Clear Thinking in an Uncertain World: Human Reasoning and its Foundations

Lecture 12

Eric Pacuit

Department of Philosophy
University of Maryland, College Park
pacuit.org
epacuit@umd.edu

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Two Puzzles about Rationality and Coordination

1. The Prisoner's Dilemma
2. Newcomb's Paradox

Game Situations

1. a group of *self-interested* agents (players) involved in some interdependent decision problem

Game Situations

	Bob	
	L	R
	1	0

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	Bob	
	L	R
	1	0
	0	1

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Game Situations

		Bob L	Bob R
Ann	U	1 1	0 0
Ann	D	0 0	1 1

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Game Situations

Bob

Ann	L	R
U	1,1	0,0
D	0,0	1,1

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Game Situations

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Ann \ Bob	L	R
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What should Ann (Bob) *do*?

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Just Enough Game Theory

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- actions the players *can* take
- description of the players' interests (i.e., preferences),
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- actions the players *can* take
- description of the players' interests (i.e., preferences),
- description of the "structure" of the decision problem

It does not specify the actions that the players do take.

A **solution concept** is a systematic description of the outcomes that may emerge in a family of games.

This is the starting point for most of game theory and includes many variants: Nash equilibrium, backwards inductions, or iterated dominance of various kinds.

These are usually thought of as the embodiment of “rational behavior” in some way and used to analyze game situations.

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For this course, **solution concepts** are more of an *endpoint*.

Suppose there are two players Ann and Bob dividing a cake. Suppose that Ann cuts the cake and then Bob chooses the first piece. (Suppose they *only* care about the size of the piece). Ann cannot cut the cake exactly evenly, so one piece is always larger than the other.

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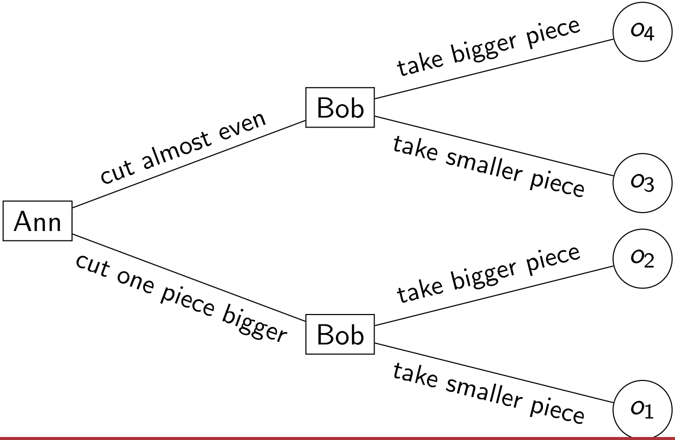

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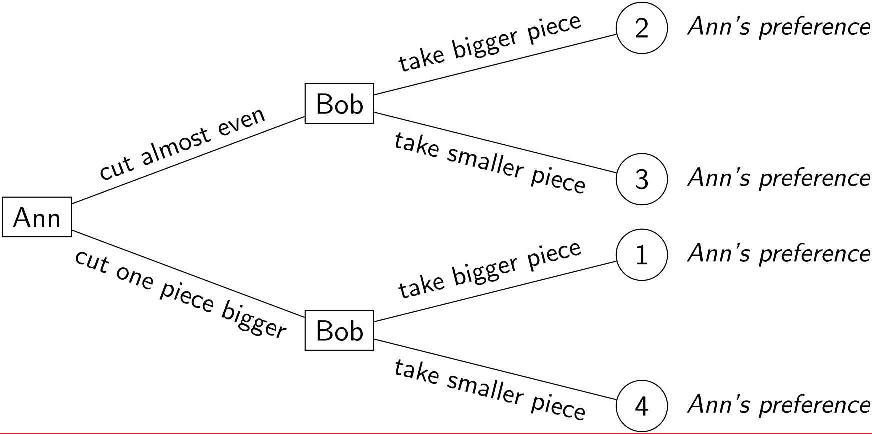

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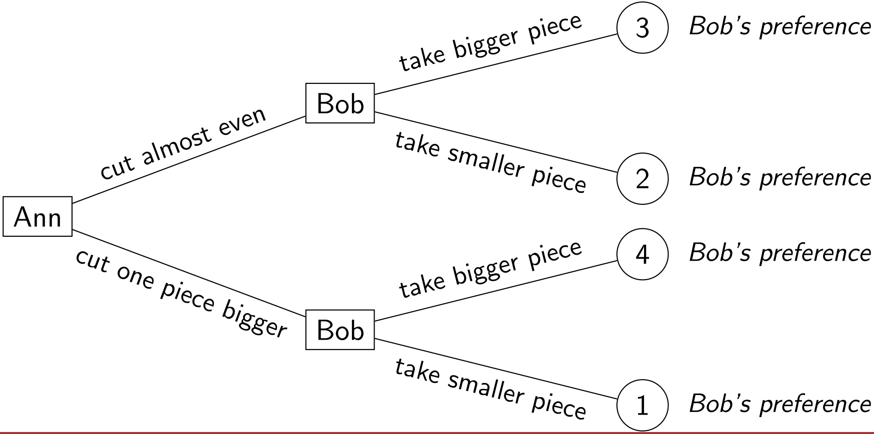

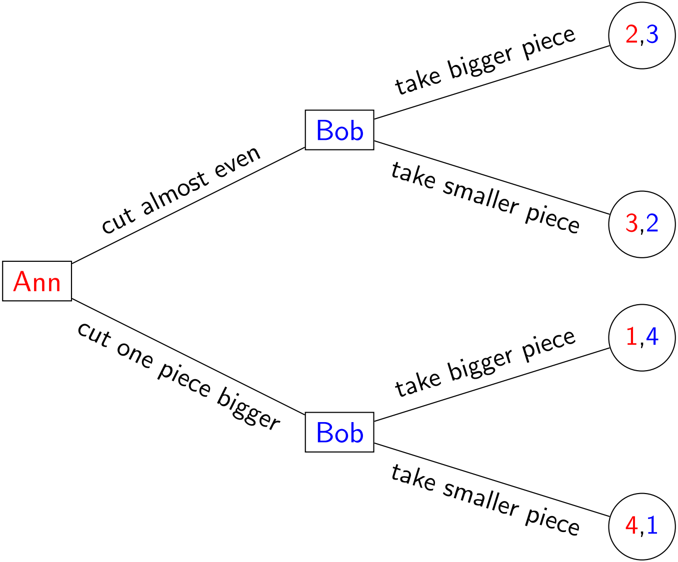
Ann
cut almost even
cut one piece bigger
Bob
take bigger piece
take smaller piece
Bob
take bigger piece
take smaller piece
2,3
3,2
1,4
4,1

		Bob	
		TB	*TS*
Ann	*CB*	1,4	4,1
	CE	2,3	3,2

What should Ann *do*?

		Bob	
		TB	*TS*
Ann	*CB*	1,4	4,1
	CE	2,3	3,2

What should Ann *do*? *Bob best choice in Ann's worst choice*

		Bob		
		TB	*TS*	
Ann	*CB*	1,4	4,1	1
	CE	2,3	3,2	2

What should Ann *do*? *maximize over each row and choose the maximum value*

		Bob	
		TB	*TS*
Ann	*CB*	1,4	4,1
	CE	2,3	3,2
		3	1

What should Bob *do*? *minimize over each column and choose the maximum value*

Zero-Sum Games

Von Neumann Minmax Theorem. In any finite, two-player, zero-sum game, there is always at least one minmax solution.

		Bob	
		H	T
Ann	H	1,-1	-1,1
	T	-1,1	1,-1

What is a rational choice for Ann (Bob)?

Ann \ Bob	H	T
H	1,-1	-1,1
T	-1,1	1,-1

What is a rational choice for Ann (Bob)? *Flip a coin!*

		Bob	
		$C1$	$C2$
Ann	$P1$	1,-1	-1,1
	$P2$	-1,1	1,-1

What is a rational choice for Ann (Bob)?

Ann \ Bob	$C1$	$C2$
$P1$	1,-1	-1,1
$P2$	-1,1	1,-1

Ann \ Bob	$C1$	$C2$
$P1$	1,-1	1,-1
$P2$	1,-1	1,-1

What is a rational choice for Ann (Bob)? *Play a different game!*

Prisoner's Dilemma

Two people commit a crime.

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Prisoner's Dilemma

Two options: Confess (C), Don't Confess (D)

Prisoner's Dilemma

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Possible outcomes:

Prisoner's Dilemma

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Possible outcomes: We both confess (C, C), I confess but my partner doesn't (C, D),

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Prisoner's Dilemma

Two options: Confess (C), Don't Confess (D)

Possible outcomes: We both confess (C, C), I confess but my partner doesn't (C, D), My partner confesses but I don't (D, C), neither of us confess (D, D).

Prisoner's Dilemma

		Bob	
		D	C
Ann	D		
	C		

Prisoner's Dilemma

Bob

Ann		D	C
	D	3	1
	C	4	2

Ann's preferences

Prisoner's Dilemma

		Bob	
		D	C
Ann	D	3	4
	C	1	2

Bob's preferences

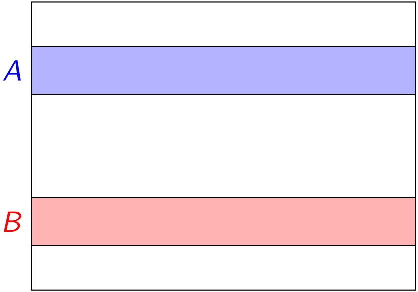
Prisoner's Dilemma

Bob

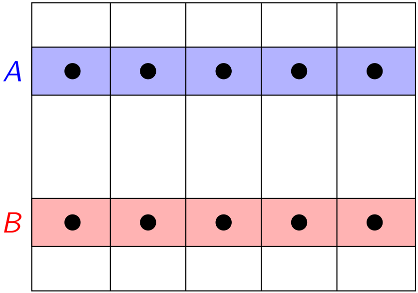
Ann		D	C
	D	3,3	1,4
	C	4,1	2,2

What should Ann (Bob) do?

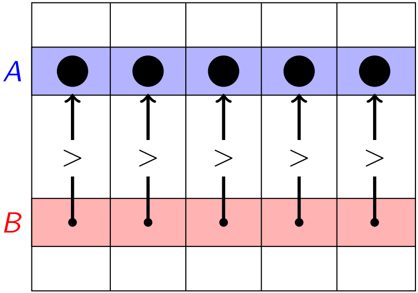
Dominance Reasoning



Dominance Reasoning



Dominance Reasoning



Prisoner's Dilemma

		Bob D	Bob C
Ann	D	3,3	1,4
Ann	C	4,1	2,2

What should Ann (Bob) do?

Prisoner's Dilemma

		Bob D	Bob C
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What should Ann (Bob) do? *Dominance reasoning*

Prisoner's Dilemma

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What should Ann (Bob) do? *Dominance reasoning*

Prisoner's Dilemma

		Bob	
		D	C
Ann	D	3,3	1,4
	C	4,1	2,2

What should Ann (Bob) do? *Dominance reasoning* is not **Pareto**!

Prisoner's Dilemma

		Bob	
		D	C
Ann	D	3	2.5
	C	2.5	2

What should Ann (Bob) do? *Think as a group*!

Prisoner's Dilemma

		Bob D	Bob C
Ann	D	3,3	1,4
Ann	C	4,1	2,2

What should Ann (Bob) do? *Play against your mirror image*!

Prisoner's Dilemma

		Bob	
		D	*C*
Ann	*D*	3,3	1,4
	C	4,1	2,2

What should Ann (Bob) do? *Play against your mirror image*!

Prisoner's Dilemma

		Bob	
		D	C
Ann	D	ϵ,ϵ	1,4
	C	4,1	2,2

What should Ann (Bob) do? *Change the game* (eg., Symbolic Utilities)

		Bob	
		D	C
Ann	D	4,4	1,3
	C	3,1	2,2

What should/will Ann (Bob) do?

Ann \ Bob	D	C
D	4,4	1,3
C	3,1	2,2

Assurance Game

What should/will Ann (Bob) do?

Ann \ Bob	D	C
D	3,3	1,4
C	4,1	2,2

Prisoner's Dilemma

Ann \ Bob	D	C
D	4,4	1,3
C	3,1	2,2

Assurance Game

What should/will Ann (Bob) do?

Nozick: Symbolic Utility

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R. Nozick. *The Nature of Rationality*. Princeton University Press, 1993.

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		D	C
Ann	D	3,3	1,4
	C	4,1	2,2

Prisoner's Dilemma

What should/will Ann (Bob) do?

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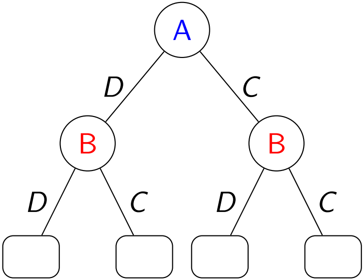
Prisoner's Dilemma



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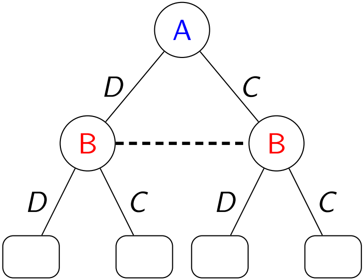

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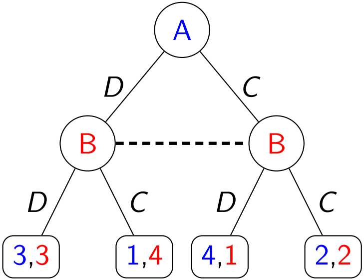

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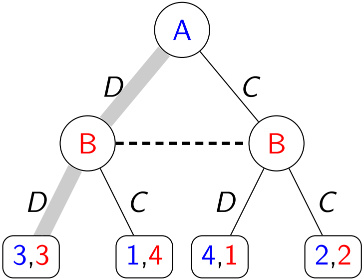

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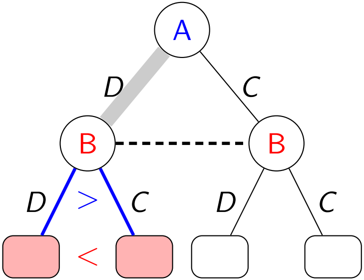

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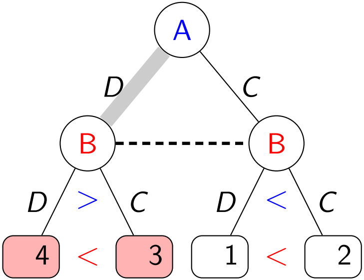

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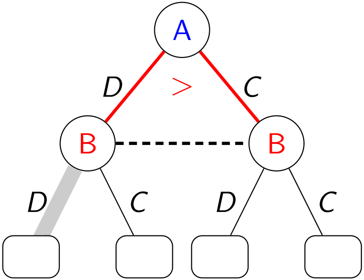

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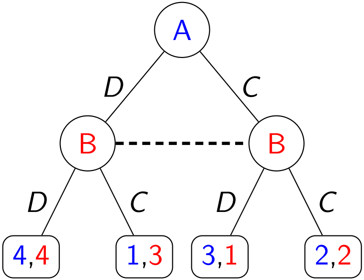
Prisoner's Dilemma



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"Game theorists think it just plain wrong to claim that the Prisoners' Dilemma embodies the essence of the problem of human cooperation. On the contrary, it represents a situation in which the dice are as loaded against the emergence of cooperation as they could possibly be. If the great game of life played by the human species were the Prisoner's Dilemma, we wouldn't have evolved as social animals! .... No paradox of rationality exists. Rational players don't cooperate in the Prisoners' Dilemma, because the conditions necessary for rational cooperation are absent in this game." (pg. 63)

K. Binmore. *Natural Justice*. Oxford University Press, 2005.

Newcomb's Paradox

Two boxes in front of you, A and B.

Box A contains \$1,000 and box B contains either \$1,000,000 or nothing.

Newcomb's Paradox

Two boxes in front of you, A and B.

Box A contains $1,000 and box B contains either $1,000,000 or nothing.

Your choice: either open both boxes, or else just open B. (You can keep whatever is inside any box you open, but you may not keep what is inside a box you do not open).

Newcomb's Paradox

A very powerful being, who has been invariably accurate in his predictions about your behavior in the past, has already acted in the following way:

1. If he has predicted that you will open just box B, he has in addition put \$1,000,000 in box B
2. If he has predicted you will open both boxes, he has put nothing in box B.

What should you do?

R. Nozick. *Newcomb's Problem and Two Principles of Choice*. 1969.

Newcomb's Paradox

	B = 1M	B = 0
1 Box	1M	0
2 Boxes	1M + 1000	1000

Newcomb's Paradox

	B = 1M	B = 0
1 Box	1M	0
2 Boxes	1M + 1000	1000

	B = 1M	B = 0
1 Box	h	$1 - h$
2 Boxes	$1 - h$	h

Newcomb's Paradox

J. Collins. *Newcomb's Problem*. International Encyclopedia of Social and Behavioral Sciences, 1999.

Newcomb's Paradox

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What the Predictor did yesterday is *probabilistically dependent* on the choice today, but *causally independent* of today's choice.

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(the expected value of act A is a probability weighted average of the values of the ways w in which A might turn out to be true)

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Orthodox Bayesian Decision Theory: $P_A(w) := P(w \mid A)$
(Probability of w given A is chosen)

Causal Decision theory: $P_A(w) = P(A \mathrel{\Box\!\!\rightarrow} w)$ (Probability of *if A were chosen then w would be true*)

Suppose 99% confidence in predictors reliability.

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

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$$V(B_1) = V(M)P(M \mid B_1) + V(N)P(N \mid B_1)$$

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$$1000000 \cdot 0.99 + 0 \cdot 0.01$$

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$$1000000 \cdot 0.99 + 0 \cdot 0.01 = 990,000$$

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$$V(B_1) = V(M)P(M \mid B_1) + V(N)P(N \mid B_1) = 1000000 \cdot 0.99 + 0 \cdot 0.01 = 990,000$$

$$V(B_2) = V(L)P(L \mid B_2) + V(K)P(K \mid B_2)$$

Suppose 99% confidence in predictors reliability.

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B_2: two-box choice (open both A and B)
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M: receive \$1,000,000
L: receive \$1,001,000

$$V(B_1) = V(M)P(M \mid B_1) + V(N)P(N \mid B_1) =$$
$$1000000 \cdot 0.99 + 0 \cdot 0.01 = 990,000$$

$$V(B_2) = V(L)P(L \mid B_2) + V(K)P(K \mid B_2) =$$
$$1001000 \cdot 0.01 + 1000 \cdot 0.99$$

Suppose 99% confidence in predictors reliability.

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

$$V(B_1) = V(M)P(M \mid B_1) + V(N)P(N \mid B_1) =$$
$$1000000 \cdot 0.99 + 0 \cdot 0.01 = 990,000$$

$$V(B_2) = V(L)P(L \mid B_2) + V(K)P(K \mid B_2) =$$
$$1001000 \cdot 0.01 + 1000 \cdot 0.99 = 11,000$$

Let μ be the assigned to the conditional $B_1 \mathrel{\Box\!\!\rightarrow} M$ (and $B_2 \mathrel{\Box\!\!\rightarrow} L$) (both conditional are true iff the Predictor put \$1,000,000 in box B yesterday).

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

Let μ be the assigned to the conditional $B_1 \; \Box\!\!\rightarrow M$ (and $B_2 \; \Box\!\!\rightarrow L$) (both conditional are true iff the Predictor put \$1,000,000 in box B yesterday).

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

$$V(B_1) = V(M)P(B_1 \; \Box\!\!\rightarrow M) + V(N)P(B_1 \; \Box\!\!\rightarrow N)$$

Let μ be the assigned to the conditional $B_1 \mathrel{\Box\!\!\rightarrow} M$ (and $B_2 \mathrel{\Box\!\!\rightarrow} L$) (both conditional are true iff the Predictor put \$1,000,000 in box B yesterday).

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

$V(B_1) = V(M)P(B_1 \mathrel{\Box\!\!\rightarrow} M) + V(N)P(B_1 \mathrel{\Box\!\!\rightarrow} N) = 1000000 \cdot \mu + 0 \cdot 1 - \mu$

Let μ be the assigned to the conditional $B_1 \Box\!\!\rightarrow M$ (and $B_2 \Box\!\!\rightarrow L$) (both conditional are true iff the Predictor put \$1,000,000 in box B yesterday).

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

$V(B_1) = V(M)P(B_1 \Box\!\!\rightarrow M) + V(N)P(B_1 \Box\!\!\rightarrow N) = 1000000 \cdot \mu + 0 \cdot 1 - \mu = 1000000\mu$

Let μ be the assigned to the conditional $B_1 \mathrel{\Box\!\!\rightarrow} M$ (and $B_2 \mathrel{\Box\!\!\rightarrow} L$) (both conditional are true iff the Predictor put \$1,000,000 in box B yesterday).

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$V(B_1) = V(M)P(B_1 \mathrel{\Box\!\!\rightarrow} M) + V(N)P(B_1 \mathrel{\Box\!\!\rightarrow} N) =$
$1000000 \cdot \mu + 0 \cdot 1 - \mu = 1000000\mu$

$V(B_2) = V(L)P(B_2 \mathrel{\Box\!\!\rightarrow} L) + V(K)P(B_2 \mathrel{\Box\!\!\rightarrow} K)$

Let μ be the assigned to the conditional $B_1 \mathrel{\Box\!\!\rightarrow} M$ (and $B_2 \mathrel{\Box\!\!\rightarrow} L$) (both conditional are true iff the Predictor put \$1,000,000 in box B yesterday).

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

$V(B_1) = V(M)P(B_1 \mathrel{\Box\!\!\rightarrow} M) + V(N)P(B_1 \mathrel{\Box\!\!\rightarrow} N) = 1000000 \cdot \mu + 0 \cdot 1 - \mu = 1000000\mu$

$V(B_2) = V(L)P(B_2 \mathrel{\Box\!\!\rightarrow} L) + V(K)P(B_2 \mathrel{\Box\!\!\rightarrow} K) = 1001000 \cdot \mu + 1000 \cdot 1 - \mu$

Let μ be the assigned to the conditional $B_1 \mathrel{\Box\!\!\rightarrow} M$ (and $B_2 \mathrel{\Box\!\!\rightarrow} L$) (both conditional are true iff the Predictor put \$1,000,000 in box B yesterday).

B_1: one-box (open box B)
B_2: two-box choice (open both A and B)
N: receive nothing
K: receive \$1,000
M: receive \$1,000,000
L: receive \$1,001,000

$$V(B_1) = V(M)P(B_1 \mathrel{\Box\!\!\rightarrow} M) + V(N)P(B_1 \mathrel{\Box\!\!\rightarrow} N) = 1000000 \cdot \mu + 0 \cdot 1 - \mu = 1000000\mu$$

$$V(B_2) = V(L)P(B_2 \mathrel{\Box\!\!\rightarrow} L) + V(K)P(B_2 \mathrel{\Box\!\!\rightarrow} K) = 1001000 \cdot \mu + 1000 \cdot 1 - \mu = 1000000\mu + 1000$$

D. Lewis. *Prisoner's Dilemma Is a Newcomb Problem*. Philosophy and Public Affairs, 8, pgs. 235-240, 1979.

S. Brams. *Newcomb's Problem and Prisoners' Dilemma*. The Journal of Conflict Resolution, 19:4, pgs. 596 - 612, 1975.

S. Hurley. *Newcomb's Problem, Prisoner's Dilemma and Collective Action*. Synthese 86, pgs. 173 - 196, 1991.