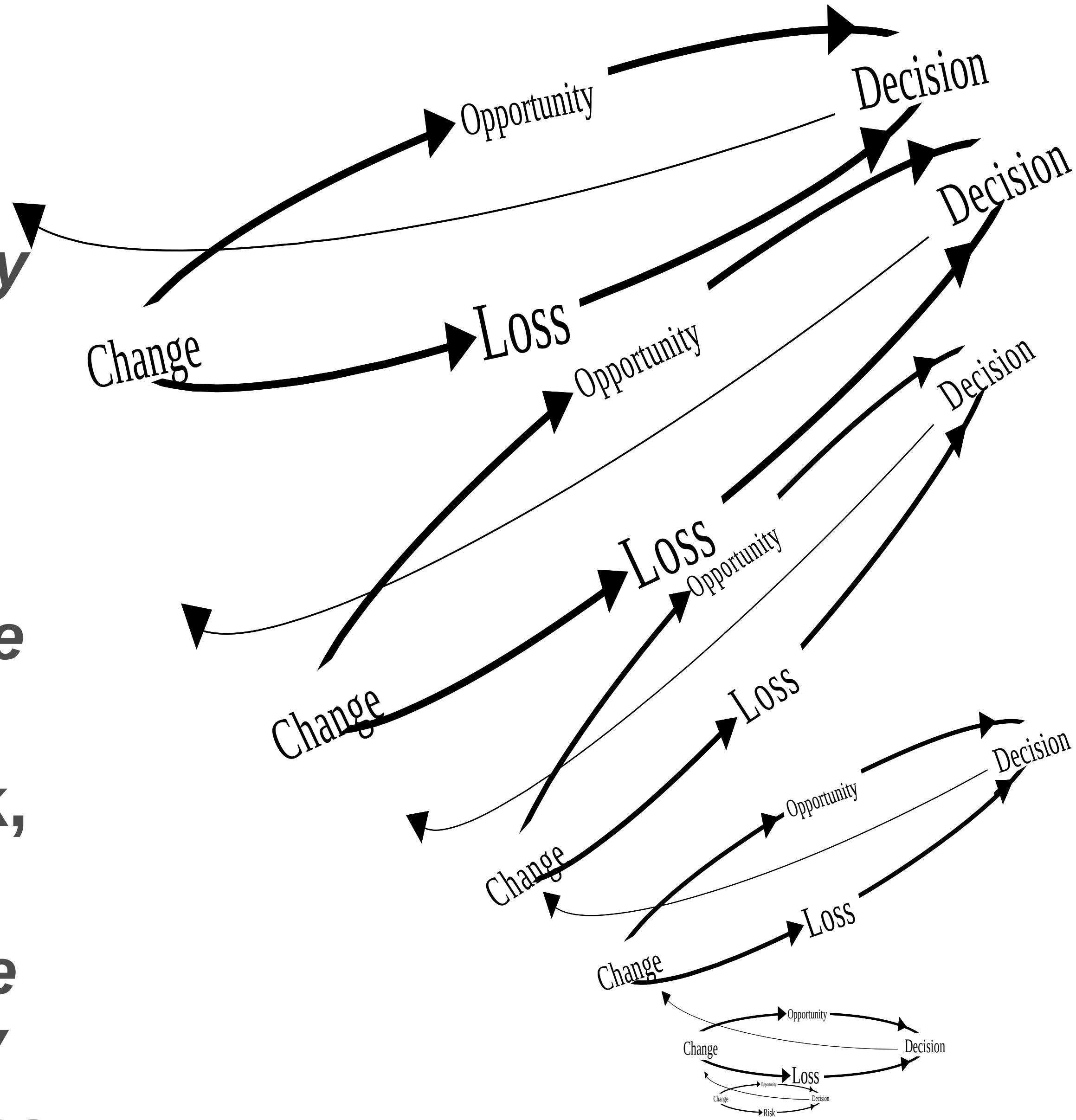
On Risk Assessment and Risk Perception

… And the significant impact risk perception can have on people's behavior

First things first…
What is a risk ?

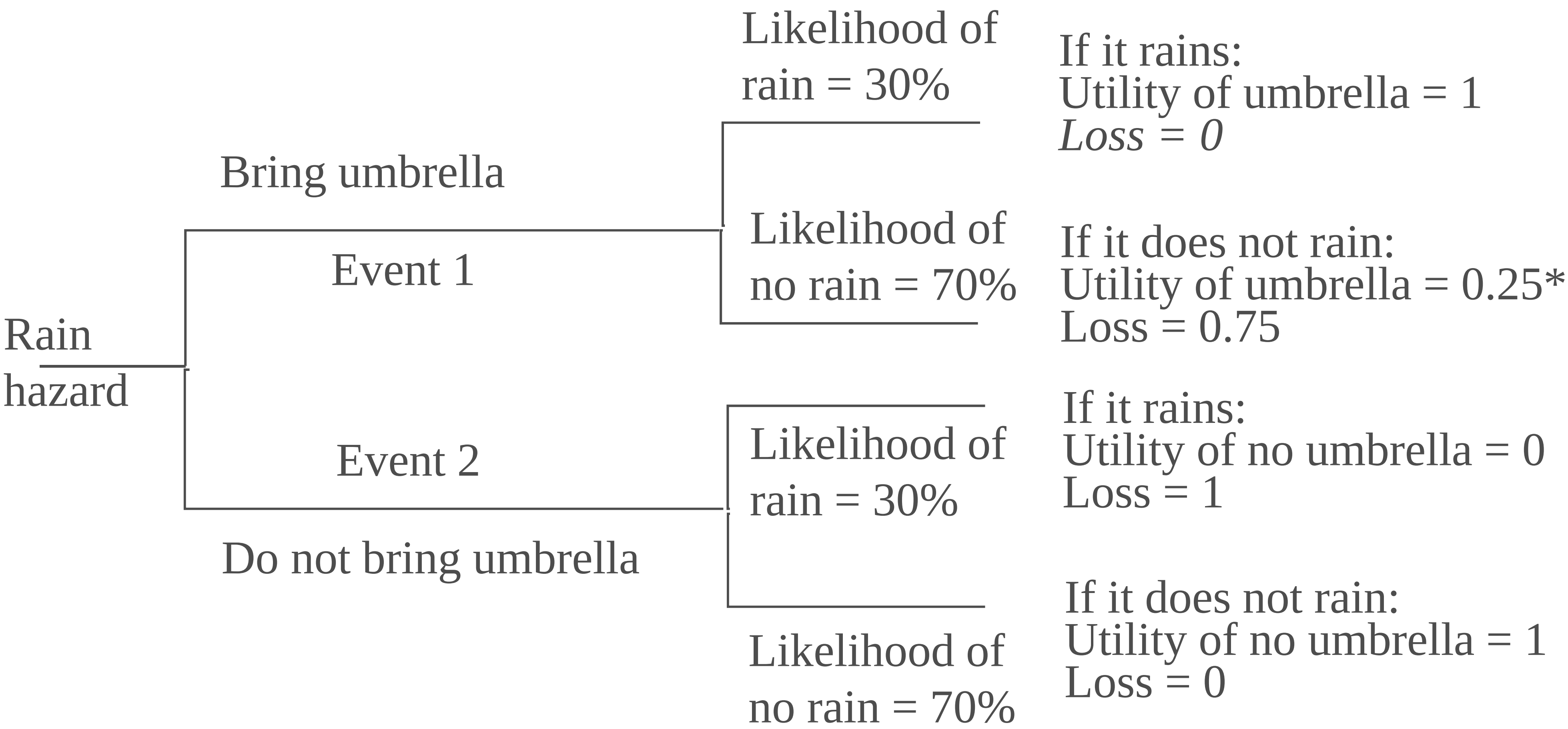
- **Webster's dictionary definition**
  - ***"Risk is the possibility of suffering loss"***
  - ***Risk is the result of undesirable events liable to occur or desirable events liable not to happen***
- **To be considered a risk, there must be**
  - ***Uncertainty or change leading to uncertainty***
  - ***A potential gain or loss***



Formal definition of Risk

- Risk ≡ {Li, Oi, Ui, CSi, POi | i =1,...,n}
  - *Li = Likelihood (or frequency of occurrence) of risk i*
  - *Oi = Outcome of risk i*
  - *Ui = Utility of risk i*
    - Utility is proportional to gain and inversely proportional to loss
  - *CSi = Causal scenario of risk i*
    - Allows an easier evaluation of Likelihood and Utility
  - *POi = Population affected by risk i*
    - Population affected will help evaluate risk priority

Risk assessment example



* A utility of 0.25 in absence of rain means that the umbrella is a significant burden to carry around

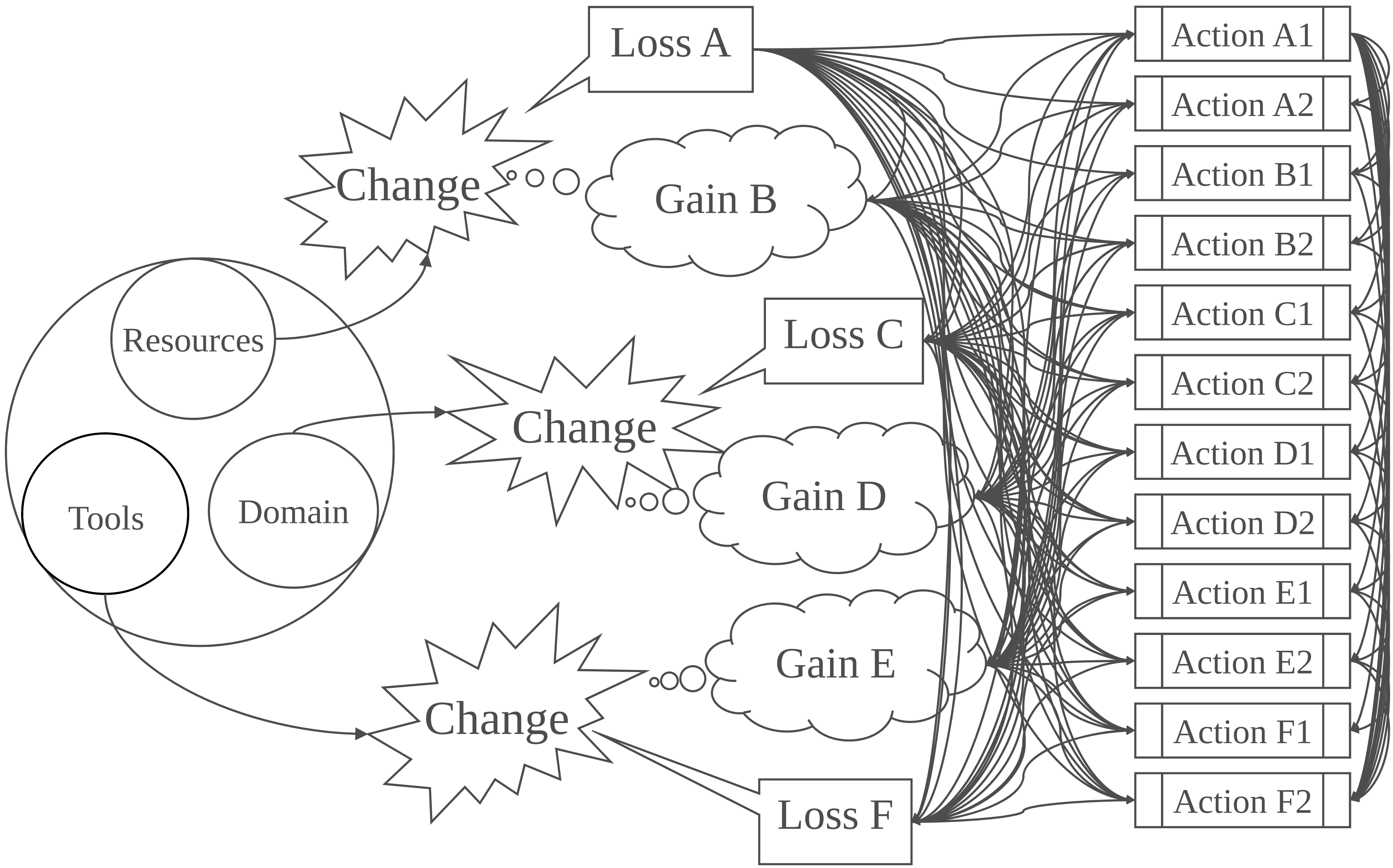
Risk assessment example (Cont'd)

- Calculation of Expected Utility (EU)
  - *EU(Alternative 1) = 0.3 x 1 + 0.7 x 0.25 = 0.475*
  - *EU(Alternative 2) = 0.3 x 0 + 0.7 x 1 = 0.7*
- The second alternative is chosen because it has a higher expected utility, given the likelihood of rain
- Alternatively, Risk Exposure (RE) can be calculated
  - *RE(Alternative 1) = 0.3 x 0 + 0.7 x 0.75 = 0.525*
  - *RE(Alternative 2) = 0.3 x 1 + 0.7 x 0 = 0.3*
- The second alternative would still be chosen as it presents less exposure to risk (lower loss)

However …

- **In practice, assessing risk can be quite a challenge !**
- **Especially when many changes can occur over a relatively short period of time**
  - ***Leading to a large number of uncertainties***
  - ***Where each uncertainty is liable to translate into a gain or a loss***
  - ***And where several actions are available either to reduce the loss or to realize the gain***

Complexity of assessing risk



Complexity of assessing risk (Cont'd)

- **Assume…**
  - ***5 events on each axis liable to result in a loss or a gain***
  - ***3 options to reduce a loss resulting from the change***
  - ***3 options to realize the gain resulting from the change***
- **How many relationships does one need to examine after a change in order to come up with the best possible solution?**

Complexity of assessing risk (Cont'd)

- **Assumptions translate into…**
  - ***3 axes x (5 losses + 5 gains) = 30 possible events***
  - ***3 axes x 3 options x (5 losses + 5 gains) = 90 possible actions***
  - ***Number of relationships to examine after each change before taking a decision***

    = Number of event-action, event-event, and action-action pairs among 120

    = 120!/(2!118!)

    = 7,140

Complexity of assessing risk (Cont'd)

- And many changes are susceptible to occur in one day !!!
  - *To complicate things even more, each option may be described with an intensity scale as opposed to simply being a discrete choice*
- This made Napoleon Bonaparte say that all he wanted from his generals is that they be lucky

Risk perception

- **It is then not surprising, given the complexity described in preceding slides, that people often rely on intuition, based on their perception of what can go well and what can go wrong**

The “Monty Hall” problem

- You participate in a game in which there are three doors
  - *Behind one of the doors, there is a Ferrari*
  - *Behind the two other doors, there is a goat*
  - *The animator asks you to choose one of the three doors*
  - *He then opens one of the two remaining doors behind which he knows there is a goat*
  - *The animator offers you to change your mind about the door you had previously chosen and to select the other one*
- Will you say Yes or No?
- Why?

Intuition can be misleading!

- **Intuitively, it seems that choosing the other door does not result in any gain, since the odds of winning the Ferrari are equal, that is, 50% in each case**
- **WRONG !**

Solution

- Let us say that “X, Y, Z” represent the three doors
- Now assume that “Fx, Fy, Fz” represent the outcomes “the Ferrari is behind door X, Y, Z, respectively”
- Finally, let us say that “Ax, Ay, Az” represent the event “the animator opens door X, Y, Z, respectively”

Solution (Cont'd)

- Application of Bayes theorem
  - *The probability of event A and event B occurring is denoted by the expression $P(A \cap B)$ or $P(A, B)$*
  - *The probability of event B occurring, given that event A has also occurred is given by the expression $P(B \mid A)$*
  - *$P(A, B) = P(A) \bullet P(B \mid A)$, where • is the multiplication symbol*
  - *The probability of event A or event B occurring is denoted by the expression $P(A \cup B)$*
    - Equal to $P(A) \cup P(B)$ or $P(A) + P(B)$, if events A and B are mutually exclusive

Solution (Cont'd)

- The probability P(F) of winning the Ferrari after having chosen a door, for example door X, and then changing your mind (i.e. selecting door Z after the animator has opened door Y, or selecting door Y after the animator has opened door Z), is expressed as follows:

$$P(F) = P(A_y, F_z) + P(A_z, F_y)$$

- Using Bayes theorem

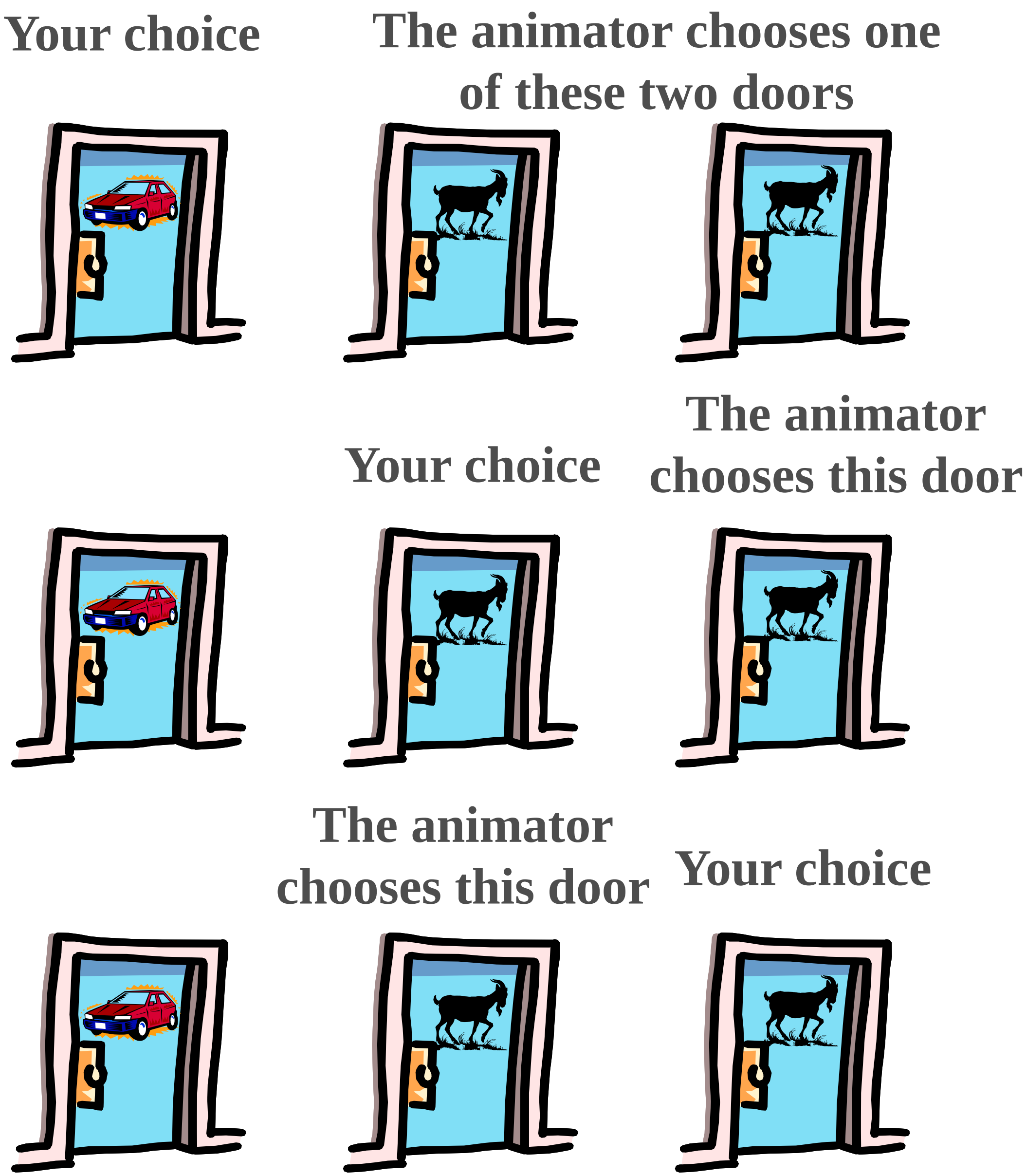
$$P(F) = P(F_z) \cdot P(A_y \mid F_z) + P(F_y) \cdot P(A_z \mid F_y)$$

$$P(F) = \tfrac{1}{3} \cdot 1 + \tfrac{1}{3} \cdot 1 = \tfrac{2}{3}$$

Solution (Cont'd)

- This simple calculation demonstrates that you should change your mind after being offered to do so !
- The probability of winning the Ferrari, if you change your mind, is twice the probability of winning it if you don't !

A graphical representation…



- If you change your mind, you win a goat
- If you don't change your mind, you win the Ferrari

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- If you change your mind. You win the Ferrari
- If you don't change your mind, you win a goat

Another example of risk perception significance

- The northeastern United States and eastern Canada suffered a major ice storm in 1998
  - *Some areas did not have electricity for a duration exceeding one month (not a particularly pleasant experience in 30ºC below zero)*
  - *Diesel generators were selling like little hot cakes*
- In the fall following the storm, there was another brisk sale of generators as people wanted to be ready in case of another such storm

Another example of risk perception significance (Cont'd)

- **Assume that the meteorologists tell us the following**
  - ***An ice storm of this magnitude occurs once over a period of 200 years with a 99.95% probability***
  - ***It occurs once over a period of 10 years with a probability of 0.05%***

Another example of risk perception significance (Cont'd)

- **Establishing the a priori probability distribution of an ice storm of this magnitude**
  - ***IS98=Such an ice storm occurred in 1998***
  - ***E=An ice storm of this magnitude occurs once every 200 years with a probability of 0.9995***
    - **P(E)=0.005 corresponding to a frequency of once every 200 years**
    - **P(IS98/E)=0.9995**
  - ***$\bar{E}$=An ice storm of this magnitude occurs once every 10 years with a probability of 0.0005***
    - **P($\bar{E}$)=0.1 corresponding to a frequency of once every 10 years**
    - **P(IS98/$\bar{E}$)=0.0005**

Another example of risk perception significance (Cont'd)

- **Establishing the a posteriori probability distribution of an ice storm of this magnitude**
  - ***In other words, what was now the perception of people that such an ice storm would happen again within the next 10 years after it had happened in 1998?***

Another example of risk perception significance (Cont'd)

- **Using Boolean algebra**
  - $P(IS98) = P(IS98 \cap (E \cup \overline{E}))$
  - $P(IS98) = P((IS98 \cap E) \cup (IS98 \cap \overline{E}))$
  - $P(IS98) = P(IS98 \cap E) \cup P(IS98 \cap \overline{E})$

Which translates into

- $P(IS98) = P(IS98, E) + P(IS98, \overline{E})$

And using Bayes theorem

- $P(IS98, E) = P(E) \bullet P(IS98 \mid E)$
- $P(IS98, \overline{E}) = P(\overline{E}) \bullet P(IS98 \mid \overline{E})$

Another example of risk perception significance (Cont'd)

- The posteriori probability distribution of an ice storm of the magnitude of the ice storm experienced in 1998 is given by
  - $P(\overline{E} \mid IS98) = P(\overline{E}, IS98) / P(IS98)$
  - $P(\overline{E} \mid IS98) = P(\overline{E}) \cdot P(IS98 \mid \overline{E}) / P(IS98)$
  - $P(\overline{E} \mid IS98) = P(\overline{E}) \cdot P(IS98 \mid \overline{E}) /$
    $(P(E) \cdot P(IS98 \mid E) + P(\overline{E}) \cdot P(IS98 \mid \overline{E}))$
  - $P(\overline{E} \mid IS98) = 0.1 \cdot 0.0005 /$
    $(0.005 \cdot 0.9995 + 0.1 \cdot 0.0005)$
  - $P(\overline{E} \mid IS98) = 0.009906$

Another example of risk perception significance (Cont'd)

- **Behavioral impact**
  - ***People's perception that an ice storm of the magnitude of the ice storm experienced in 1998 would happen again within the next 10 years increased by a factor equal to***

    0.009906 / 0.0005 = 198

  - ***Even though the probability that such an ice storm would happen again within that timeframe had not changed***

Risk perception and behavior

- Making decisions based on risk perception can sometimes result in curious consequences…
- … Such as this Canadian couple who, wishing to find shelter from a possible nuclear conflict, went to live in the Falkland Islands on the eve of the war between Great Britain and Argentina