A Quantum Approach To Cognitive Bias Modelling

A Survey

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Outline

Quantum cognition as a new theory to reduce bias

" "Rational" decision-making methods ... logic, mathematics, probability theory ... [are] incapable of solving the natural adaptive problems ..." [Cosmides & Tooby 1994 p.329]

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- Who produces the bias?
  - the theory or people
- Our solution: use another theory

What is Quantum Cognition?

- A field that uses formalisms of quantum mechanics to model cognitive phenomena
  - Interference effect [Townsend et al. 2000]
  - Order effect [Wang & Busemeyer 2012]
  - Disjunction effect [Tversky & Shafir 1992]
  - Conjunction effect ["Linda is a bank teller" Tversky & Kahneman, 1983]
  - Concept combination, Prototype theory [Rosch, Aerts & Gabora 2005]

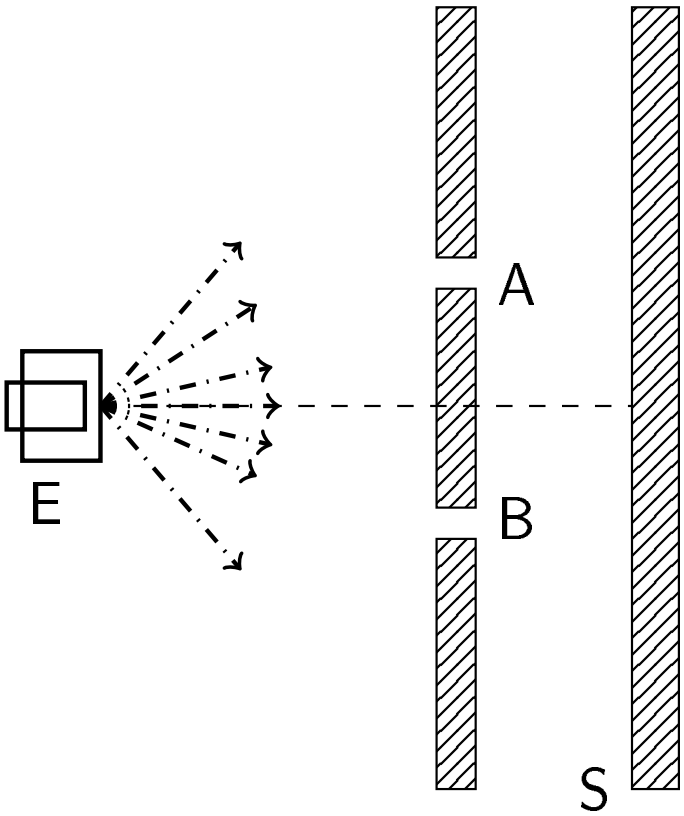
Example - Superposition

(a) Old/ Young lady

(b) Two faces/ Vase

Figure : Bi-stable visualizations can be interpreted as in a superposition state: An observer is not able to perceive both interpretations simutaneouslly

Double slit experiment



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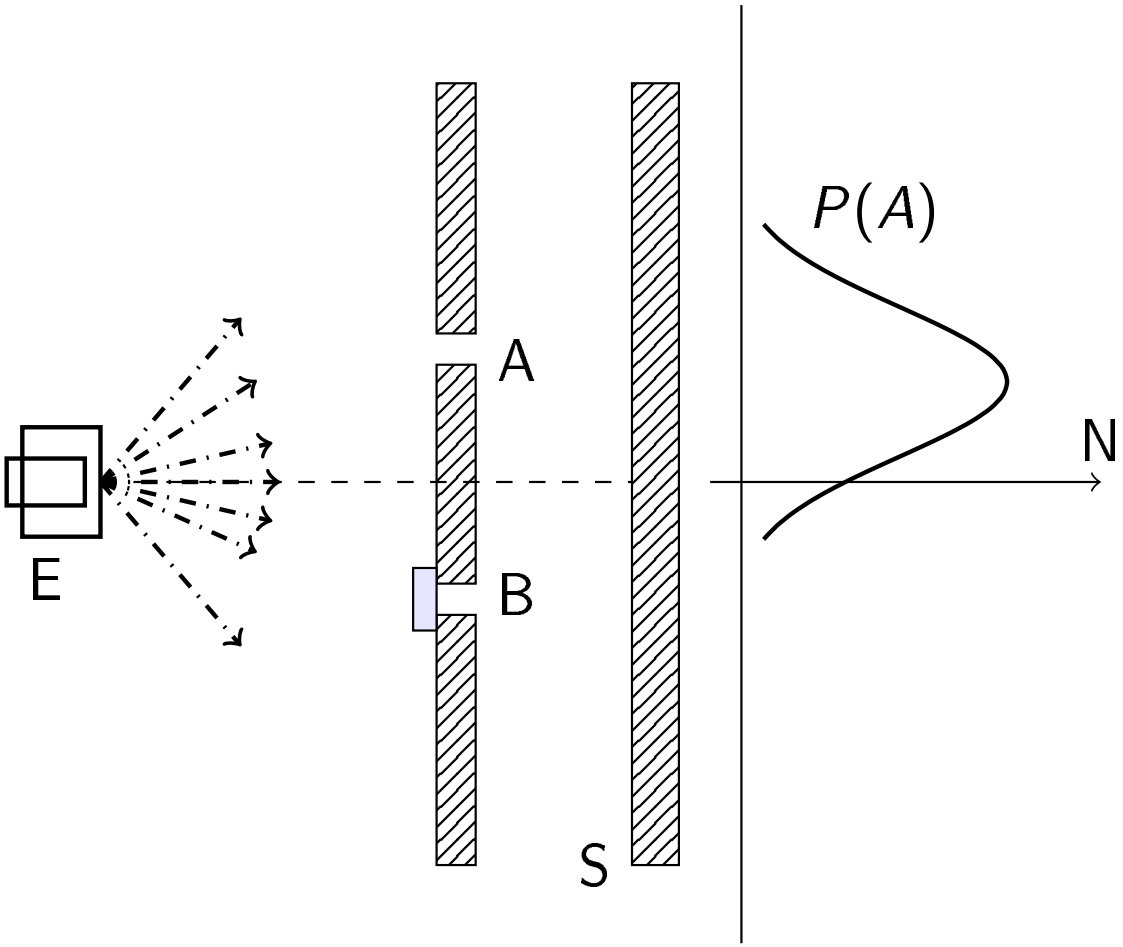

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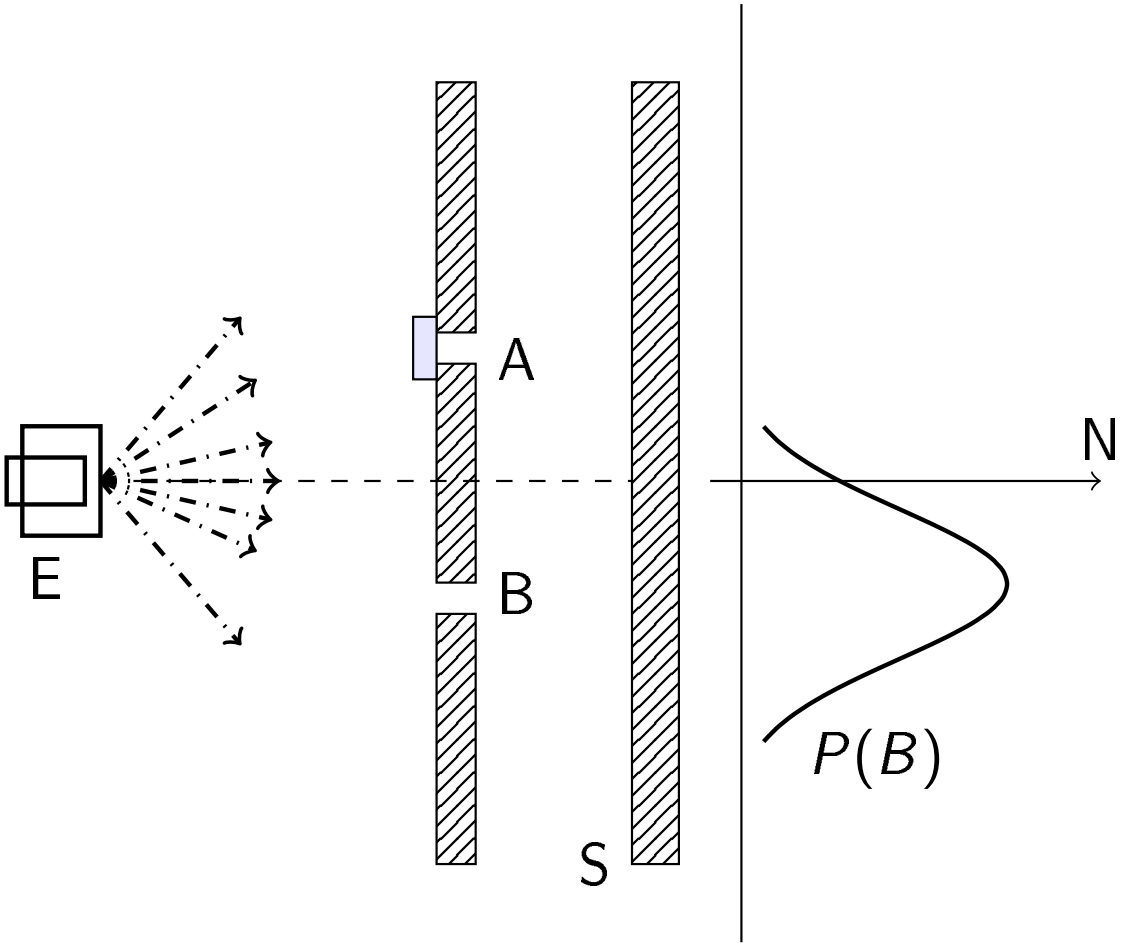
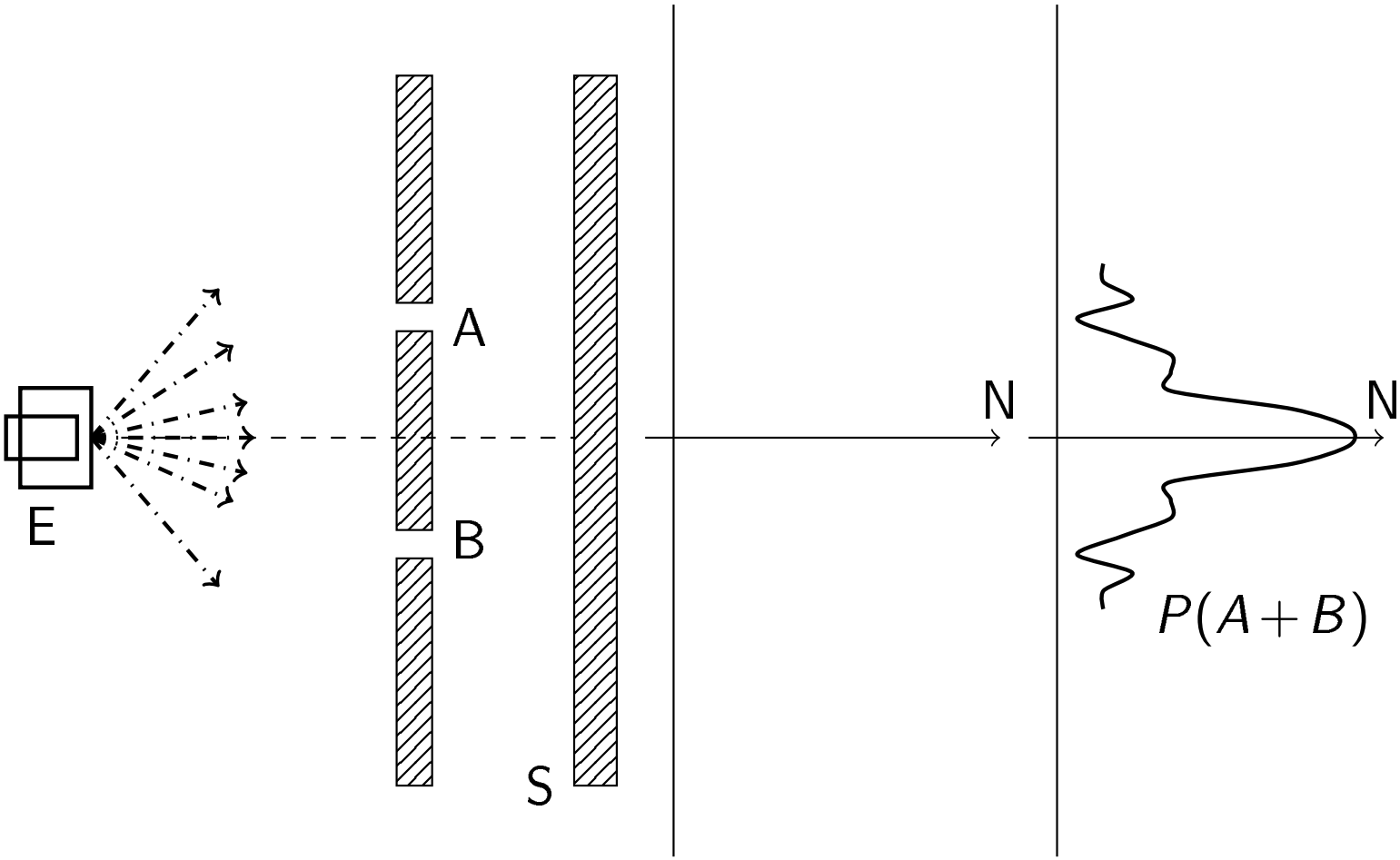


Double slit experiment



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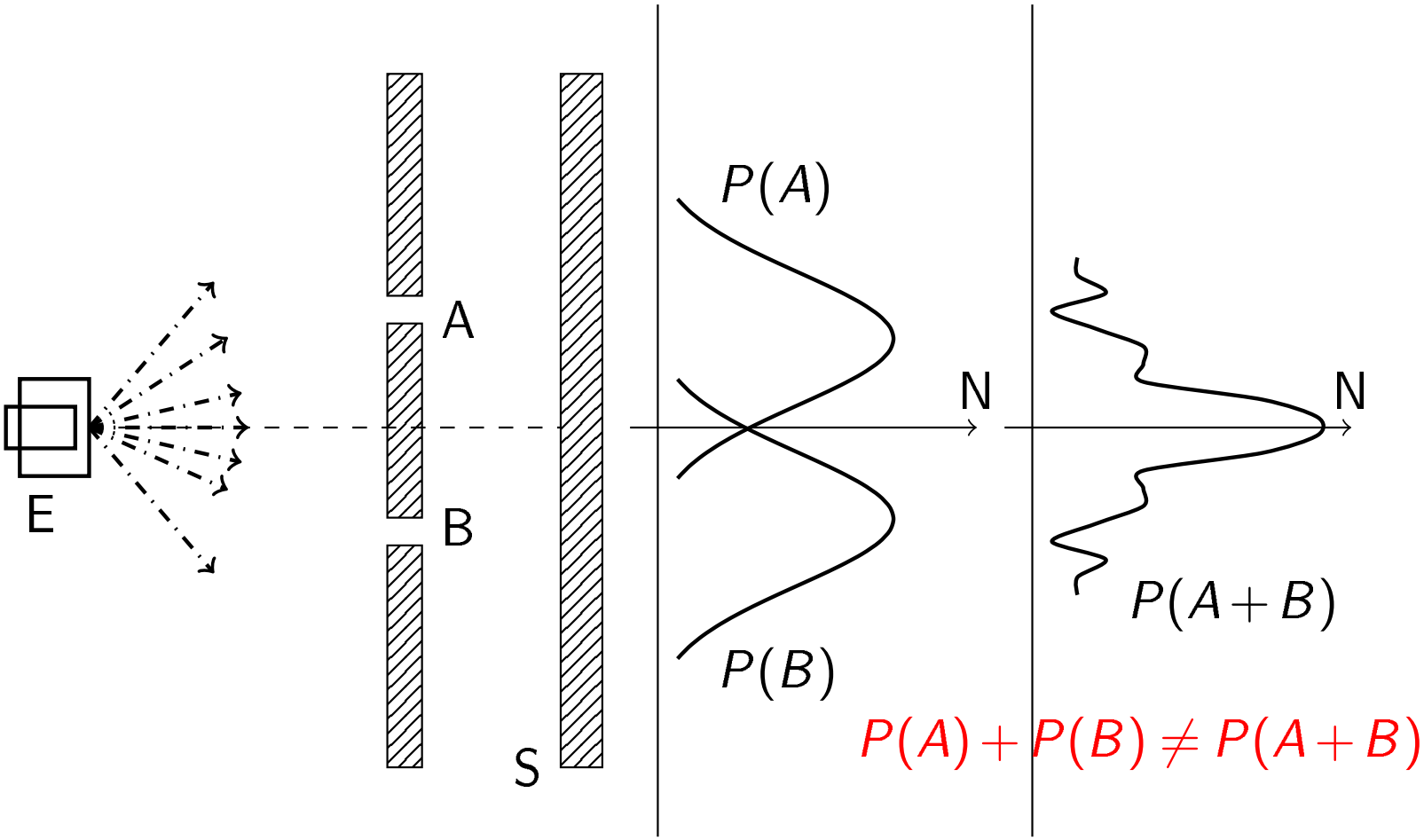

Mathematics of Quantum Cognition

classical statistic

- set theory

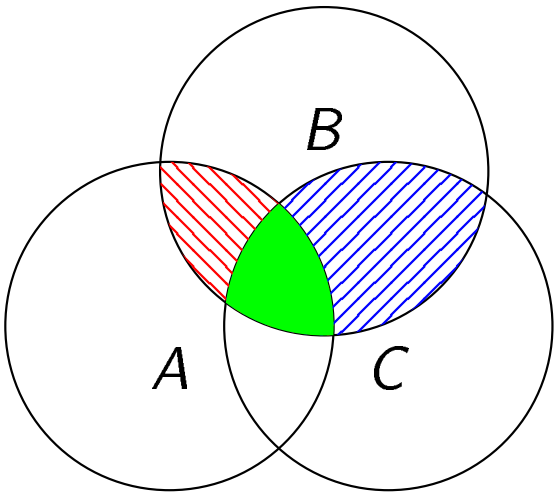

Figure : Venn diagram of sets

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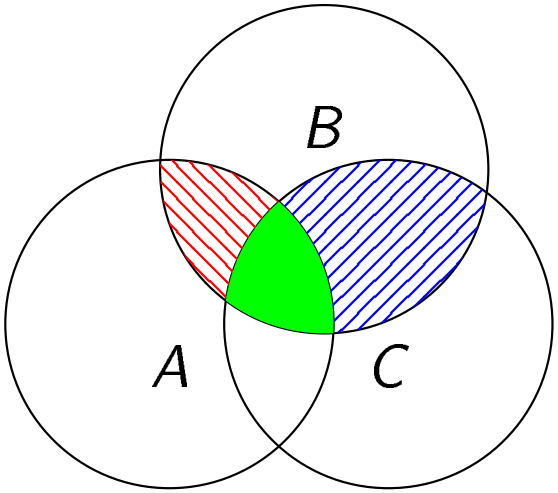


Figure : Venn diagram of sets

quantum theory

- vector space

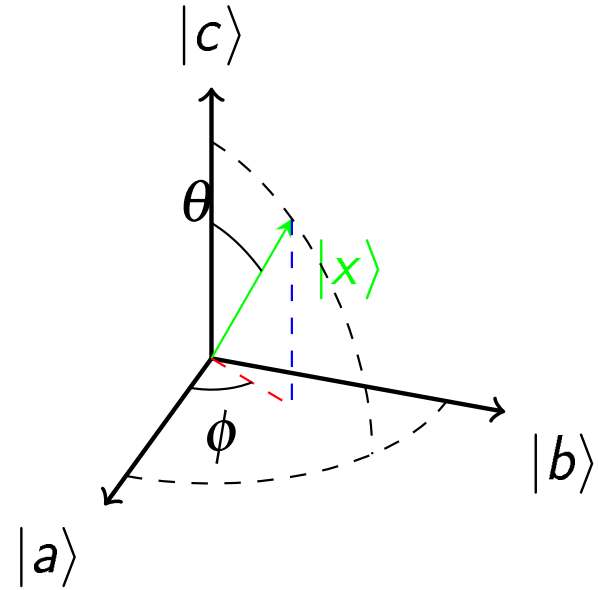
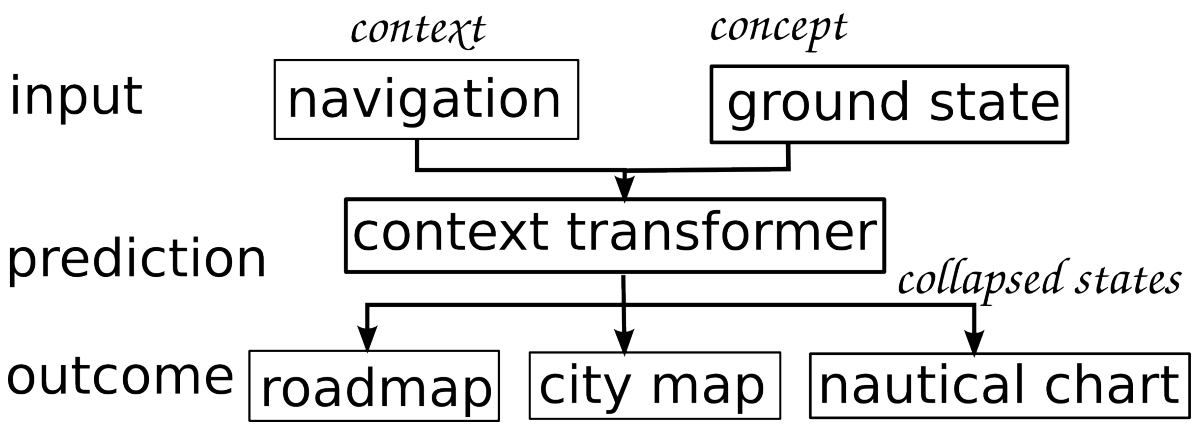


Figure : 3 dimensional Hilbert space

Prediction of an appropriate Map with a Hilbert Space Model

Include the SCOP in a map service to reduce cognitive biases



[Hahn & Frank 2014]

A Hilbert Space Model for Concepts

presented by [Aerts and Gabora 2005a,b]

State Context Property (SCOP)

- sets:
  - $\Sigma = \{p1, p2, ...\}$ representing the *states* a concept can assume
  - $\mathscr{M} = \{e1, e2, ..., f1, f2, ...\}$ including *contexts* for a concept
  - $\mathscr{L} = \{a1, a2, ...\}$ containing *properties* or features for a concept
- functions:
  - $\mu(q, e, p)$ calculates the transition probability from one state q to another state p under the influence of context e
  - $\nu(p, a)$ weights the importance of one property a in a particular state p

SCOP representation of the concept map

States of the map, set Σ

$\widehat{p}$ map

p1 roadmap

p2 hiking map

p3 city map

p4 nautical chart

p5 ski runway map

p6 bicycling map

SCOP representation of the concept map

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Layers of the map, set $\mathscr{L}$

a1	road
a2	lake
a3	buildings
a4	mountains
a5	ski runs
a6	bicycling lanes
a7	hiking path
a8	contour lines

Calculate the appropriate Map via context

Agent

1. I need a map.

state of the concept map

- calculations

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1. map

- calculations
  - $|x_{\hat{p}}\rangle = \sum_{u \in M} \frac{1}{\sqrt{1800}} |u\rangle$

Calculate the appropriate Map via context

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2. map for bicycling

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  - $|x_{p_6}\rangle = \frac{P_{e_6}|x_{\hat{p}}\rangle}{\sqrt{\langle x_{\hat{p}}|P_{e_6}|x_{\hat{p}}\rangle}} = \sum_{u \in e6} \frac{1}{\sqrt{100}} |u\rangle$

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    - nautical map? $\mu(p_4, e4, x_{p_6}) = \langle x_{p_6}|P_{e4}|x_{p_6}\rangle = 0\ \%$

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    - bicycle map? $\mu(p_6, e6, x_{p_6}) = \langle x_{p_6}|P_{e6}|x_{p_6}\rangle = 0.88\ \%$
    - include roads in the map? $\nu(x_{p_6}, a_1) = 0.8\ \%$

Is there a visual interference?

- hypothesis: visual - double slit experiment
- evidence that simultaneous tasks can interfere [Pashler 1994]

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whole webpage

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Summary

- Quantum cognition uses formalisms of quantum mechanics to model cognitive phenomena
- Reduce cognitive load with serving appropriate information

- Outlook
  - visual priming
  - visual interference
  - .... any suggestions?