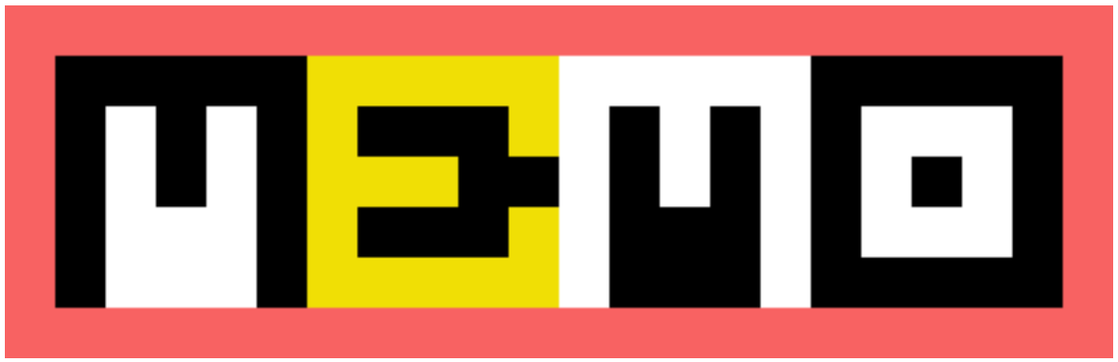
The **memo** handbook

v1.1.2



Anatomy of a memo

axes of array to compute

name

scalar free parameters

```
@memo
def model[x: X, y: Y](a, b, c):
    ''' This is a model of ____! '''
    alice: …
    bob: …
    return …
```

optional comment for documentation

sequence of **statements**

expression whose value to compute for each cell in returned array

Statements

chooses

Domain of choice (name of Python list/enum or JAX array)

Agent making choice

```
bob: chooses(a in Actions, wpp=exp(β*utility(a)))
```

Name of choice

"With probability proportional to"
For softmax, use wpp=exp(…)
For uniform choice, use wpp=1

Can make multiple choices simultaneously

```
bob: chooses(x in X, y in Y, wpp=joint(x, y))
```

more ways to choose

```
bob: chooses(a in Actions, to_maximize=utility(a))
```

For argmax use to_maximize
For argmin use to_minimize

Aliases of "chooses" that don't imply agency/goal-orientation

(These all mean the same, but can make your model easier to read.)

```
bob: given(r in Roles, wpp=1)
bob: draws(r in Roles, wpp=1)
bob: assigned(r in Roles, wpp=1)
bob: guesses(r in Roles, wpp=1)
```

thinks

Agent doing the thinking

```
bob: thinks[
    alice: chooses(...),
    charlie: chooses(...),
    ...
]
```

What that agent thinks
(notice the commas!)

observes

Agent observing

Choice being observed (square brackets are a mnemonic for "someone else's choice")

```
bob: observes [alice.x] is y
```

What the choice is observed to actually be. Can create false beliefs this way!

```
bob: observes [alice.x] is charlie.y
```

This value can also be another agent's choice.

advanced use of observes

Agent observing

Condition that was observed (boolean expression)

```
bob: observes_that [coin.bias > 0.5]
```

like "condition(…)" in WebPPL

Agent observing

Probability of event observed

```
bob: observes_event(wpp=coin.bias)
```

like "factor(log(…))" in WebPPL

You generally shouldn't need these advanced constructs — most models should only use `observes` as documented on the previous page.

knows

Agent who knows

Choices that are known

```
bob: knows(x, alice.y)
```

This utility is useful for the common case of "pushing" a variable into an agent's frame of mind. Roughly shorthand for this:

```
bob: thinks[ alice: chooses(y in Y, wpp=...) ]
bob: observes [alice.y] is alice.y
```

snapshots_self_as

Agents can remember "snapshots" of their past selves. Useful for counterfactuals and hypotheticals, especially when used with "imagine" expressions (see below…).

Agent who snapshots

"aliases" of snapshots

```
alice: snapshots_self_as(past_alice, …)
```

```
alice: observes [bob.x] is x
return alice[ past_alice[ E[bob.x] ] ]
```

not affected by "observe" statement

Expressions

literals

floating-point numbers only

↓

```
3.14
```

also references to declared free parameters

↓

```
a, b, c, …
```

operators

memo supports most Python unary/binary ops

```
1 + 1
```

also some free bonus functions

```
exp(…), log(…), abs(…)
```

can also call any function tagged with @jax.jit

useful for calling deep learning, etc.
JAX is a big ecosystem

```
@jax.jit
def f(x):
  return np.cos(x)
```

note: can only take scalar inputs and can only return one scalar output

choices

```
alice: chooses(x in X, wpp=1)
alice: chooses(y in Y, wpp=f(x, y))
```

you can refer to an agent's own choice as if it were simply a variable

or refer to other agents' choices with "dot" notation

```
alice.x + alice.y
```

equivalent to either of these

```
alice[x] + alice[y]
alice[x + y]
```

probabilistic operators

expectation

```
E[alice.x + bob.z]
```

variance

```
Var[alice.y * 2]
```

probability

```
Pr[alice.y >= 0]
Pr[a.x > 0, b.y < 2]
```

can use both commas and "and" for joint

information-theoretic operators

(mutual) entropy between choices

```
H[alice.x, bob.y, …]
```

KL divergence

```
KL[alice.x | bob.y]
```

queries

```
Var[alice[abs(x) * 2]]
alice[bob.y == 7]
```

can "query" another agent for the value
of an expression using square brackets

hypotheticals

set up hypothetical world by running statements

```
imagine[
  bob: chooses(y in Y, wpp=1),
  alice: observes [bob.y] is bob.y,
  alice[Pr[bob.x == 7]]
]
```

last line = expression to evaluate in that world

memo calls

```
@memo
def f[x: X](a, b, c): …

@memo
def g():
  alice: chooses(x in X, wpp=f[x](1.0, 0.0, 3.1))
```

can reference one memo from another. (don't forget to pass parameters!)

shorthand: can use "..." if f should be called with all of g's parameters; in this case, (a, b, c).

```
@memo
def g(a, b, c):
  alice: chooses(x in X, wpp=f[x](...))
```

cost reflection

```
@memo def f[…](a, b, c): …
cost @ f(3, 4, 5)
```

get number of FLOPs needed
to evaluate f
(note: no axes, params only!)

reference to Python variable

```
class Action(IntEnum): WAIT = 0; …
@memo def f[…](…):
    return {Action.WAIT}
```

use braces for inline reference
to a global Python variable

Things to do with a memo

Running a memo

call it like a function with params
(returns an array with prescribed axes)

```
f(a, b)
```

pretty-print table of results

```
f(a, b, print_table=True)
```

```
f(a, b, return_pandas=True)
f(a, b, return_xarray=True)
```

get outputs in other formats

save "comic book" visualization of model via graphviz

```
f(a, b, save_comic="file")
```

@memo def options

cache results (keyed by scalar parameters)

```
@memo(cache=True)
```

trace execution, showing time taken

```
@memo(debug_trace=True)
```

Automatic differentiation (useful for fitting by gradient descent)

```
@memo
def f[…](a, b): …
```

returns tuple of value + gradient wrt params a & b

↓

```
jax.value_and_grad(f)(a, b)
```