Web Appendix of

Prince: An Improved Method for Measuring Incentivized Preferences

Cathleen Johnson, Aurélien Baillon, Han Bleichrodt, Zhihua Li, Dennie van Dolder, & Peter P. Wakker

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Web Appendix WA. Questions 2 and 3

This web appendix presents Questions 2 and 3, with matching and a choice list for chocolate instead of a mug.

Instructions for envelopes of type τ (Question 2)

In each of the 10 envelopes of type τ, one option is the chocolate you just saw, and the other option is a money amount. The note in each envelope of type τ is as follows.

Type τ

Option 1: the chocolate

Option 2: €x

The money amount x varies between €0 and €10 in different envelopes. One of the envelopes contains a randomly generated amount between €0 and €1, one envelope contains a randomly generated amount between €1 and €2, one contains a randomly generated amount between €2 and €3, and so on, with finally one envelope containing a randomly generated amount between €9 and €10. Thus the amount in your envelope can be any amount, in cents, between €0 and €10.

Please give us instructions, for each possible envelope of type τ that your envelope may be, whether we should give you the money amount or the chocolate. Do so by specifying a threshold (in cents).

My threshold is € ……,……

If the money amount x in my envelope is equal to or above the threshold, then give me that money amount.

If the money amount x in my envelope is below the threshold then give me the chocolate.

Instructions for envelopes of type ψ (Question 3)

In each of the 10 envelopes of type ψ, one option is the chocolate you just saw, and the other option is a money amount. The money amount x varies between €0.50 and €9.50 in different envelopes (see below).

The note in each envelope of type ψ is as follows.

Type ψ

Option 1: the chocolate

Option 2: € x

In the following list, each line describes the content of one envelope of type ψ. On each line, cross out the square before the option that we should give you if that line describes the two options in your envelope.

1. □CHOCOLATE □€0.50
2. □CHOCOLATE □€1.50
3. □CHOCOLATE □€2.50
4. □CHOCOLATE □€3.50
5. □CHOCOLATE □€4.50
6. □CHOCOLATE □€5.50
7. □CHOCOLATE □€6.50
8. □CHOCOLATE □€7.50
9. □CHOCOLATE □€8.50
10. □CHOCOLATE □€9.50

Web Appendix WB. Questions 4, 5, and 6: Testing preference reversals

Questions 4, 5, and 6 investigate classical preference reversals for probability distributions over money. Objective probabilities p were generated using two ten-sided dice. Figure WB.1 displays Question 4 (*choice question*), being a choice between $4_{0.97}0$ (receiving €4 with probability 0.97 and €0 otherwise) and $16_{0.3}10$. Question 5 (Figure WB.2) is called the *CE-P-bet* question. It measures the *certainty equivalent* (*CE*), i.e. the equally preferred sure amount, of $4_{0.97}0$. The latter bet is called the *P-bet* because it has a high probability of winning. Question 6 (Figure WB.3) is called the *CE-$-bet* question. It measures the CE of $16_{0.3}10$, called the *$-bet* because it involves the highest money amount (in dollars when receiving its name; Lichtenstein & Slovic 1971).

This time we specified no range or further information on the values x in Questions 5 and 6, leaving its choice entirely to the subjects. This neither affects incentive compatibility nor transparency. It still is perfectly clear to subjects that providing wrong instructions can only harm themselves, possibly leading to less preferred options.

FIGURE WB.1. Instructions for choice between bets (Question 4, the choice question)

Instructions for envelopes of type θ

In the 10 envelopes of type θ, both options are probability-contingent money. The note in each envelope of type θ is as follows.

Type θ

Option 1: €4 with a probability of 97%

Option 2: €16 with a probability of 31%

Please give us instructions whether we should give you option 1 or option 2 if your envelope is of type θ.

Give me option .....

FIGURE WB.2. Instructions for certainty equivalent of P-bet (Question 5, the CE-P-bet)

Instructions for envelopes of type λ

In the 10 envelopes of type λ, one option is probability-contingent money, and the other option is a sure money amount. The note in each envelope of type λ is as follows.

Type λ

Option 1: €4 with a probability of 97%

Option 2: € x

The money amount x varies between the envelopes. Please give us instructions for each possible envelope of type λ that your envelope may be, whether we should give you the sure money amount or the probability-contingent money. Do so by specifying a threshold (in cents):

My threshold is € ……,……

If the money amount x in my envelope is equal to or above the threshold, then give me that money amount.
If the money amount x in my envelope is below the threshold then give me the probability-contingent money.

FIGURE WB.3. Instructions for certainty equivalent of $-bet (Question 6, CE-$-bet)

Instructions for envelopes of type ρ

In the 10 envelopes of type ρ, one option is probability-contingent money, and the other option is a sure money amount. The note in each envelope of type ρ is as follows.

Type ρ

Option 1: €16 with a probability of 31%

Option 2: €x

The money amount x varies between the envelopes. Please give us instructions for each possible envelope of type ρ that your envelope may be, whether we should give you the sure money amount or the probability-contingent money. Do so by specifying a threshold (in cents):

My threshold is € ……,……

If the money amount x in my envelope is equal to or above the threshold, then give me that money amount.
If the money amount x in my envelope is below the threshold then give me the probability-contingent money.

Analysis. In Question 5, the CE-P-bet, we removed 12 subjects who violated stochastic dominance with CEs exceeding 5. Violations of stochastic dominance up to 1 can be explained by choice errors, rounding, and the indifference-bias-upwards. So as to treat upward and downward biases symmetrically and reduce the biasing effects of removing only high values, we also removed subjects with CE-P values below 3; this concerned only 3 subjects. Incorporating the removed subjects would not affect any conclusion. The average CE of the CE-P-bet is 3.96. The average CE of the CE-$-bet is larger: 5.99, which is in agreement with common findings. However, 63 subject preferred to $-bet in direct choice, and only 17 preferred the P-bet, deviating from common findings. Our group averages suggest that, unlike

common findings. we have no preference reversals. Our conclusion is confirmed by an analysis at the individual level: Normal preference reversals (higher CE of the $ bet but choosing the P bet) occurred for 11% of the subjects, and the opposite preference reversal (higher CE of the P bet but choosing the $ bet) happened for 7% of the subjects. These percentages are not significantly different ($p = 0.55$).

Discussion of preference reversals. There are only few preference reversals, and they are random, resulting from random choice inconsistencies commonly found (Schmidt & Hey 2004). Our findings deviate from other studies into preference reversals, where the normal preference reversals are found in great majorities (surveyed by Seidl 2002). Preference reversals reflect errors in the measurement of preferences (procedural variance) rather than genuine properties of preferences such as intransitivities (Tversky, Slovic, & Kahneman 1990). Prince has restored consistency between choice and matching, thus resolving preference reversals.

Discussion of no provision of range in matching. In the CE-P questions, we found many violations of stochastic dominance. For the preference reversals we used the classical and often used stimuli of Lichtenstein & Slovic (1971). These stimuli for preference reversals involve small outcomes and weak strengths of preferences, generating extra noise. Further noise is generated because we specified no range for matching, unlike in Question 3. In the CE-P questions, 24 CEs thus exceeded 4. It is plausible that the true indifference value, very close to €4, is rounded to €4, and then because of the indifference-bias-upwards a value exceeding €4 may be chosen. However, 12 CEs even exceeded 5 (and these were removed for being erratic). This result suggests that specifying a range as in §4.2 is preferable, supporting Birnbaum's (1992) views. The indifference-bias-upwards, which also played a role here, can be avoided by implementing random choice (rather than always the sure amount) at the stated switching value.

Web Appendix WC. Questions 7, 8, and 9: Measuring subjective probabilities and ambiguity attitudes

Questions 7 (Figure WC.1), 8, and 9 show how Prince can be used to measure subjective probabilities and ambiguity attitudes. They were taken from Baillon & Bleichrodt (2014 Study 1). Question 7 measures the probability p such that

$$10_A0 \sim 10_p0, \qquad \text{(WC.1)}$$

using matching. Here A denotes an uncertain event that may or may not happen. In Figure WC.1, A means that the Dutch AEX stock index increases or decreases by no more than 0.5% during the experiment (which we immediately verified online). 10_A0 means that the subject receives €10 if A happens, and nothing otherwise. 10_p0 similarly means that the subject received €10 with objective probability p. The objective probability p in Eq. WC.1 is called the *matching probability* of event A, denoted m(A). Matching probabilities were widely used in classical Bayesian models. They have recently been found to serve the analysis of ambiguity attitudes well (Wakker 2010 p. 321).

Question 8 (Figure WC.2) is like Question 7, but with event A replaced by event B: the AEX stock index increases by more than 0.5% during the experiment. Question 9 (Figure WC.3) concerns event A∪B, meaning the AEX stock index decreases by no more than 0.5% during the experiment. We will compare our values m(A), m(B), m(A∪B), and the nonadditivity index m(A∪B) – m(A) – m(B), with those obtained by Baillon & Bleichrodt (2014). These authors used classical choice lists with the classical RIS instead of our matching with Prince. They found a positive nonadditivity index.

FIGURE WC.1. Instructions for matching probability (Question 7)

Instructions for envelopes of type φ

In each of the 10 envelopes of type φ, one option is AEX-contingent money, and the other option is probability-contingent money. The note in each envelope of type φ is as follows.

Type φ

Option 1: €10 if the AEX (Dutch stock index) increases by more than –0.5% and by less than 0.5% during the experiment

Option 2: €10 with a probability of p%

The probability p varies between 0% and 100% in different envelopes. One of the envelopes contains a randomly selected probability between 0 and 10%, one envelope contains a randomly selected probability between 10% and 20%, one contains a randomly selected probability between 20% and 30%, and so on, with finally one containing a randomly selected probability between 90% and 100%. Thus the probability in your envelope can be any percentage between 0% and 100%.

Please give us instructions for each possible envelope of type φ that your envelope may be, whether we should give you the AEX-contingent money or the probability-contingent money. Do so by specifying a threshold (in percentage):

My threshold is ..... %

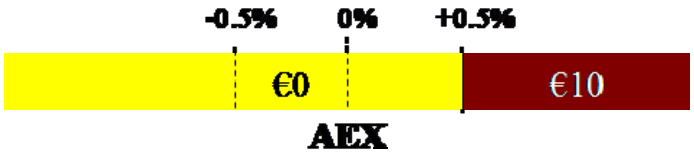
If the probability p in my envelope is equal to the threshold or above, then give me the probability-contingent option 2.
If the probability p in my envelope is below the threshold then give me the AEX-contingent option 1.

FIGURE WC.2. Instructions for matching probability (Question 8)

In each of the 10 envelopes of type ω, one option is AEX-contingent money, and the other option is probability-contingent money. The note in each envelope of type ω is as follows.

Type ω

Option 1: €10 if the AEX (Dutch stock index) increases by more than 0.5% during the experiment



Option 2: €10 with a probability of p%

The probability p varies between 0% and 100% in different envelopes. One of the envelopes contains a randomly selected probability between 0 and 10%, one envelope contains a randomly selected probability between 10% and 20%, one contains a randomly selected probability between 20% and 30%, and so on, with finally one containing a randomly selected probability between 90% and 100%. Thus the probability in your envelope can be any percentage between 0% and 100%.

Please give us instructions for each possible envelope of type ω that your envelope may be, whether we should give you the AEX-contingent money or the probability-contingent money. Do so by specifying a threshold (in percentage):

My threshold is ..... %

If the probability p in my envelope is equal to the threshold or above, then give me the probability-contingent option 2.

If the probability p in my envelope is below the threshold then give me the AEX-contingent option 1.

FIGURE WC.3. Instructions for matching probability (Question 9)

In each of the 10 envelopes of type χ, one option is AEX-contingent money, and the other option is probability-contingent money. The note in each envelope of type χ is as follows.

Type χ

Option 1: €10 if the AEX (Dutch stock index) increases by more than -0.5% during the experiment

Option 2: €10 with a probability of p%

The probability p varies between 0% and 100% in different envelopes. One of the envelopes contains a randomly selected probability between 0 and 10%, one envelope contains a randomly selected probability between 10% and 20%, one contains a randomly selected probability between 20% and 30%, and so on, with finally one containing a randomly selected probability between 90% and 100%. Thus the probability in your envelope can be any percentage between 0% and 100%.

Please give us instructions for each possible envelope of type χ that your envelope may be, whether we should give you the AEX-contingent money or the probability-contingent money. Do so by specifying a threshold (in percentage):

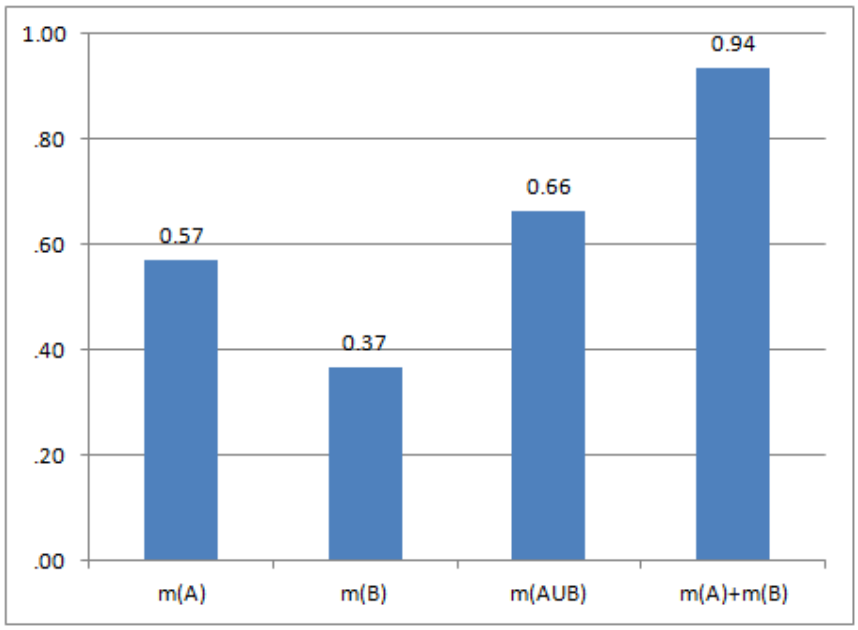
My threshold is ..... %

If the probability p in my envelope is equal to the threshold or above, then give me the probability-contingent option 2.

If the probability p in my envelope is below the threshold then give me the AEX-contingent option 1.

Results. Figure WC.4 gives results.

FIGURE WC.4. Mean of the matching probabilities of variables



Under expected utility we should have

$$m(A) + m(B) = m(A \cup B) \qquad \text{(WC.2)}$$

but this equality is rejected (Table WC.1).

TABLE WC.1. *t*-test of additivity of matching probabilities (Eq. WC.2)

	Mean	Std. Deviation	N	*t*-test for equality of means		
				t	df	p (2-tailed)
m(A)+m(B)	0.94	0.39	80	6.69	79	.000
m(A∪B)	0.66	0.28	80			

None of our values m(A), m(B), m(A∪B), and the nonadditivity index m(A∪B) − m(A) − m(B), were significantly different from those of Baillon & Bleichrodt (2014). It confirms once again that matching under Prince has the same validity as choice, and that our measurement of subjective probabilities is more efficient without being less valid.

Discussion. The inequality found $(m(A)+m(B) - m(A\cup B) > 0)$ is often called subadditivity (Tversky & Fox 1995). We briefly mention some implications for ambiguity theories. The inequality confirms a(mbiguity-generated likelihood)-insensitivity (Abdellaoui et al. 2011). This property means, roughly, that the inverse-S shaped processing of likelihoods, moving subjective likelihoods towards fifty-fifty, is more pronounced for ambiguity than for risk. Insensitivity reflects a lack of understanding and discriminatory power, and for our stimuli it entails a violation of Schmeidler's (1989) ambiguity aversion. Yet it is the common empirical finding (Riege & Teigen 2013; Wakker 2010 end of §10.4.2).

Lower subadditivity and a-insensitivity are genuine properties of preference and not artefacts of measurement. Hence Prince will not remove them. Here, as throughout, the advantage of Prince is that we obtained our data more quickly and precisely than preceding papers did without losing validity.

TABLE WC.2. A *t*-test between Baillon & Bleichrodt (2014, Study 1) and our (Prince) Questions 7,8,9

		t-test for Equality of Means				
		t	df	p (2-tailed)	Mean Difference	Std. Error Difference
m(B)	Equal variances assumed**	-0.75	114.00	0.45	-0.04	0.05
	Equal variances not assumed	-0.83	89.90	0.41	-0.04	0.04
m(A)	Equal variances assumed***	1.36	114.00	0.18	0.07	0.05
	Equal variances not assumed	1.53	94.89	0.13	0.07	0.05
m(AUB)	Equal variances assumed**	0.74	114.00	0.46	0.04	0.06
	Equal variances not assumed	0.83	95.01	0.41	0.04	0.05

m(AUB) – m(A) – m(B)	Equal variances assumed	-0.06	114.00	0.96	0.00	0.07
	Equal variances not assumed	-0.06	72.71	0.96	0.00	0.07

** the *p* value of the test of equal variance is significant at 5% level.

*** the *p* value of the test of equal variance is significant at 1% level.

nonadditivity index: $m(A) + m(B) - m(A \cup B)$

Web Appendix WD. Demographic questions

The following questions were asked to our subjects at the end.

Now please open your envelope.
Your envelope is of type …. Your instruction for type … is …. Now it is clear that you get …. Do you agree?
At the very end, we would like to ask some feedback questions. These questions have no influence on what your get from your envelope but will help us in our investigation.

Finally, please indicate your age, gender and nationality:

Age : _____

Gender : male O female O

Nationality : _____

Web Appendix WE. Further stimuli

Further stimuli and background material is here:

http://people.few.eur.nl/wakker/data/prince_stimuli_etc/links.htm

Additional references for web appendix

Riege, Anine H. & Karl Halvor Teigen (2013) "Additivity Neglect in Probability Estimates: Effects of Numeracy and Response Format," *Organizational Behavior and Human Decision Processes* 121, 41–52.

Schmeidler, David (1989) "Subjective Probability and Expected Utility without Additivity," *Econometrica* 57, 571–587.