

UMerced 2008

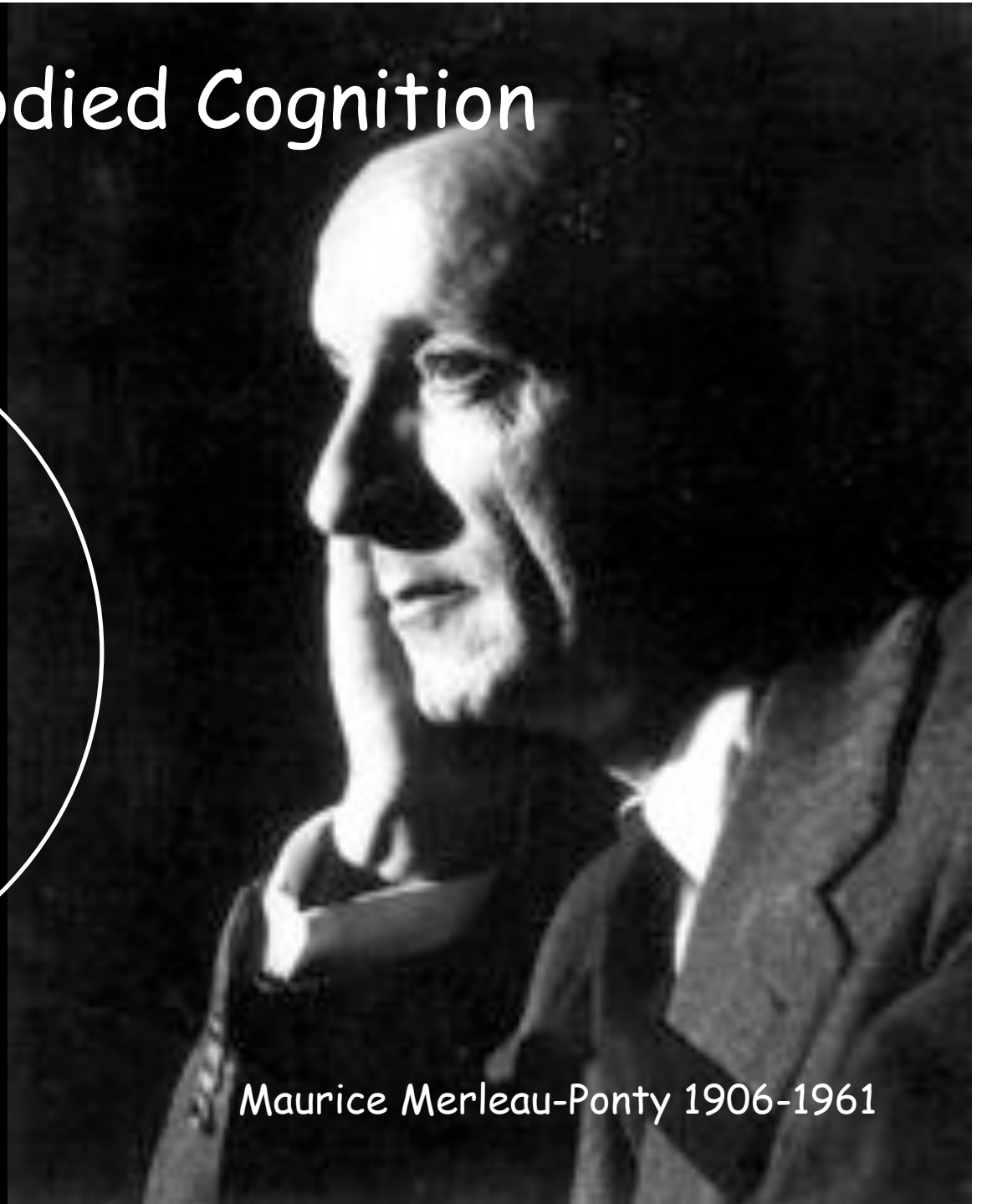
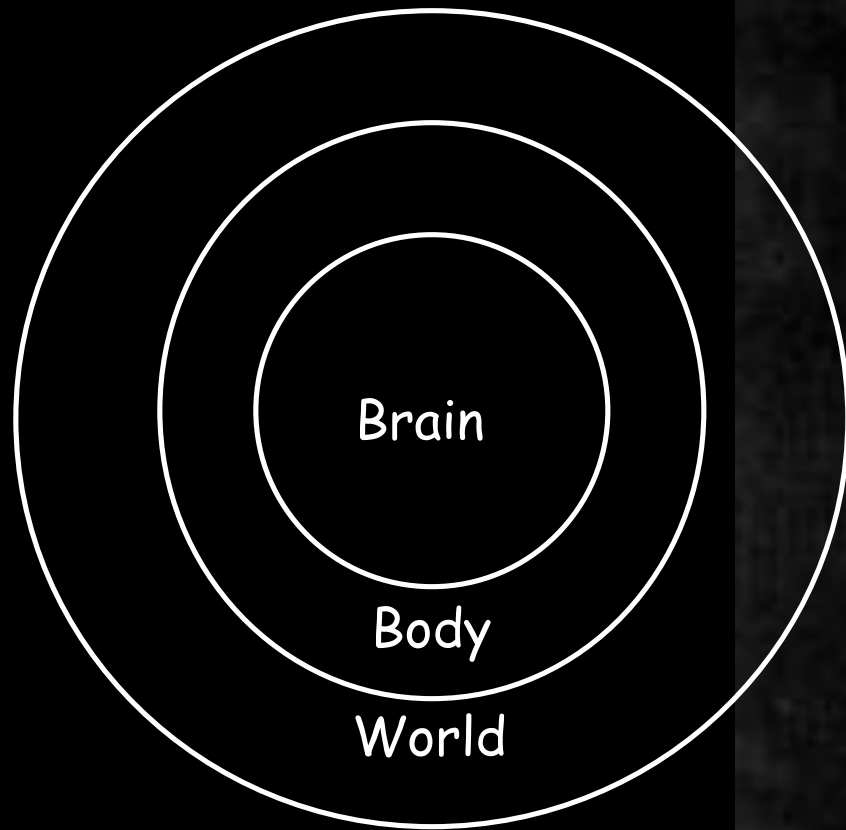
Embodied Cognition

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National Center for Research Resources
NATIONAL INSTITUTES OF HEALTH

Embodied Cognition

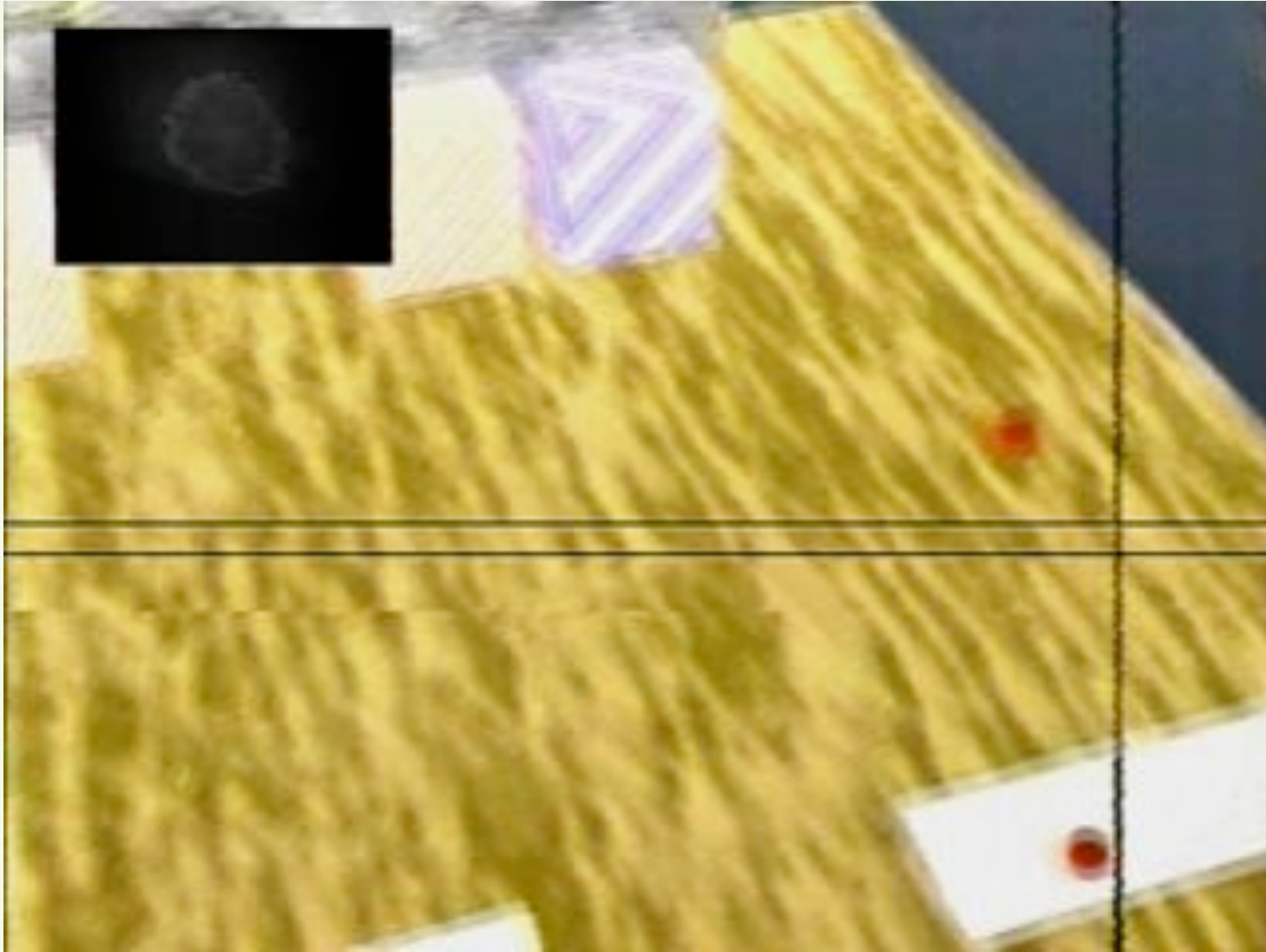


Maurice Merleau-Ponty 1906-1961

Timescales

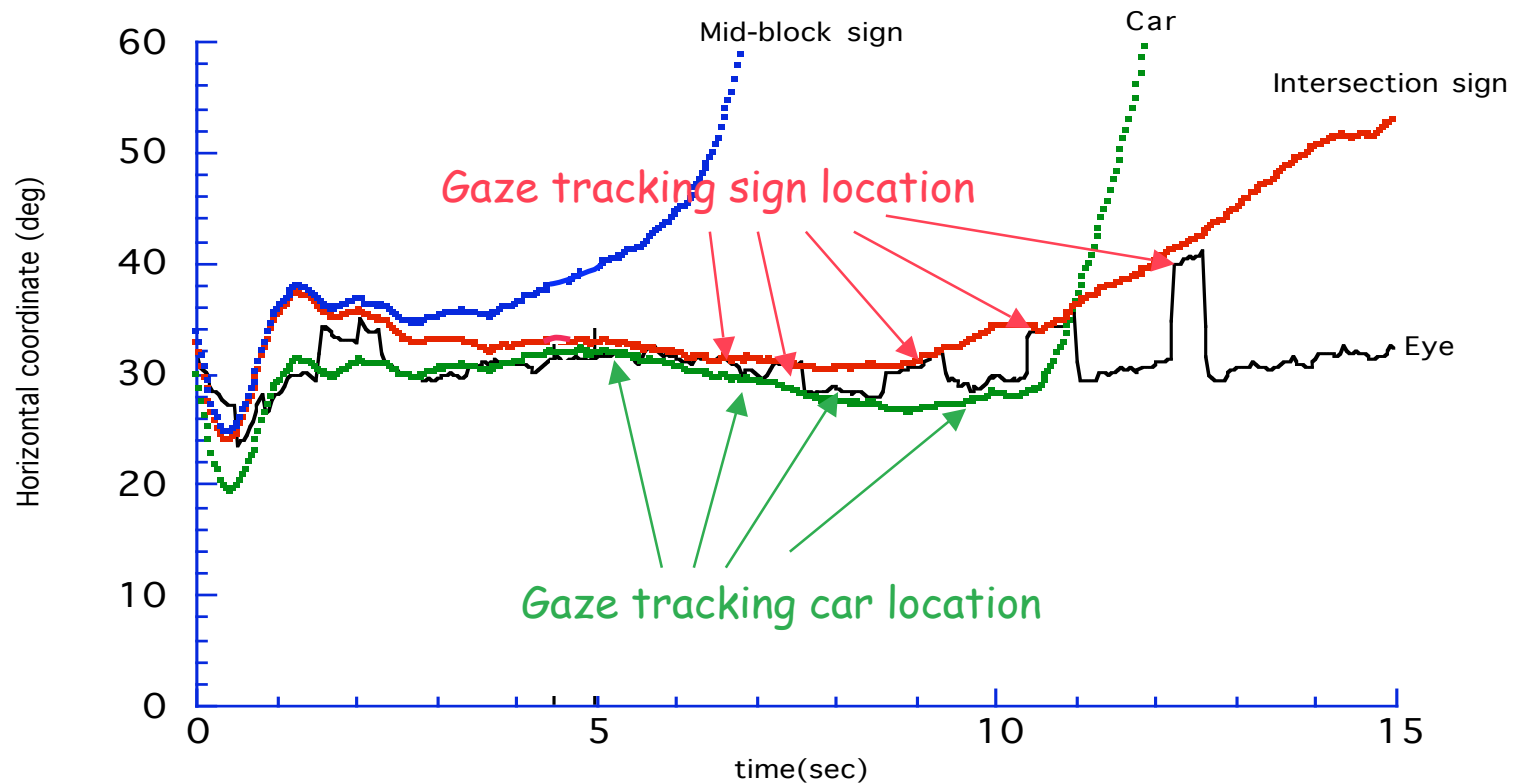


Visual Routines



Droll et al
JEP 2003

Multi-tasking revealed by gaze sharing in human data

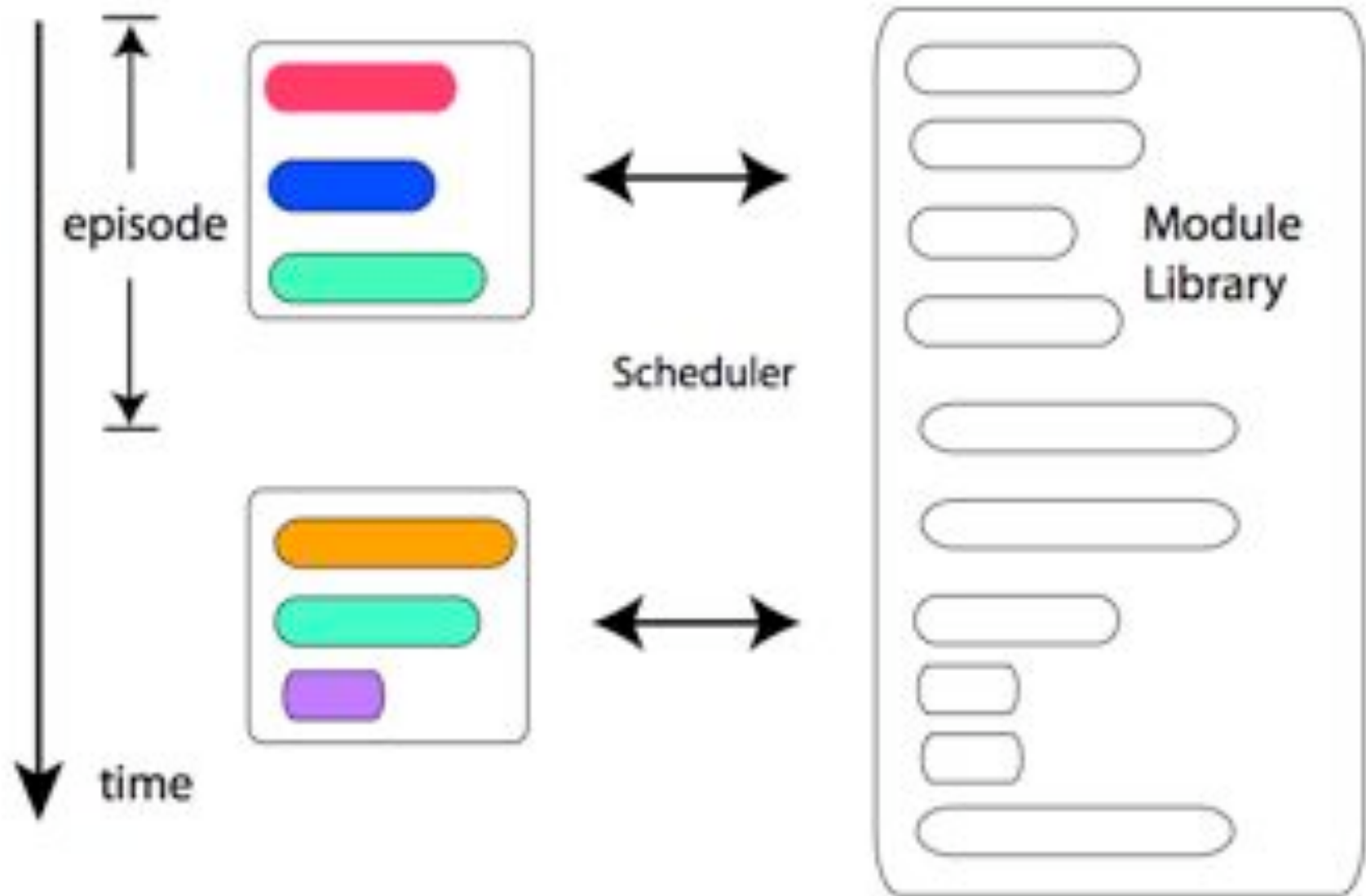


Shinoda & Hayhoe, Vision Research 2001

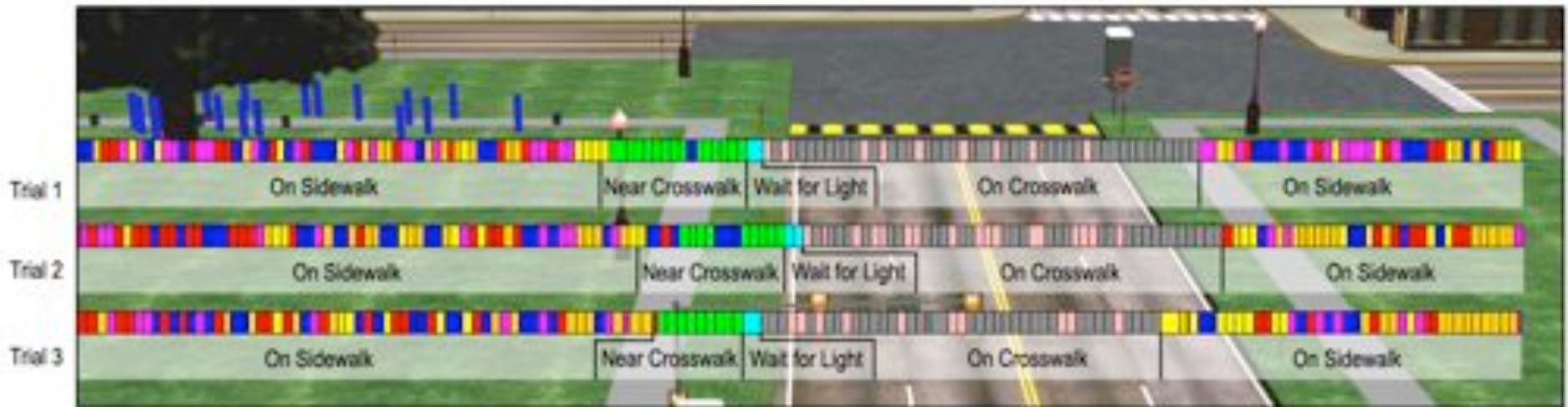
Human models are used to study multi-tasking



Scheduling of Behaviors



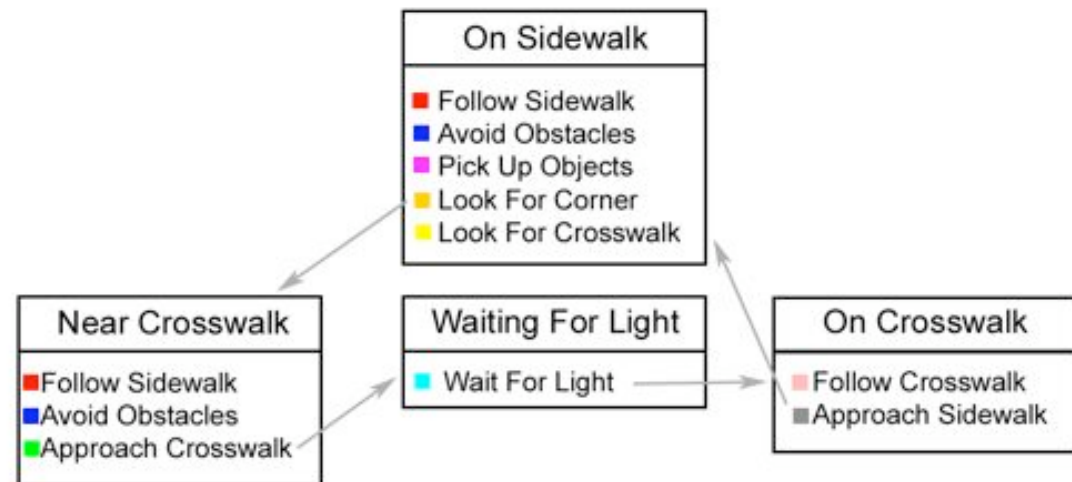
Three trials



Behavior List

- Follow Sidewalk
- Avoid Obstacles
- Pick Up Objects
- Look For Corner
- Look For Crosswalk
- Approach Crosswalk
- Wait For Light
- Follow Crosswalk
- Approach Sidewalk

State Machine Diagram



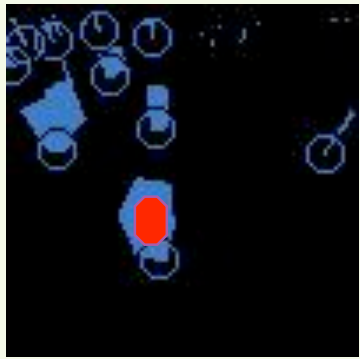
Eyetracker in V8 helmet



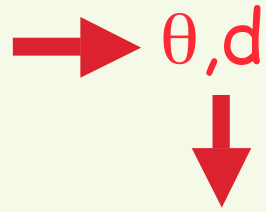
A human walks Walter's route



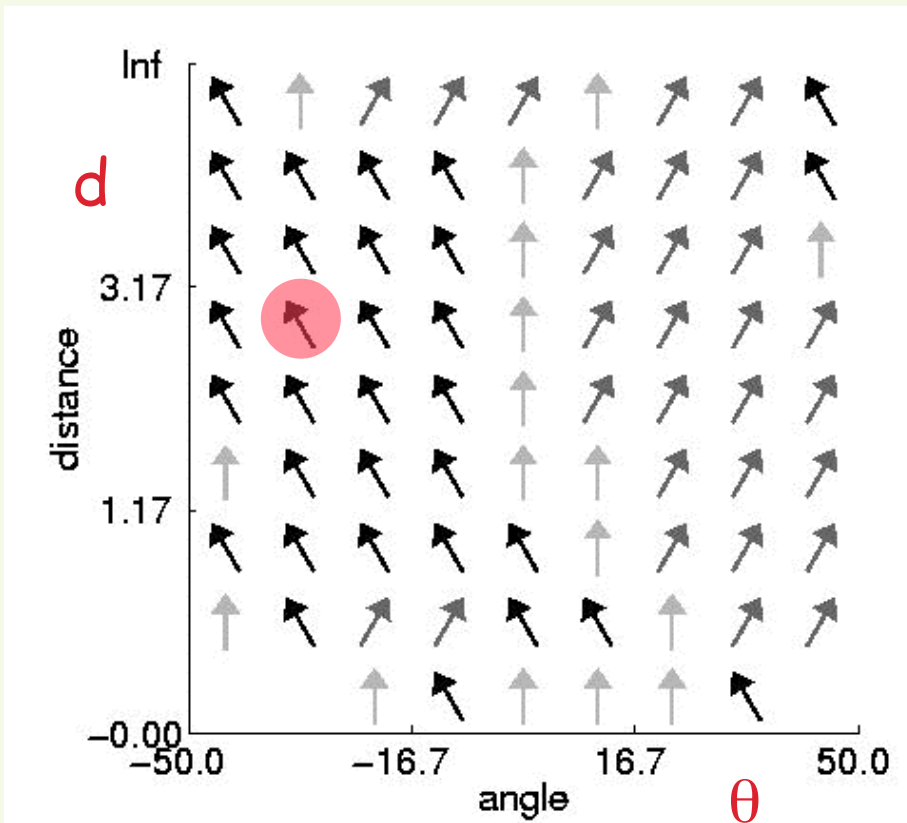
Microbehavior for Litter Cleanup



1. Visual Routine

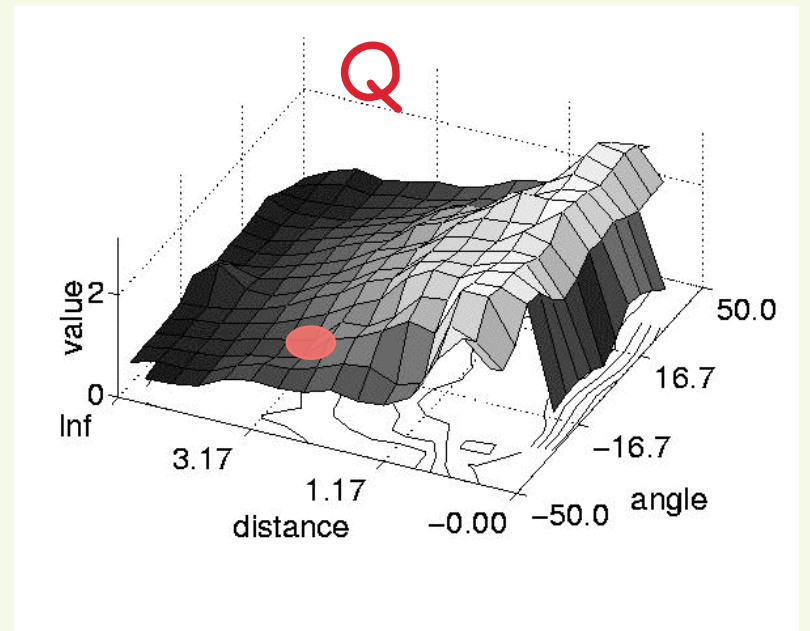


2a. Policy



Heading from Walter's perspective

2b. Value of Policy



The basic RL update: SARSA

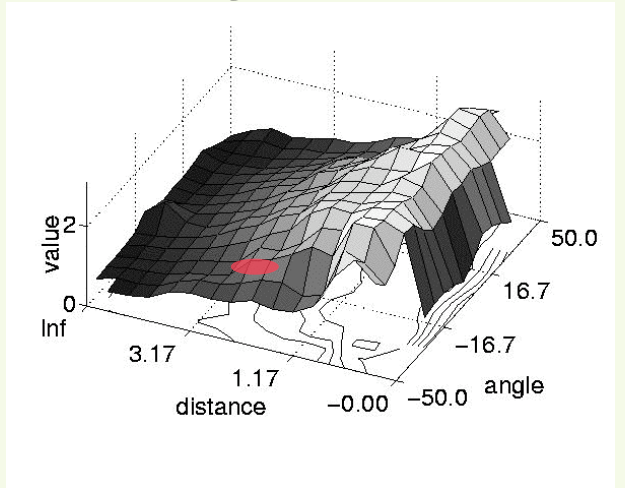
$$Q_i(s_t^{(i)}, a_t^{(i)}) \leftarrow Q_i(s_t^{(i)}, a_t^{(i)}) + \alpha \delta_{Q_i}$$

where δ_{Q_i} is given by:

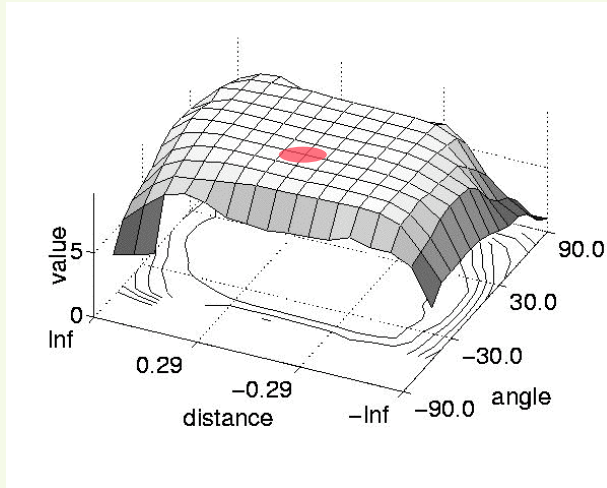
$$\delta_{Q_i} = \hat{r}_t^{(i)} + \gamma Q_i(s_{t+1}^{(i)}, a_{t+1}^{(i)}) - Q_i(s_t^{(i)}, a_t^{(i)})$$

Learned Microbehaviors

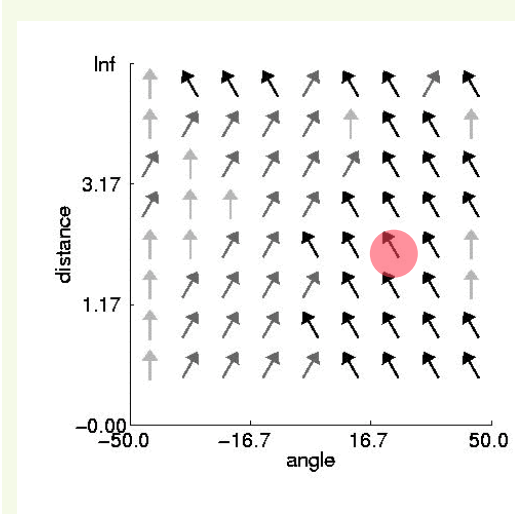
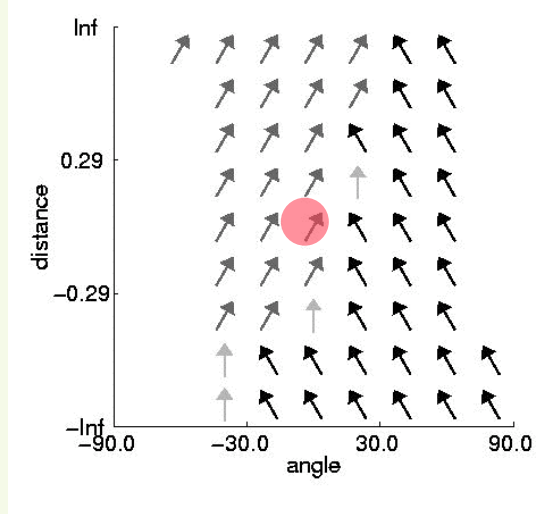
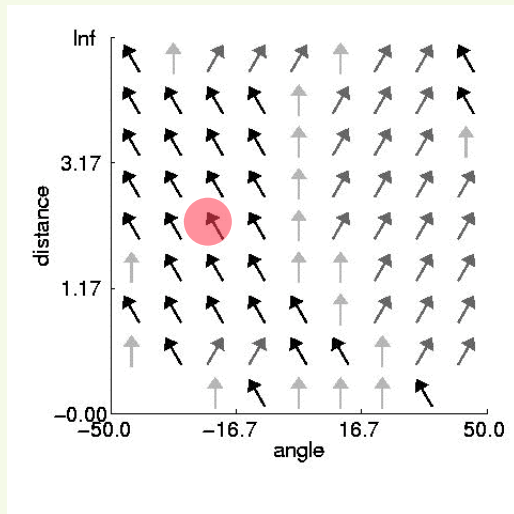
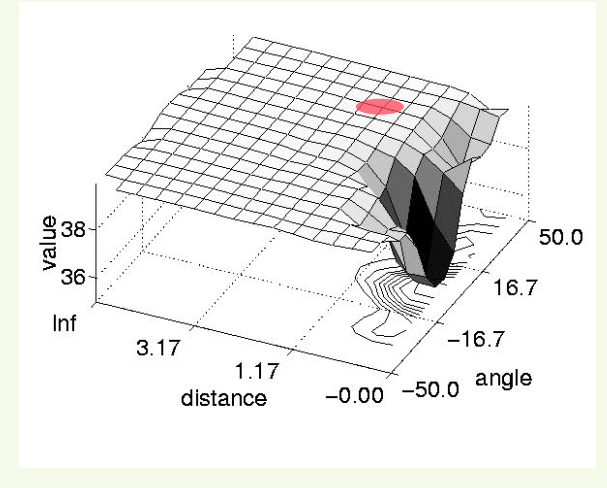
Litter

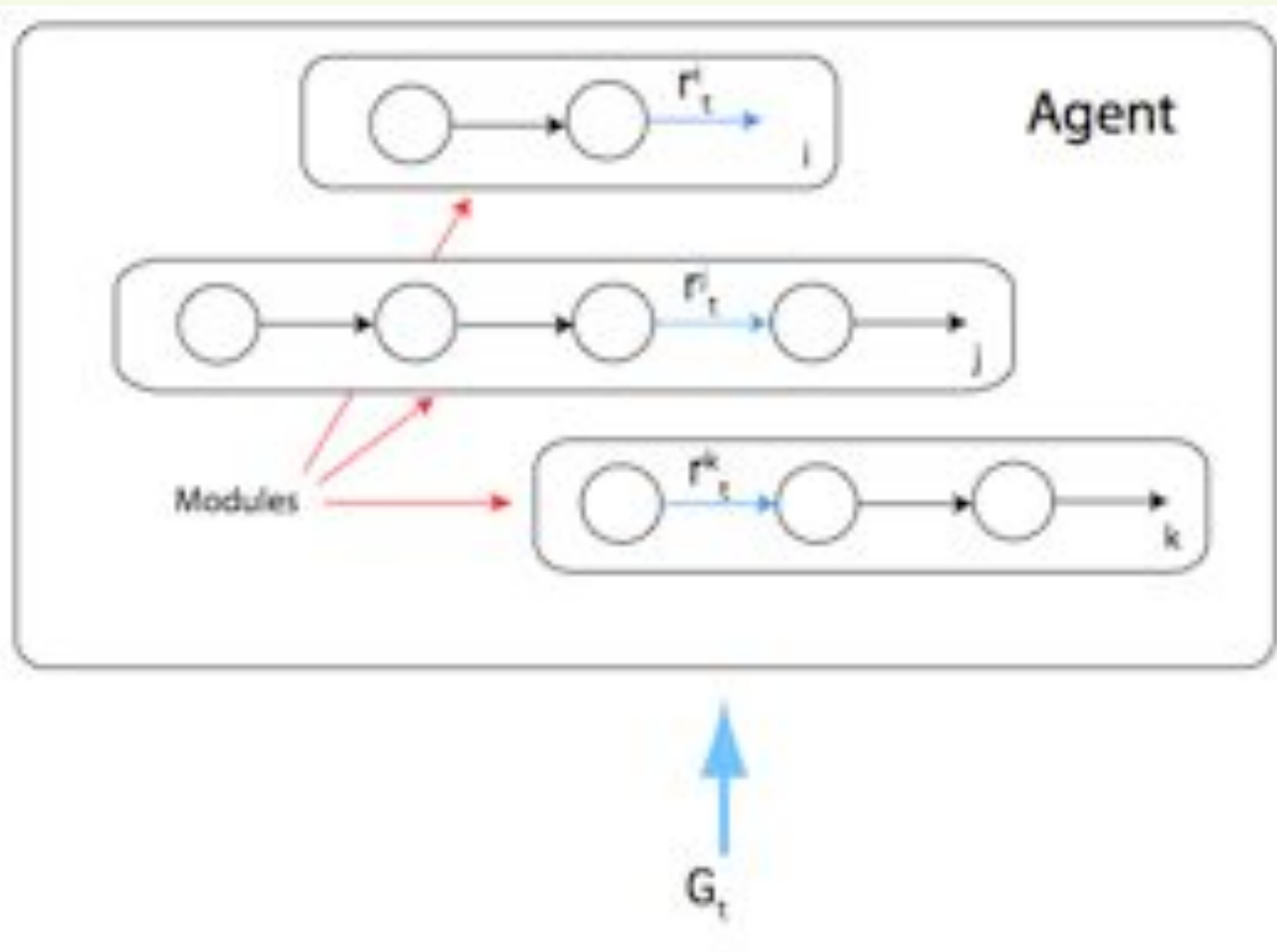


Sidewalk



Obstacles

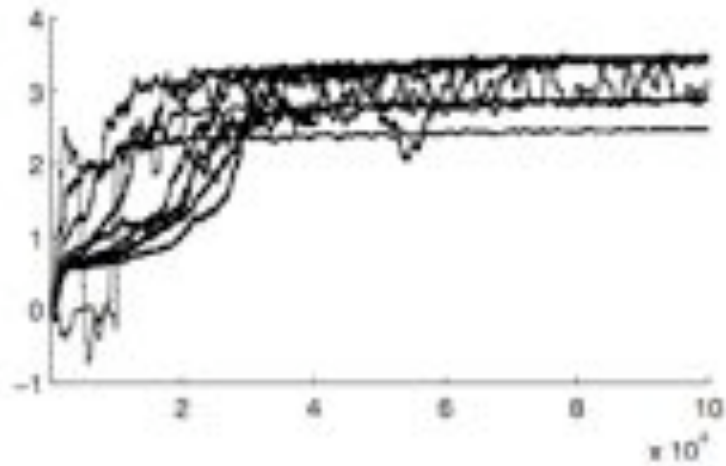




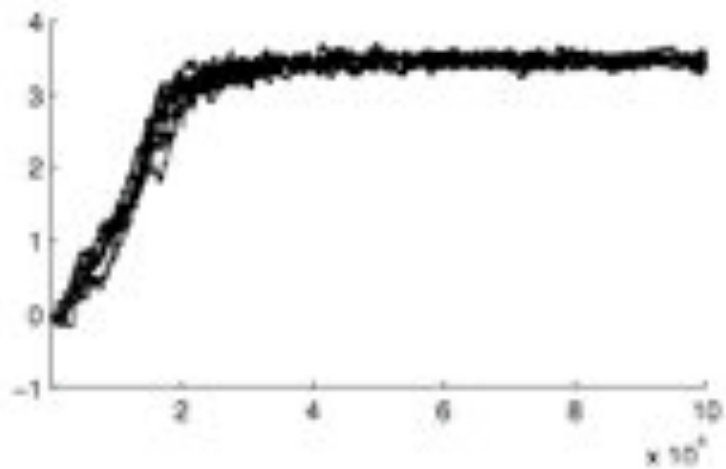
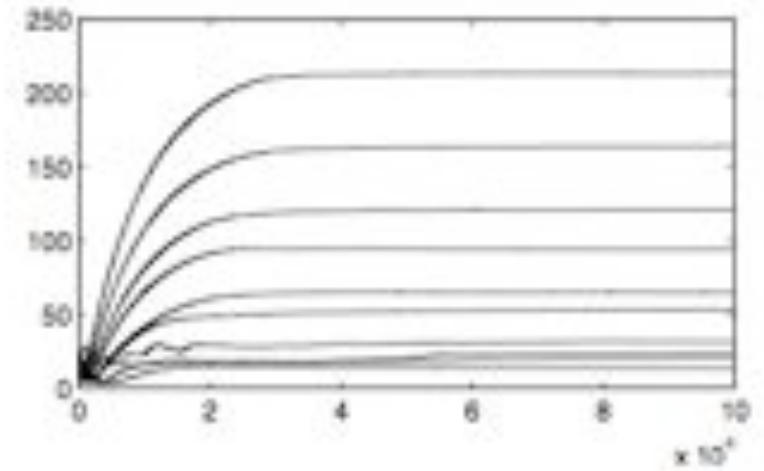
Use the reward estimates of other active processes to update your own estimate

$$\begin{aligned}\hat{r}^{(i)} &\leftarrow \hat{r}^{(i)} + \beta \left(G - \sum_j \hat{r}^{(j)} \right) \\ &= (1 - \beta) \hat{r}^{(i)} + \beta \left(G - \sum_{j \neq i} \hat{r}^{(j)} \right)\end{aligned}$$

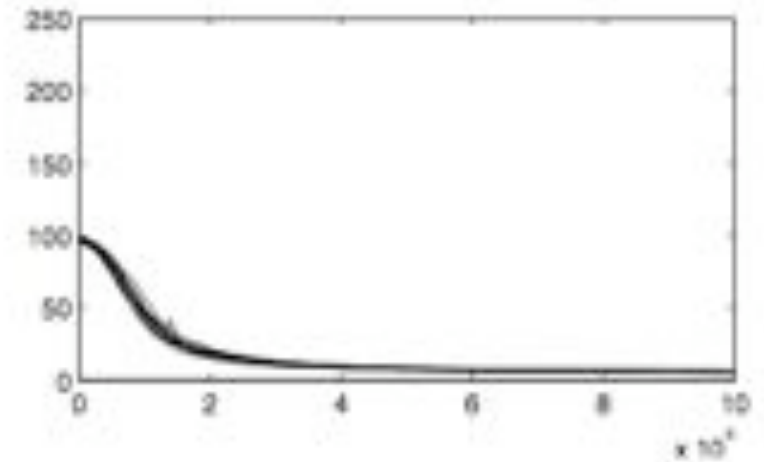
Chang et al compared to Consumable Rewards



Chang



CR



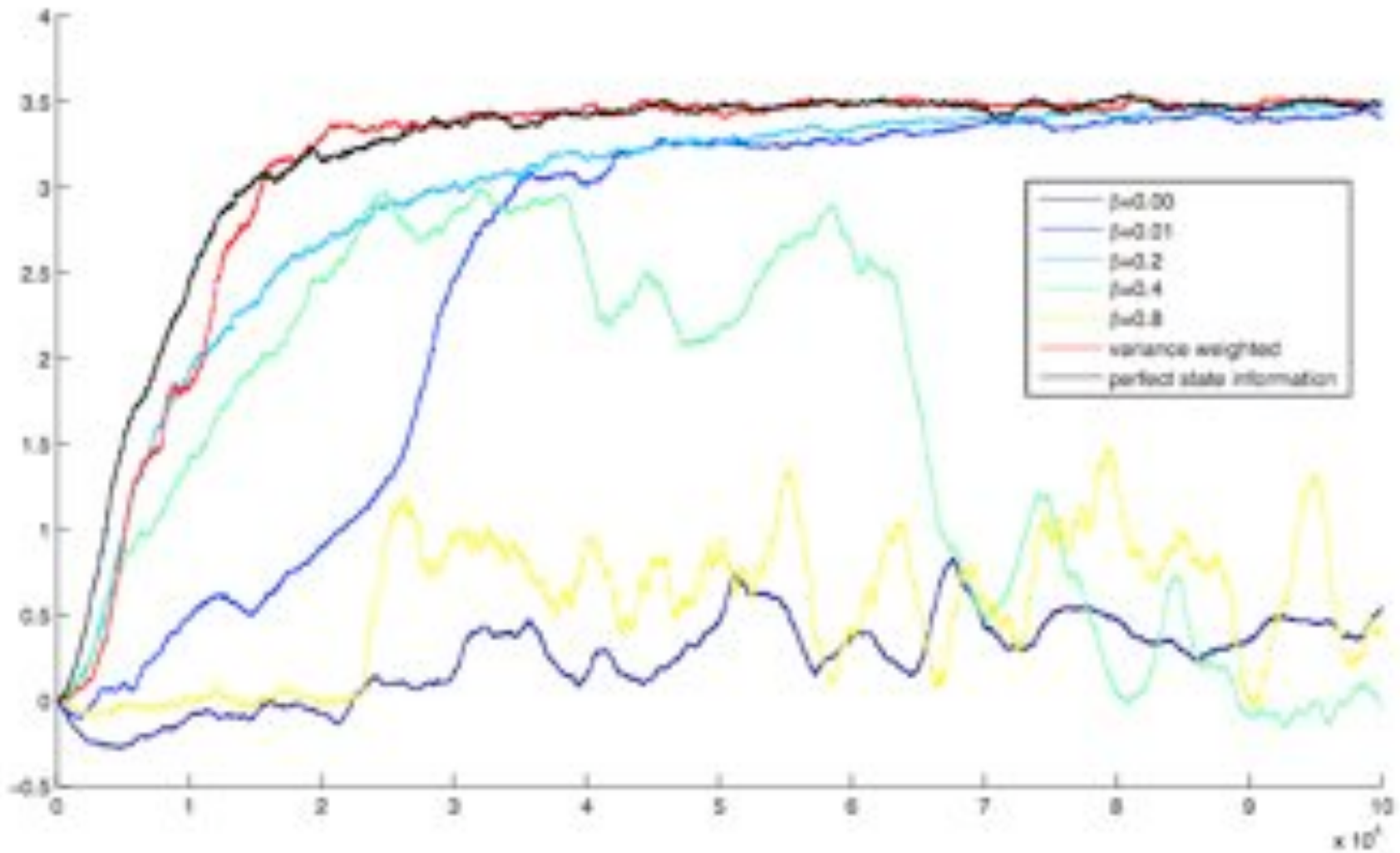
Reward

Error

Adjusting the learning rate using variance in reward

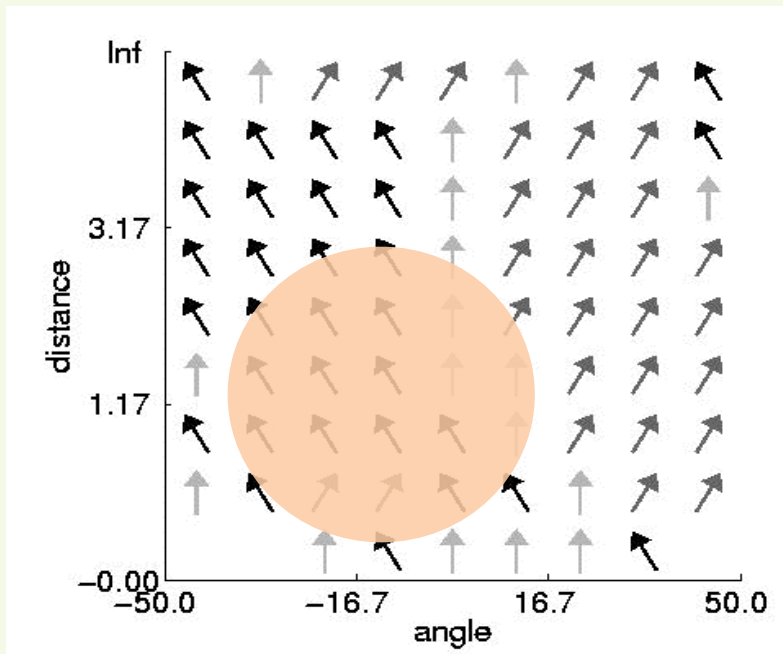
$$\begin{aligned}\beta &= \frac{(\sigma^{(i)})^2}{\sum_{j=1}^N (\sigma^{(j)})^2} \\ &= \frac{(\sigma^{(i)})^2}{\sum_{j \neq i}^N (\sigma^{(j)})^2 + (\sigma^{(i)})^2}\end{aligned}$$

Results for Barto & Sutton Problem



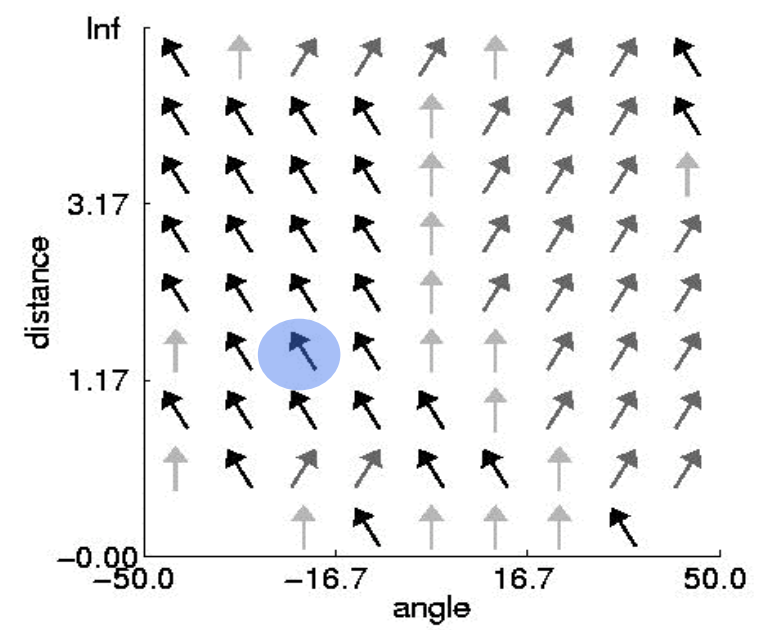
Which Microbehavior should get the gaze vector?

Before Observation

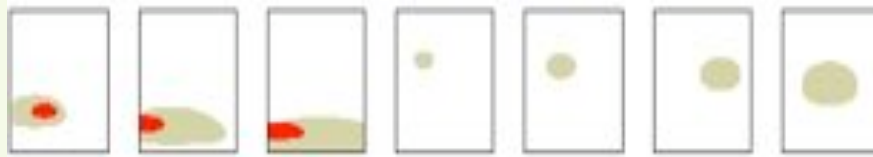


Which Microbehavior should get the gaze vector?

After Observation



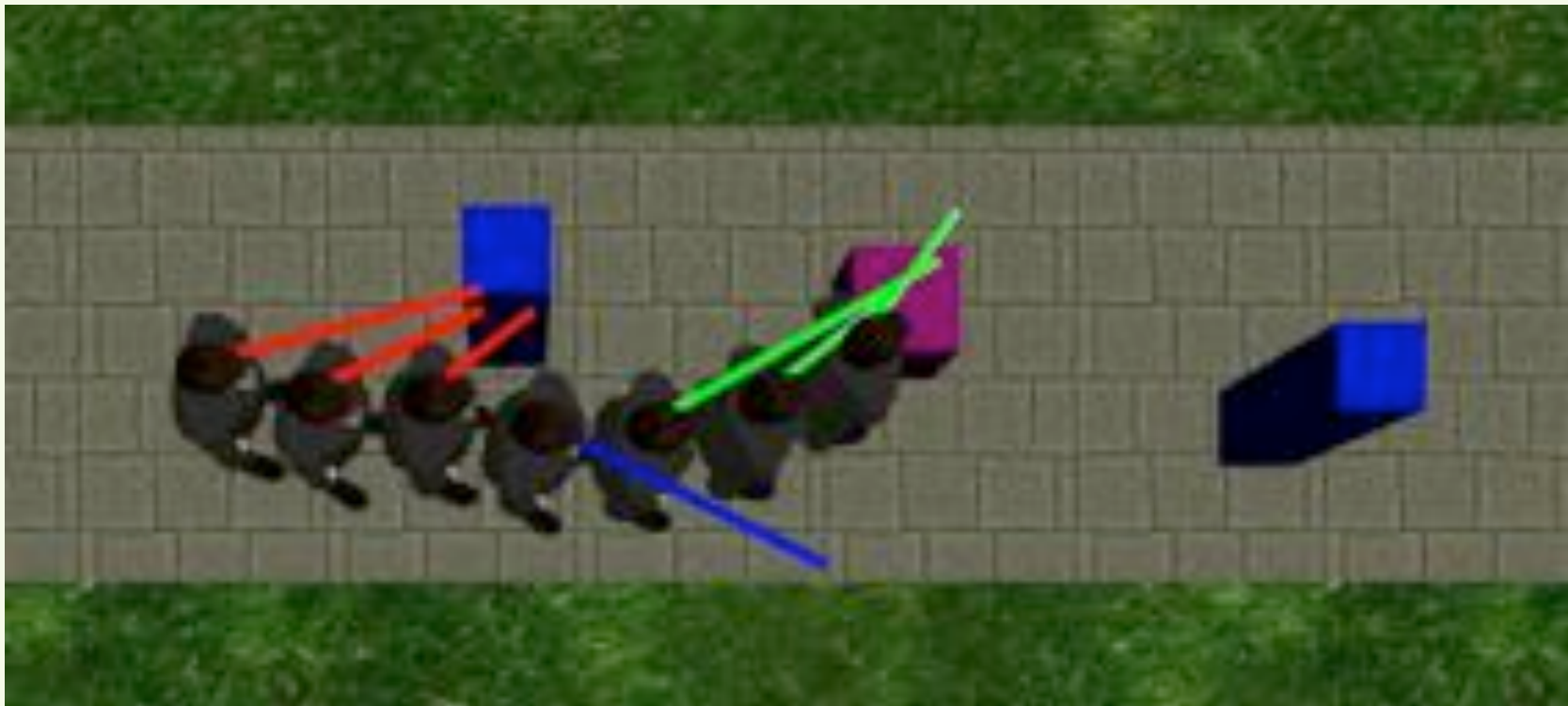
obs



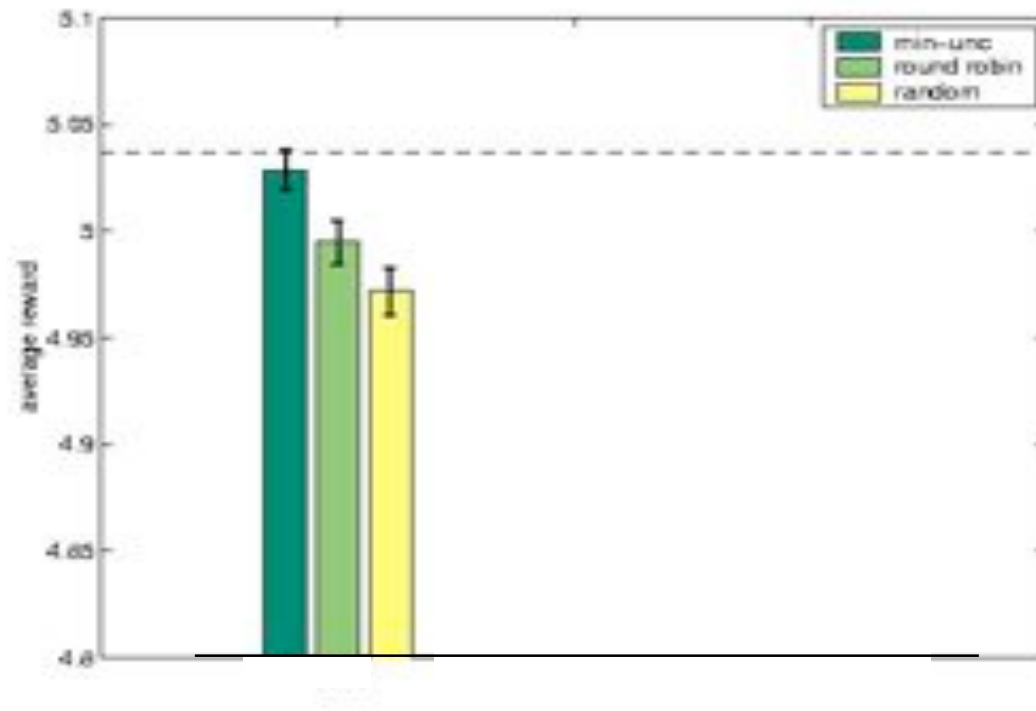
side



can



Performance Comparison



PBJ: Basic Routines

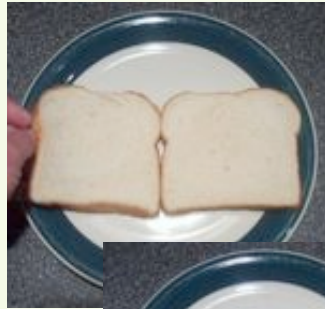
Operation	Function	Parameter(s)
SearchObject	Find an object in both views	Object characteristics
Saccade	Conjugate eye movement	Yaw, pitch and roll
Vergence	Disconjugate eye movement	Angle
ImageMatching	Test two images' similarity	Labels of remembered images
Memorize	Remember a position or an image	Label to be assigned
MoveHand	Hand movement	Current fixation point
TurnHand	Turn hand (and object in hand)	Yaw, pitch and roll
Pickup/Dropoff	Object pickup/dropoff by hand	None

Routines



```
locate bread  
remember loc_loaf  
puthand right  
pickup right  
fixate -0.1 -0.2 0.78  
remember loc_bread1  
puthand right  
turnhand right 0 0 90  
dropoff right  
turnhand right 0 0 0
```

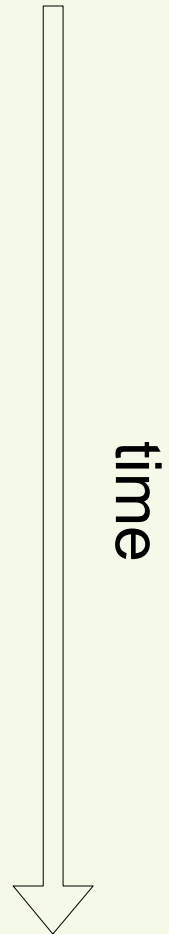
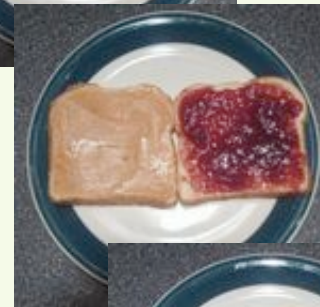
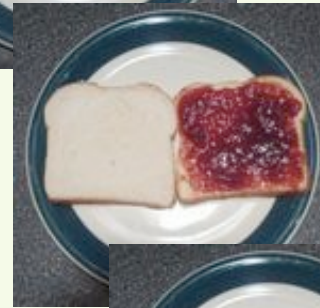
Modeling Tasks



Subject A



Subject B



Routine Segmentation

```
locate bread
remember loc_loaf
puthand right
pickup right
fixate -0.1 -0.2 0.78
remember loc_bread1
puthand right
turnhand right 0 0 90
dropoff right
turnhand right 0 0 0
fixate loc_loaf
puthand right
pickup right
fixate 0.1 -0.2 0.78
remember loc_bread2
puthand right
turnhand right 0 0 90
dropoff right
turnhand right 0 0 0
locate jar-lid
remember loc_jarlid
puthand right
pickup right
fixate -0.40 -0.2 0.65
remember loc_jarlid_on_table
puthand right
dropoff right
locate pbild
remember loc_bottlelid
puthand right
pickup right
fixate -0.3 -0.2 0.65
loc_bottlelid_on_table
puthand right
dropoff right
locate khandle
remember loc_knife
puthand right
pickup right
locate pbottle
remember loc_bottle
puthand right
fixate -0.1 -0.2 0.78
puthand right
loc_bottle
fixate -0.1 -0.2 0.78
puthand right
locate jar
remember loc_jar
puthand right
fixate 0.1 -0.2 0.78
puthand right
fixate loc_knife
puthand right
dropoff right
locate jar
fixate loc_bread1
puthand right
pickup right
turnhand right 0 0 -90
fixate loc_bread2
puthand right
dropoff right
fixate loc_knife
puthand right
dropoff right
locate jar
fixate loc_jarlid_on_table
puthand right
pickup right
fixate loc_bottlelid
puthand right
dropoff right
fixate loc_jarlid_on_table
puthand right
pickup right
fixate loc_bottlelid
puthand right
dropoff right
fixate loc_jarlid
puthand right
dropoff right
fixate loc_bottlelid
puthand right
dropoff right
```



Routine Segmentation

```

locate bread
remember loc_loaf
puthand right
pickup right
fixate -0.1 -0.2 0.78
remember loc_bread1
puthand right
turnhand right 0 0 90
dropoff right
turnhand right 0 0 0
fixate loc_loaf
puthand right
pickup right
fixate 0.1 -0.2 0.78
remember loc_bread2
puthand right
turnhand right 0 0 90
dropoff right
turnhand right 0 0 0
locate jar-lid
remember loc_jarlid
puthand right
pickup right
fixate -0.40 -0.2 0.65
remember loc_jarlid_on_table
puthand right
dropoff right
locate pblid
remember loc_bottlelid
puthand right
pickup right
fixate -0.3 -0.2 0.65
loc_bottlelid_on_table
puthand right
dropoff right
locate khandle
remember loc_knife
puthand right
pickup right
locate jar
remember loc_jar
puthand right
fixate -0.1 -0.2 0.78
puthand right
loc_bottle
fixate -0.1 -0.2 0.78
puthand right
loc_bottle
fixate -0.1 -0.2 0.78
puthand right
locate jar
remember loc_jar
puthand right
fixate 0.1 -0.2 0.78
puthand right
fixate loc_knife
puthand right
dropoff right
locate jar
fixate loc_bread1
puthand right
turnhand right 0 0 -90
fixate loc_bread2
puthand right
dropoff right
fixate loc_bottlelid_on_table
puthand right
pickup right
fixate loc_bottlelid
puthand right
dropoff right
fixate loc_jarlid_on_table
puthand right
pickup right
fixate loc_jarlid
puthand right
dropoff right
fixate loc_bottlelid
puthand right
dropoff right

```



```

puthand right
dropoff right
locate pblid
remember loc_bottlelid
puthand right
pickup right
fixate -0.3 -0.2 0.65
remember loc_bottlelid_on_table
puthand right
dropoff right
locate khandle
remember loc_knife
puthand right
pickup right
locate pbbottle

```

```

puthand right
dropoff right
locate khandle
remember loc_knife
puthand right
pickup right
locate jar
remember loc_jar
puthand right
fixate 0.1 -0.2 0.78
puthand right
locate pblid
remember loc_bottlelid
puthand right
pickup right

```


Routine Segmentation

```

locate bread
remember loc_loaf
puthand right
pickup right
fixate -0.1 -0.2 0.78
remember loc_bread1
puthand right
turnhand right 0 0 90
dropoff right
turnhand right 0 0 0
fixate loc_loaf
puthand right
pickup right
fixate 0.1 -0.2 0.78
remember loc_bread2
puthand right
turnhand right 0 0 90
dropoff right
turnhand right 0 0 0
locate jar-lid
remember loc_jarlid
puthand right
pickup right
fixate -0.40 -0.2 0.65
remember loc_jarlid_on_table
puthand right
dropoff right
locate pblid
remember loc_bottlelid
puthand right
pickup right
fixate -0.3 -0.2 0.65
loc_bottlelid_on_table
puthand right
dropoff right
locate khandle
remember loc_knife
puthand right
pickup right
locate jar
remember loc_jar
puthand right
fixate -0.1 -0.2 0.78
puthand right
puthand right loc_bottle
fixate -0.1 -0.2 0.78
puthand right
locate jar
fixate loc_bread1
puthand right
dropoff right
turnhand right 0 0 -90
fixate loc_bread2
puthand right
dropoff right
fixate loc_bottlelid_on_table
puthand right
pickup right
fixate loc_bottlelid
puthand right
dropoff right
fixate loc_jarlid_on_table
puthand right
pickup right
fixate loc_jarlid
puthand right
dropoff right
fixate loc_bottlelid_on_table
puthand right
pickup right
fixate loc_bottlelid
puthand right
dropoff right

```



```

puthand right
dropoff right
locate pblid
remember loc_bottlelid
puthand right
pickup right
fixate -0.3 -0.2 0.65
remember loc_bottlelid_on_table
puthand right
dropoff right
locate khandle
remember loc_knife
puthand right
pickup right
locate jar
remember loc_jar
puthand right
fixate 0.1 -0.2 0.78
remember loc_jar
puthand right
dropoff right
locate pblid
remember loc_bottlelid
puthand right
pickup right
fixate -0.3 -0.2 0.65
loc_bottlelid_on_table
puthand right
dropoff right
locate pbbottle
remember loc_bottle
puthand right
fixate -0.1 -0.2 0.78
puthand right
puthand right loc_bottle
fixate -0.1 -0.2 0.78
puthand right
turnhand right 0 0 -90
fixate loc_bread2
puthand right
dropoff right
fixate loc_knife
puthand right
dropoff right
fixate loc_jarlid_on_table
puthand right
pickup right
fixate loc_jarlid
puthand right
dropoff right
fixate loc_bottlelid_on_table
puthand right
pickup right
fixate loc_bottlelid
puthand right
dropoff right

```

```

puthand right
dropoff right
locate khandle
remember loc_knife
puthand right
pickup right
locate jar
remember loc_jar
puthand right
fixate 0.1 -0.2 0.78
puthand right
locate pblid
remember loc_bottlelid
puthand right
pickup right

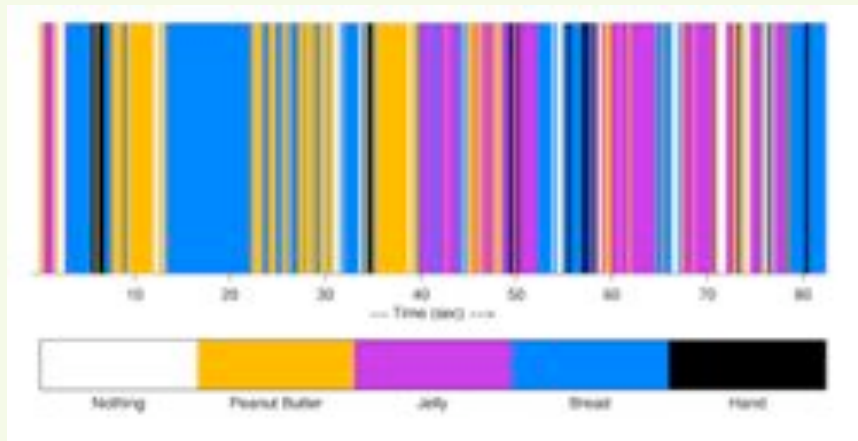
```


Subtask Recognition

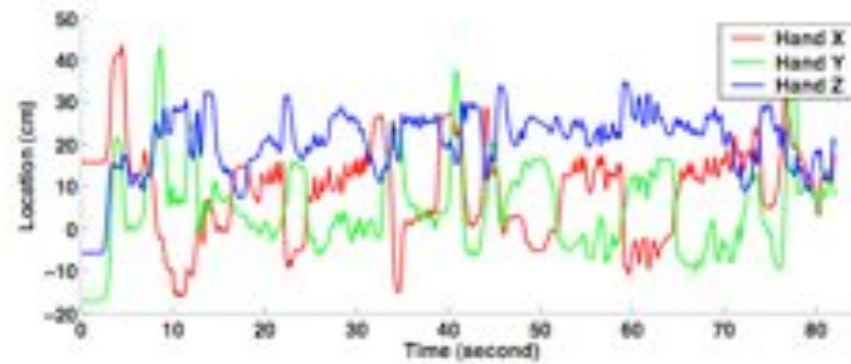
BreadOnTable	putting bread on table
PeanutButterLidOff	taking peanut butter lid off
JellyLidOff	taking jelly lid off
KnifeInHand	grabbing knife in hand
PeanutbutterOnBread	spreading peanut butter on bread
JellyOnBread	spreading jelly on bread
PeanutButterLidOn	putting peanut butter lid back on
JellyLidOn	putting jelly lid back on
KnifeOnTable	putting knife on table
FlipBread	flipping bread to make an sandwich

Task Planning

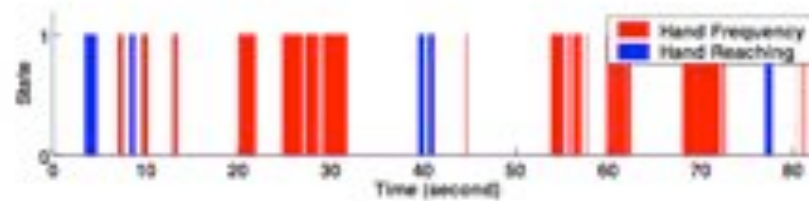
	1	2	3	4	5	6	7	8	9	10
BT	abc									
PLF		a	c		b					
JLF		bc				a				
KH			ab	c						
POB				a	c	b				
JOB				b		c	a			
PLO					a				b	c
JLO									c	ab
KT							c	ab		
FB							b	c	a	



Eye

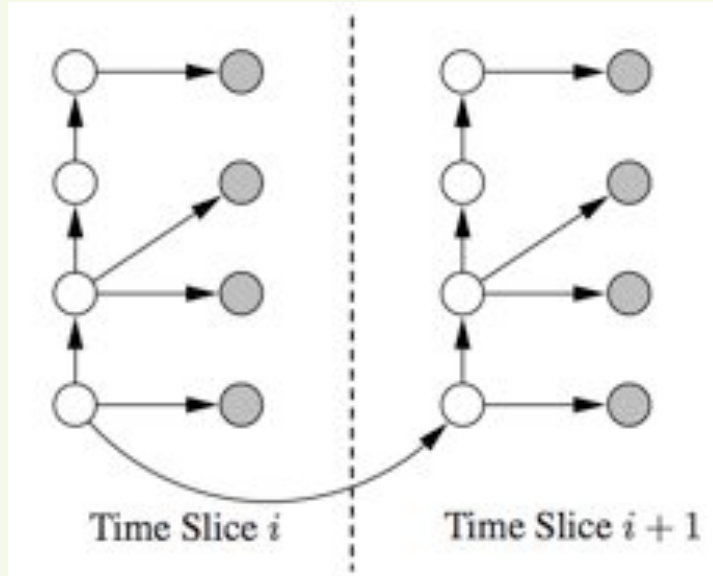
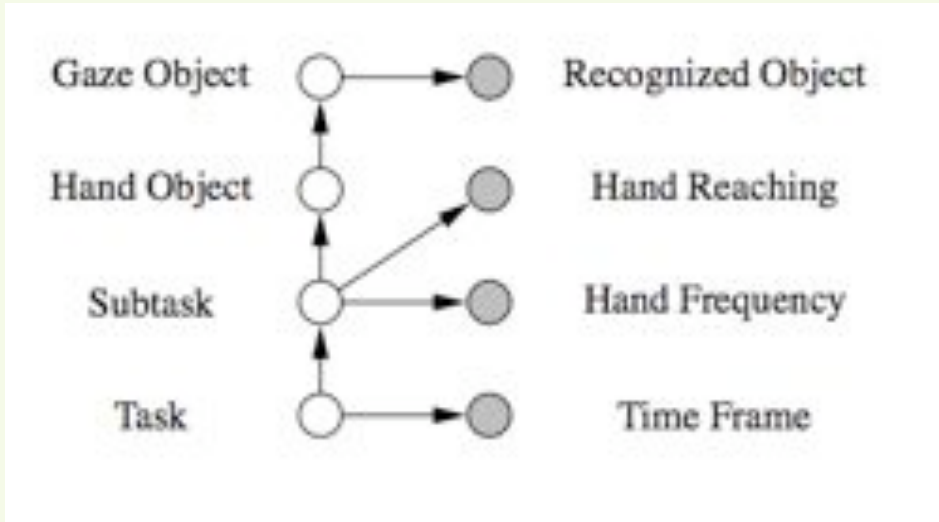


(a) Raw hand location data



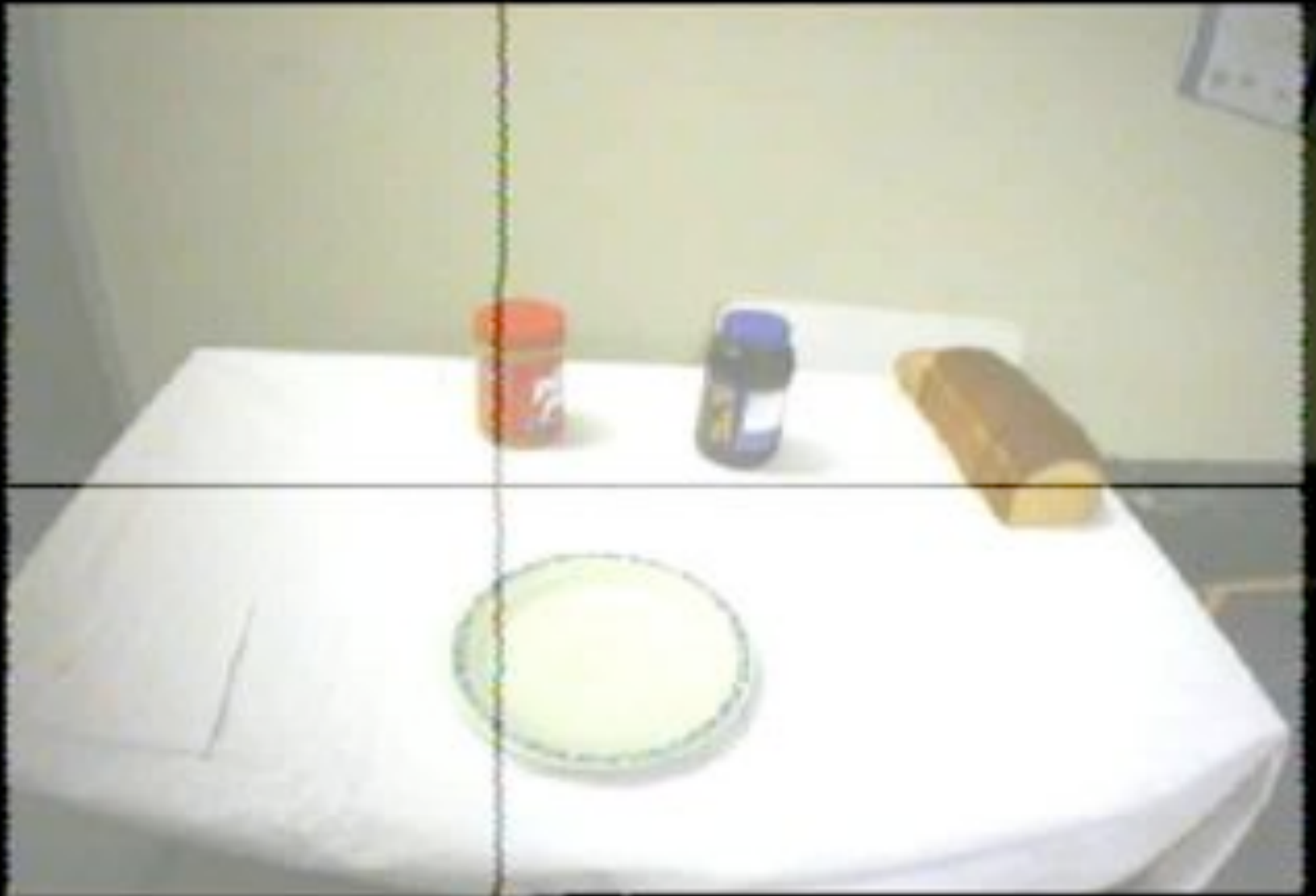
(b) Observed hand movement

Hand



Task: $(\emptyset, \{t_1\}) \xrightarrow{p} (\{t_1\}, \{t_1, t_2\}) \xrightarrow{q} (\{t_1, t_2\}, \{t_1, t_2, t_4\})$

Node Name	# of States	Node Name	# of States
task	80	time frame	20
subtask	10	hand frequency	2
hand object	4	hand reaching	2
gaze object	5	recognized object	5



The laboratory at UT Austin

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Rahul Iyer
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Jonathan Shaw

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Mary Hayhoe
Kelly Chajka

Brian Sullivan
Jelena Jovancevic

Pili Aivar
Jochen Triesch*
Neil Mennie
Jason Droll

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