693	23.9180	0	150
Loss_money	3003	15.5644	30.5333	0	180
Gain_food	3003	.3313	.7515	0	5
Loss_food	3003	.4985	.9635	0	6
Gain_food1	3003	.1106	.4254	0	4
Loss_food1	3003	.1289	.4942	0	4
Gain_food2	3003	.0599	.3261	0	5
Loss_food2	3003	.2574	.8072	0	6
Gain_food3	3003	.1608	.5878	0	5
Loss_food3	3003	.1122	.4308	0	4
Reaction time of OU	3003	.4188	.2324	0	1.98
Block 2 dummy	3003	.1652	.3714	0	1
Block 3 dummy	3003	.1665	.3726	0	1
Block 4 dummy	3003	.1698	.3755	0	1
Block 5 dummy	3003	.1688	.3747	0	1
Block 6 dummy	3003	.1642	.3705	0	1
Money (TWD)	3003	85.4945	45.5060	0	180
Food (unit)	3003	2.8272	1.4836	0	6
Food 1 (cup)	3003	.9744	1.4718	0	4
Food 2 (pack)	3003	.4399	.8391	0	6
Food 3 (pack)	3003	1.4129	2.0459	0	6

Note: CU, OU, and AU represent respectively consumption utility, overall utility, and anticipated utility.

研究成果之學術或應用價值之自評

傳統經濟學的效用概念代表偏好，係決策者的選擇依據。Kahneman et al. (1997)率先指出決策者從行為所體驗的效用，不同於決策效用。Kőszegi and Rabin (2006)進一步指出，決策者單純從結果的本質所體驗的效用，又不同於參考點依賴下的體驗效用。後者係指決策者在面對不確定下，根據理性的預期形成參考點，待實際結果發生時，其體驗的效用除消費效用外，也包含預期誤差所產生的利得—損失效用。此意謂著，即若決策者做出相同的選擇，但隨著其主觀形成的參考點之不同，所體驗的效用並不相等。假若參考點依賴的體驗效用理論成立，則此理論對社會福利指標的建立以及公共政策的制定，具有重要的意涵與參考價值。本研究結合腦神經科學、fMRI 技術與經濟學，進行行為與腦神經實驗，期對不同效用概念的差異與關聯性，提出具體的佐證。