Affordances and Robots
(The prescriptive way)

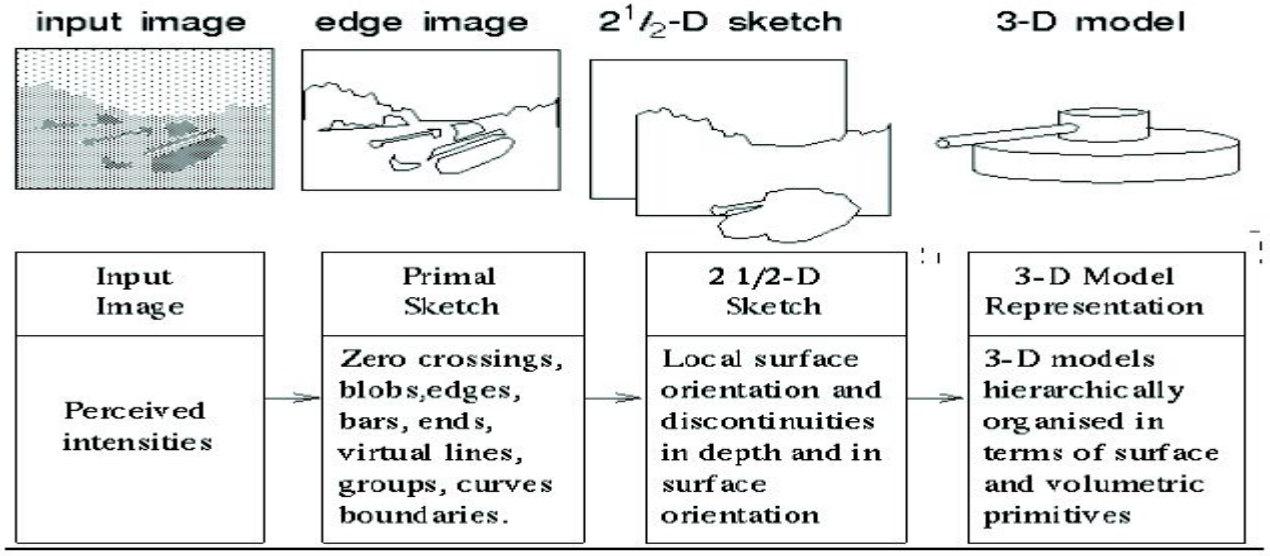
- Affordances from Ecological Psychology
- Affordances in Robotics

Readings

- Sahin, E., Cakmak, M., Dogar, M. R., Ugur, E., and Ucoluk, G. (2007). To afford or not to afford: A new formalization of affordances toward affordance-based robot control. Adaptive Behavior, 15(4), 447-472.
- Jamone, L., Ugur, E., Cangelosi, A., Fadiga, L., Bernardino, A., Piater, J. and Santos-Victor, J., 2016. Affordances in psychology, neuroscience and robotics: a survey. IEEE Transactions on Cognitive and Developmental Systems.

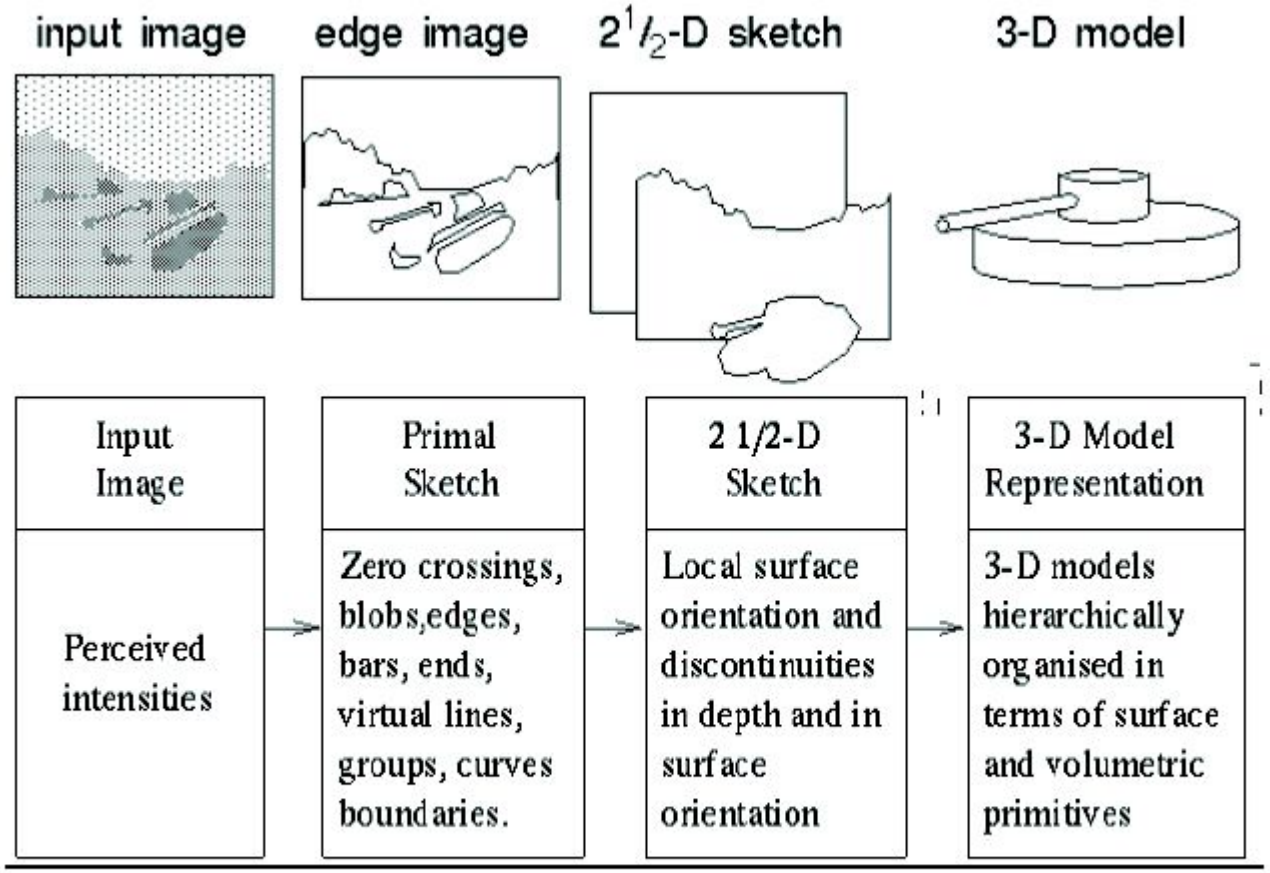
Traditional approach to visual perception in 70's

- Starting point of perception is the static pattern of light intensity on the retina
- Perception is indirect and mediated by other processes
- The outcome of the perception is the formation of an internal representation of objects in the environment



Stages of Visual Representation, David Marr, 1970s

Traditional approach to visual perception in 70's



Stages of Visual Representation, David Marr, 1970s

Traditional approach to visual perception in 70's

- In order to grasp a mug
  - Reconstruct the 3D model of the object from the retinal image
  - Recognize the object as a mug
  - Infer that the object is graspable thanks to the internal representations

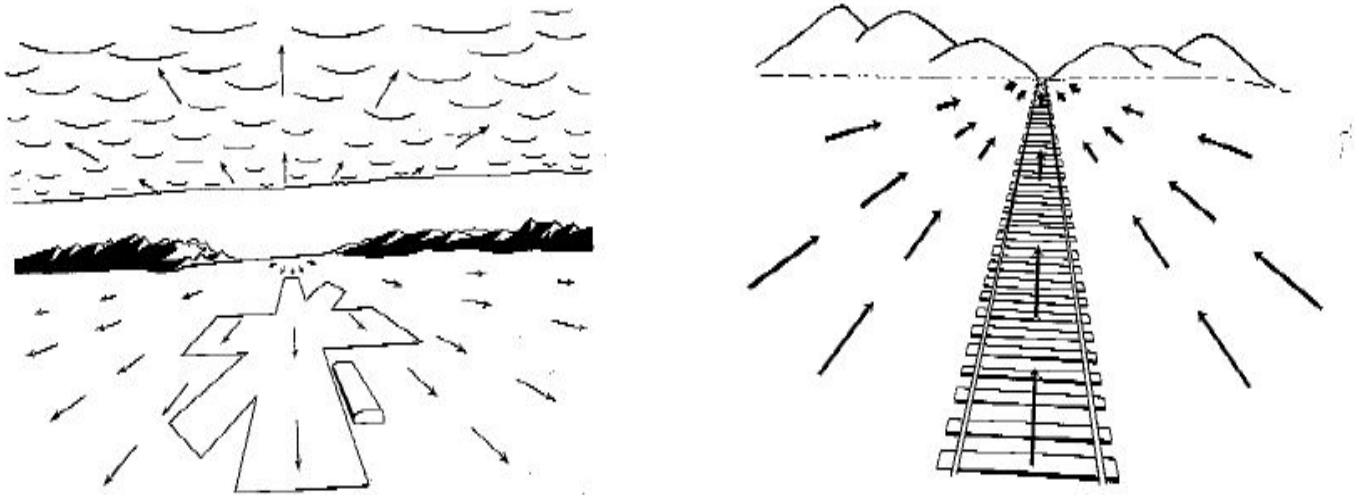
A radical approach

Each thing says what it is … a fruit says “Eat me”; water says “Drink me”; thunder says “Fear me”; and woman says “Love me”. (Koffka, 1935)

- Mug says “grasp me”

Optical variables/invariants

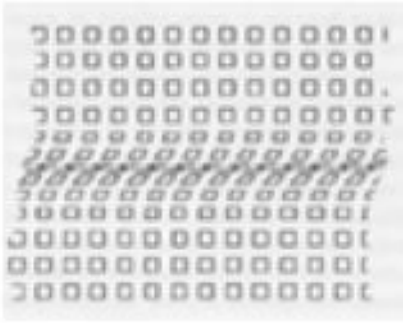
- **James Gibson**, During World War II, U.S. Army Air Force's Aviation Psychology Program.
- Visual aptitude tests for screening out pilot applicants
  - Tests in static images, e.g. depth perception
  - Perception of properties related to flying and landing
- Optical variables in the perceptual data that are meaningful.
- The optical center of expansion of the pilot's visual field. This center of expansion, indicates the direction of the glide and helping him to adjust landing behavior.



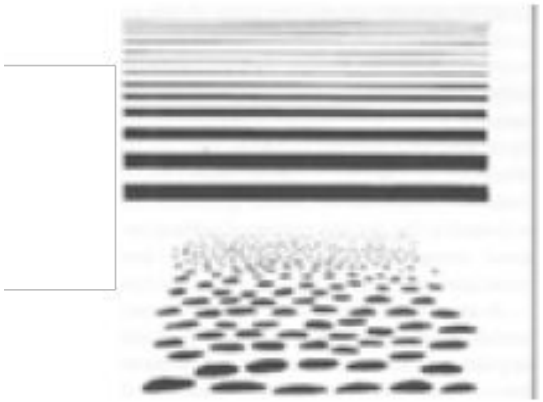
Transformational invariants

Optical variables/invariants

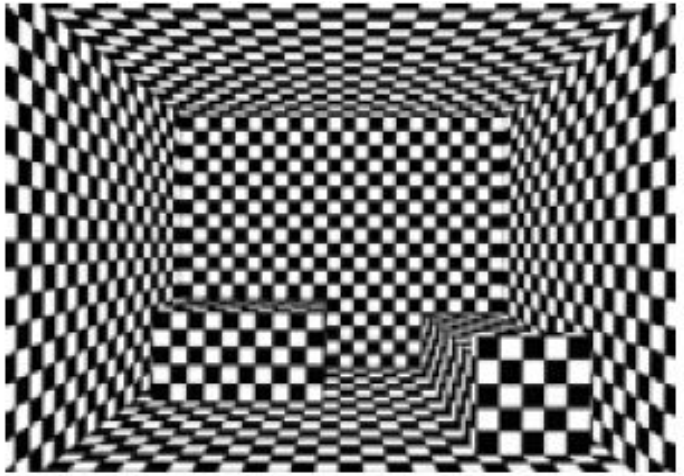
- Structured light carries information
  - e.g. light structured by texture



about shape



information about distance

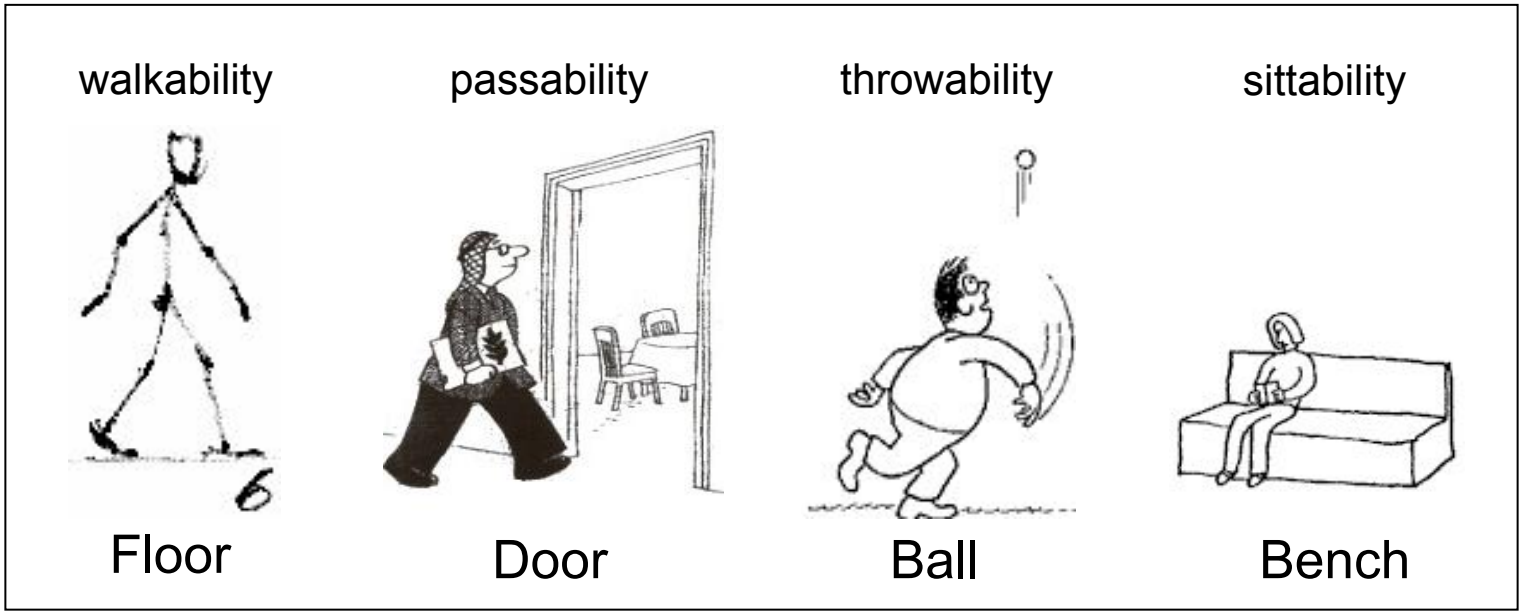


and general layout of objects in the environment

What is an affordance?

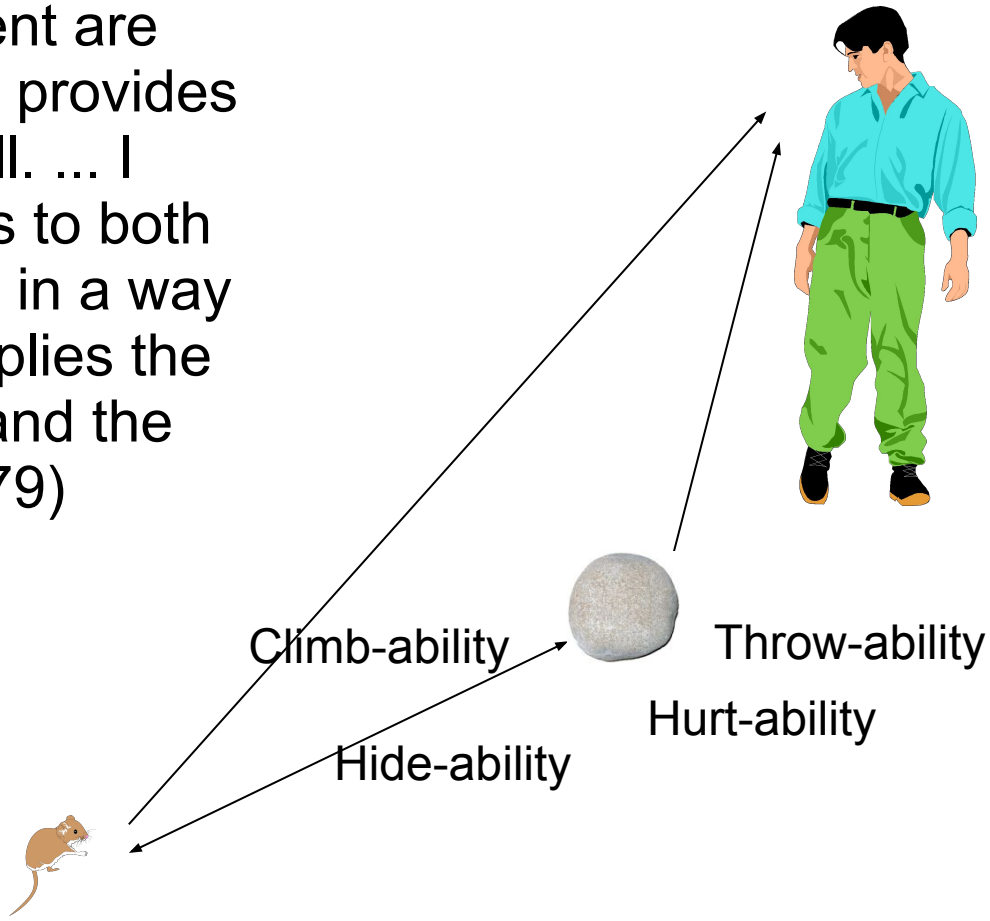
J.J. Gibson (1904–1979)

- "Affordances are action possibilities that the environment offers to an animal interacting with it"
- The organisms do not need to recognize the objects in order to act on them.
  - Direct perception.

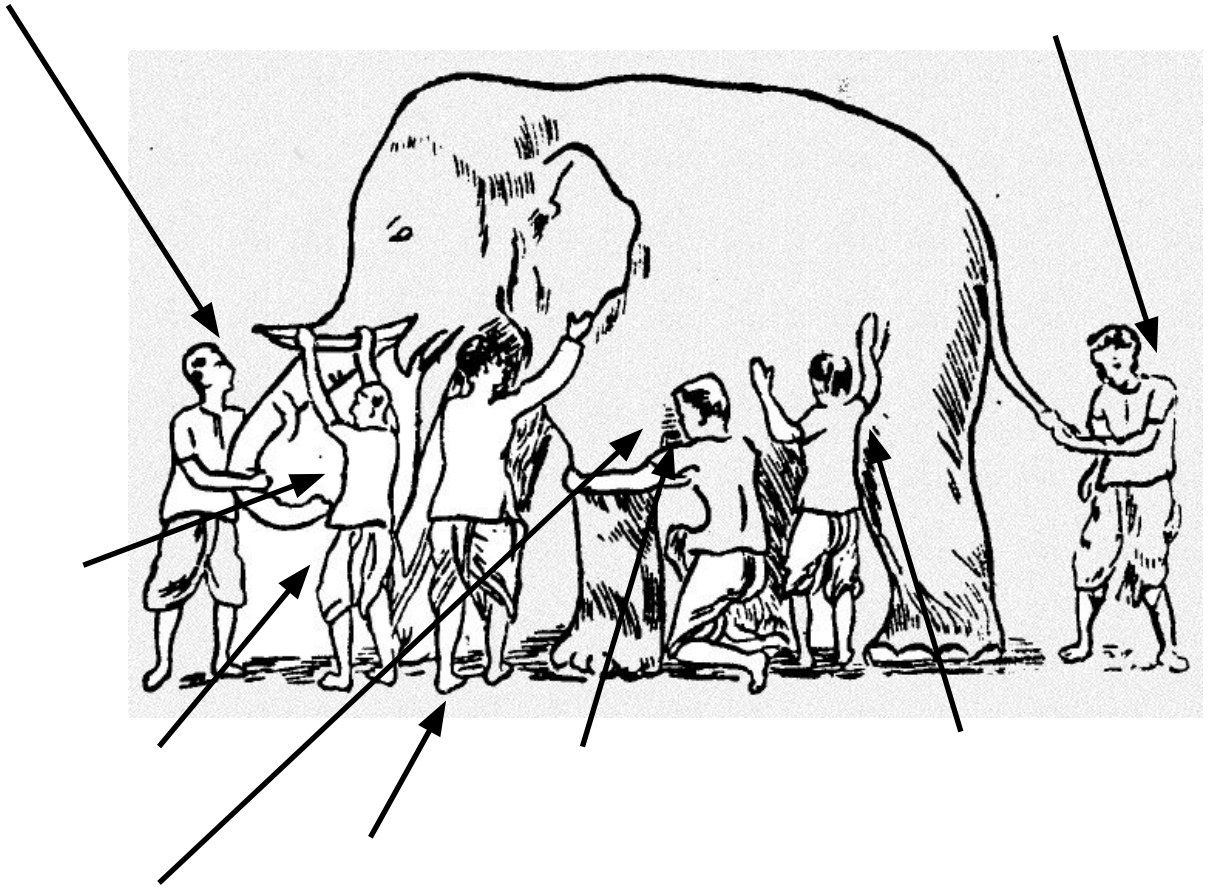


Affordances are defined in animal-environment system

"The affordances of the environment are what it offers the animal, what it provides or furnishes, either for good or ill. ... I mean by it something that refers to both the environment and the animal in a way that no existing term does. It implies the complementarity of the animal and the environment." (J. J. Gibson, 1979)



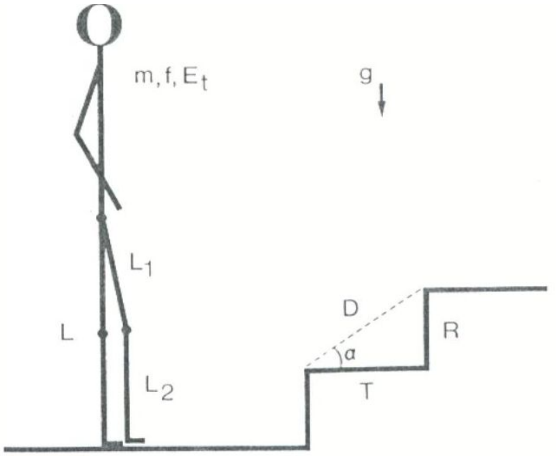
Affordances as an elephant

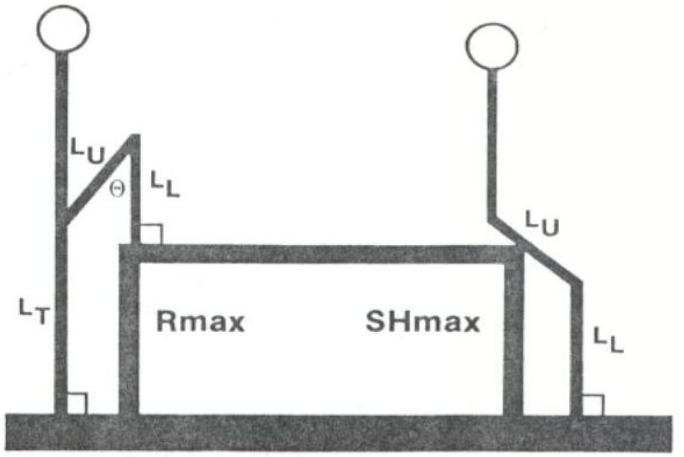


- expressed in verbose descriptions.
- evolved over time
- in contrast to the background of contemporary ideas.
- were often blended with his work on visual perception

Experiments in Ecological Psychology

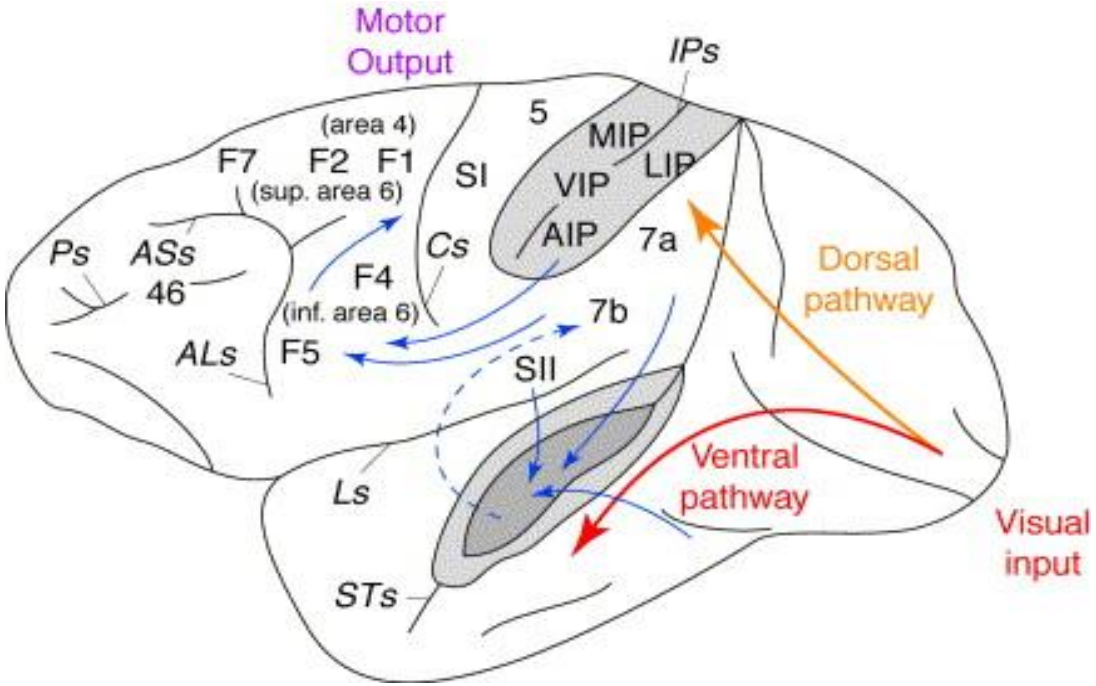
- Affordance ratios
- Warren's (1984) stair-climbing experiments
  - Claims that affordances are perceived in terms of intrinsic or body-scaled metrics
  - Identified critical points and optimal points which are perceivable, constant dimensionless ratios, called pi
- Intrinsic nature of affordance perception: eyeheight
  - Walking through aperture (Warren and Whang; 1987)
  - Sitting and climbing to various surfaces (Mark;1987)





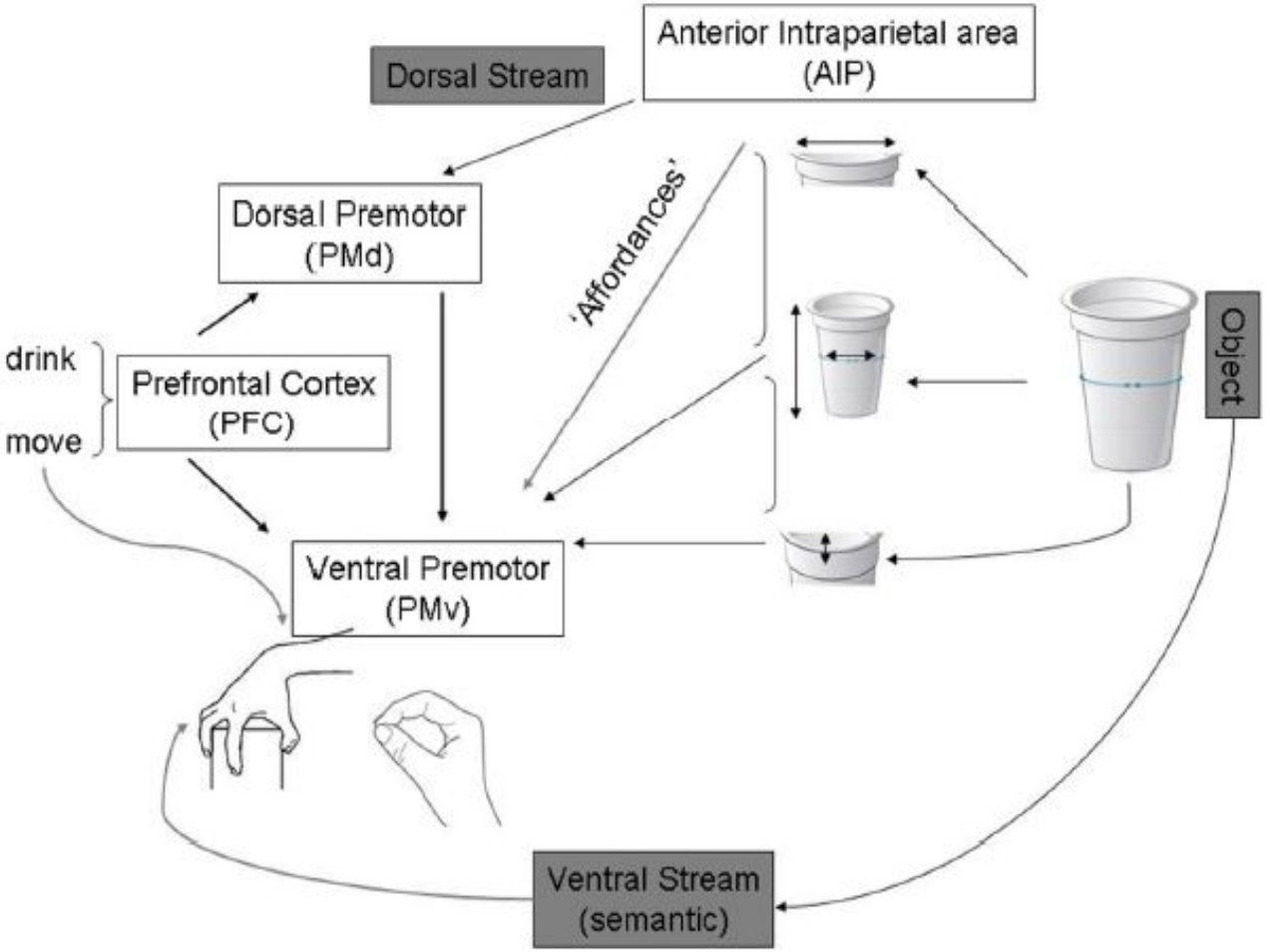
Evidence from Neurophsiology

- Dorsal system for information pickup -- AFFORDANCE
- Ventral system for high-level tasks like identification.
- The patient without a ventral system is able to successfully avoid from the obstacles or insert mails into slots in correct orientation.
- However the same patient does not recognize those objects.



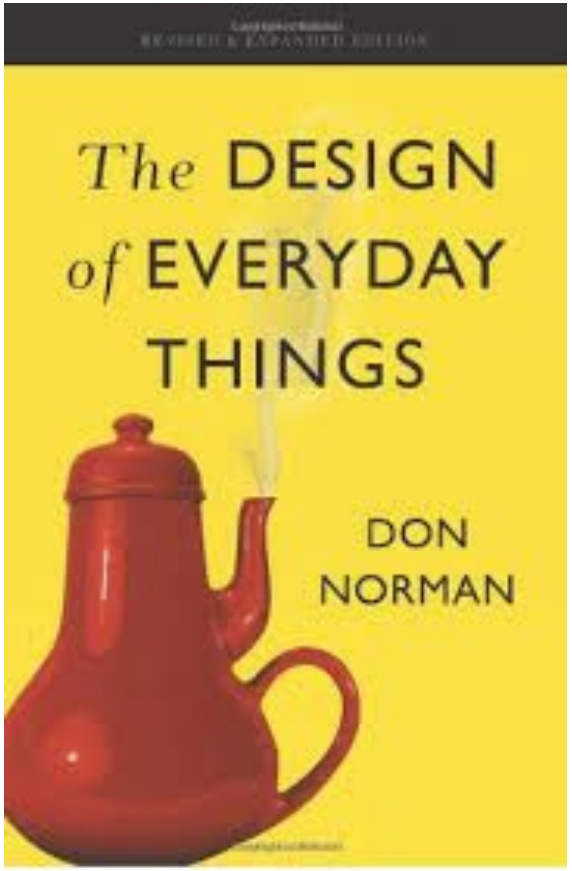
Evidence from Neurophsiology

- A computational model



Affordances in Human Computer Interaction

- Plates (on doors) are for *pushing*.
- Knobs are for *turning*.
- Slots are for *inserting* things into.
- Balls are for *throwing* or *bouncing*.
- “When affordances are taken advantage of, the user knows what to do just by looking; no picture, label, or instruction needed.”



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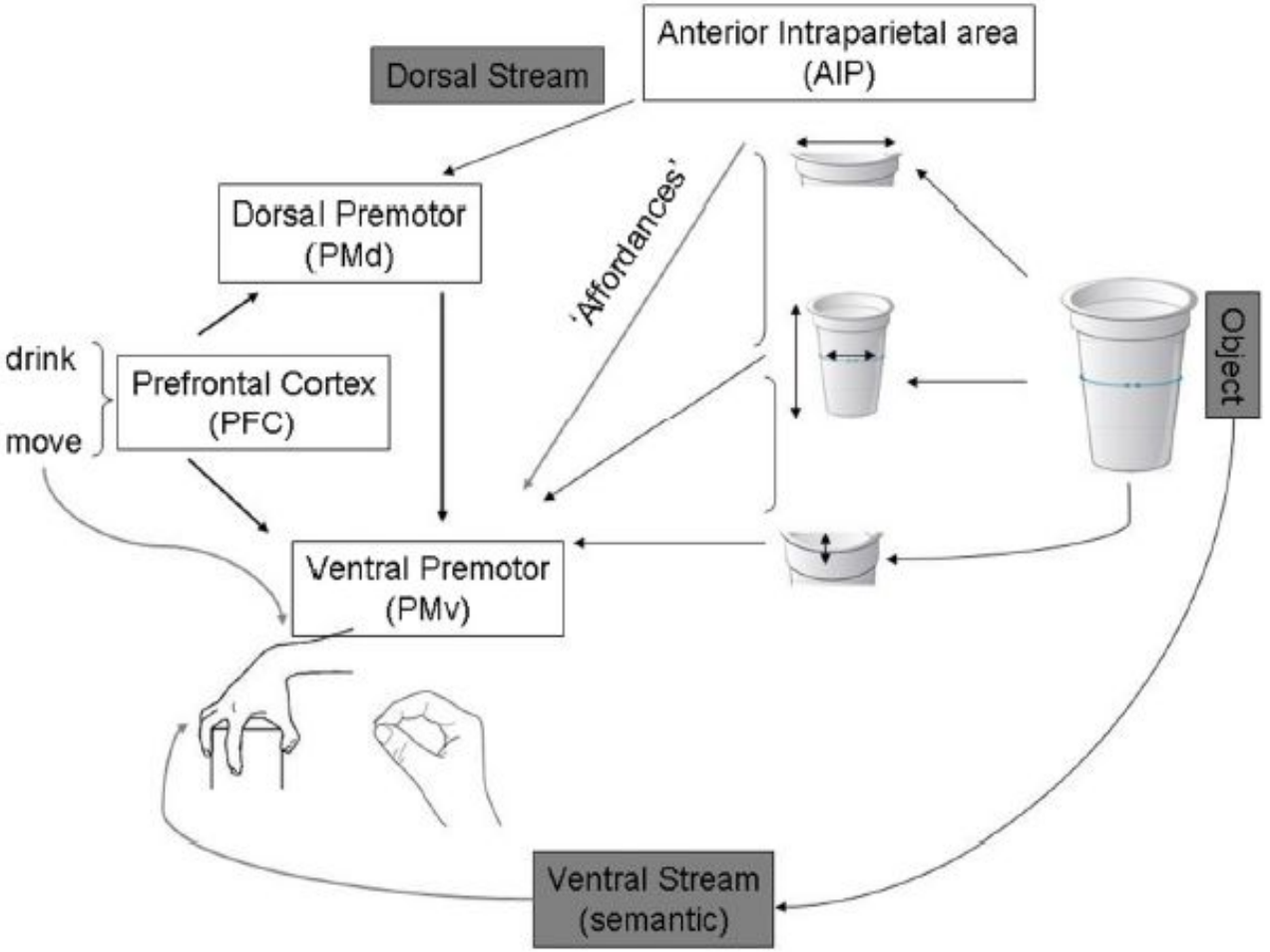


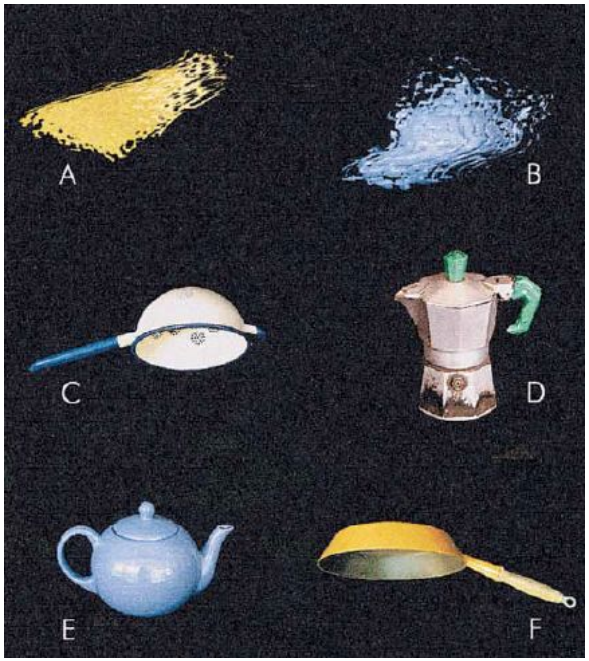
PERGAMON

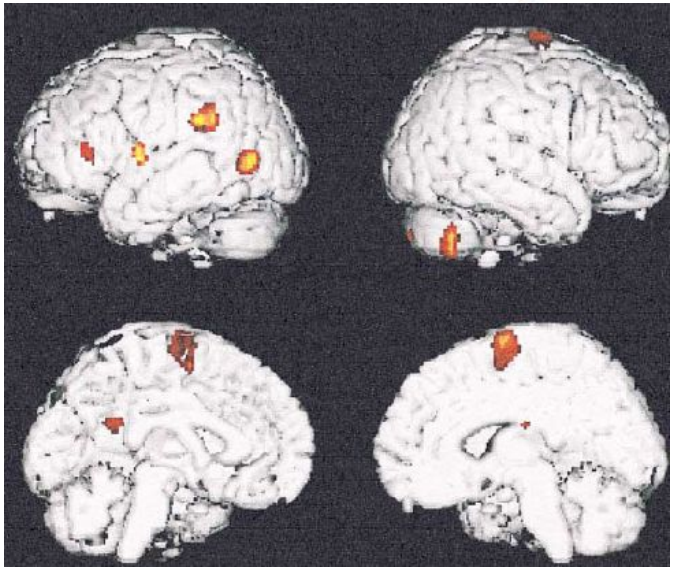
Neuropsychologia 40 (2002) 212–222

www.elsevier.com/locate/neuropsychologia

Does visual perception of object afford action? Evidence from a neuroimaging study

J. Grèzes [a], J. Decety [a,b,*]

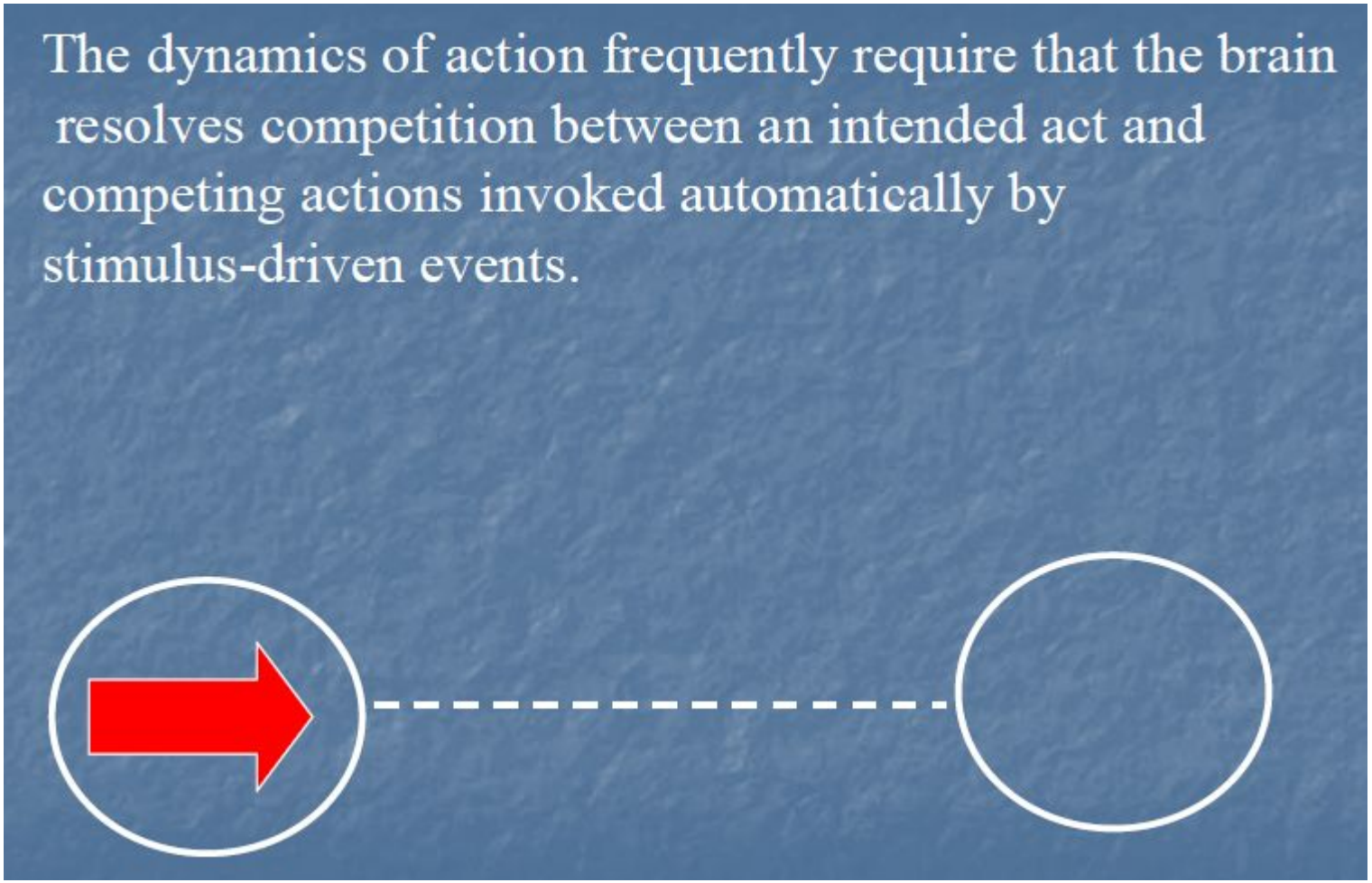




- PET
- tasks: judge orientation, motor imaginary, verbalize
- parietal and premotor activati
- The lack of involvement of the ventral stream

- Upright–inverted cond., a graspable tool, keyboard response, left or right hand depending on orientation
- motor imagery cond, imagine grasping and using obj, click left/right depending on horizontal orientation
- silent object naming task, silently name each object, then to make a keyboard response with the left or the right

Alignment paradigm



http://thesciencenetwork.org/media/videos/335/Powerpoint.pdf

Alignment paradigm

Objects with handles form an interesting subclass of manipulable artifacts because actions may be automatically invoked on one or the other side of the body, depending on the position of the handle.

But if we wish, we can apply a left-handed grasp to the beer mug, despite the habitual action invoked by the handle on the right.

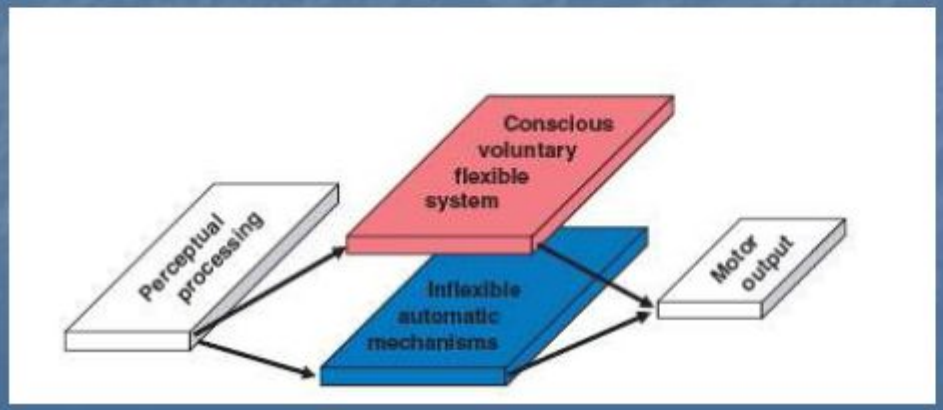
http://thesciencenetwork.org/media/videos/335/Powerpoint.pdf

Under what task conditions are motor affordances automatically evoked?

Possibility 1 (*See* $\rightarrow Act_{automatic}$): Perception of a manipulable object automatically triggers motor-based representations which then compete with the intentions of the observer.

Possibility 2 (*Motor Intention* $\rightarrow$ *See* $\rightarrow Act_{automatic}$): Objects do not inevitably afford actions during perception.

Rather, motor intentions play a crucial role in determining whether perception generates habitual actions.



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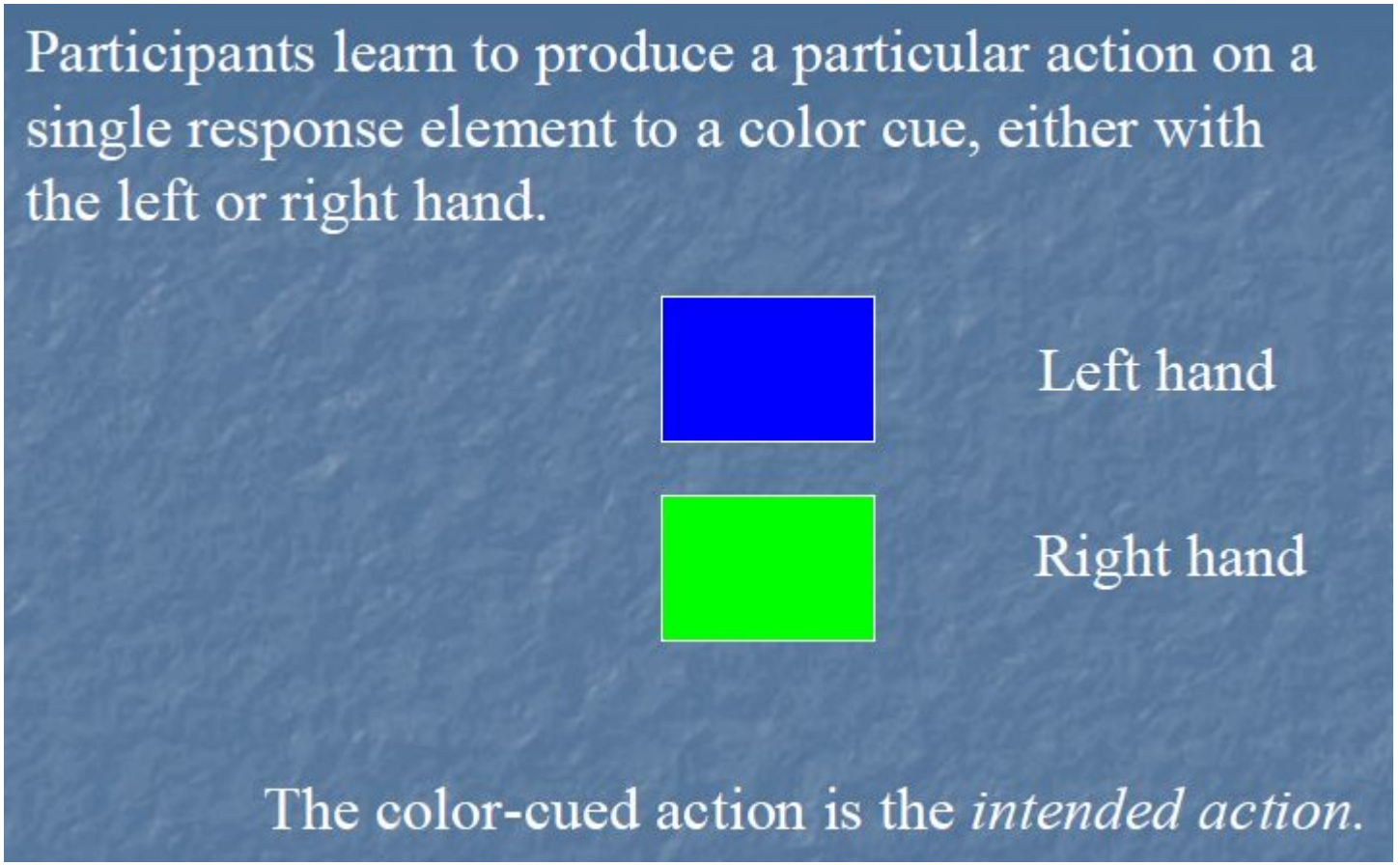


http://thesciencenetwork.org/media/videos/335/Powerpoint.pdf

Alignment paradigm

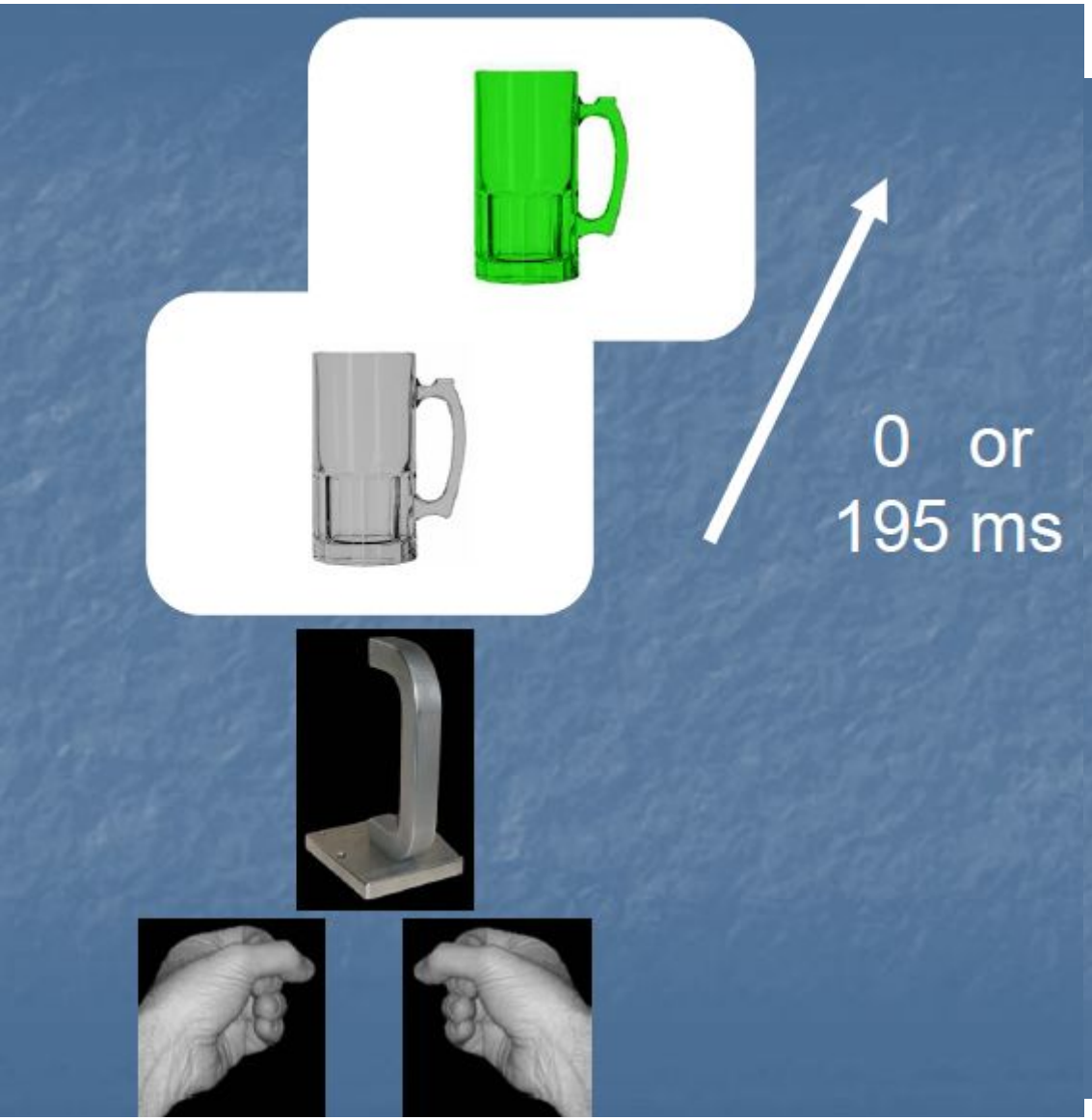
After training, the color cue is presented in the context of a handled object, with the handle facing left or right.

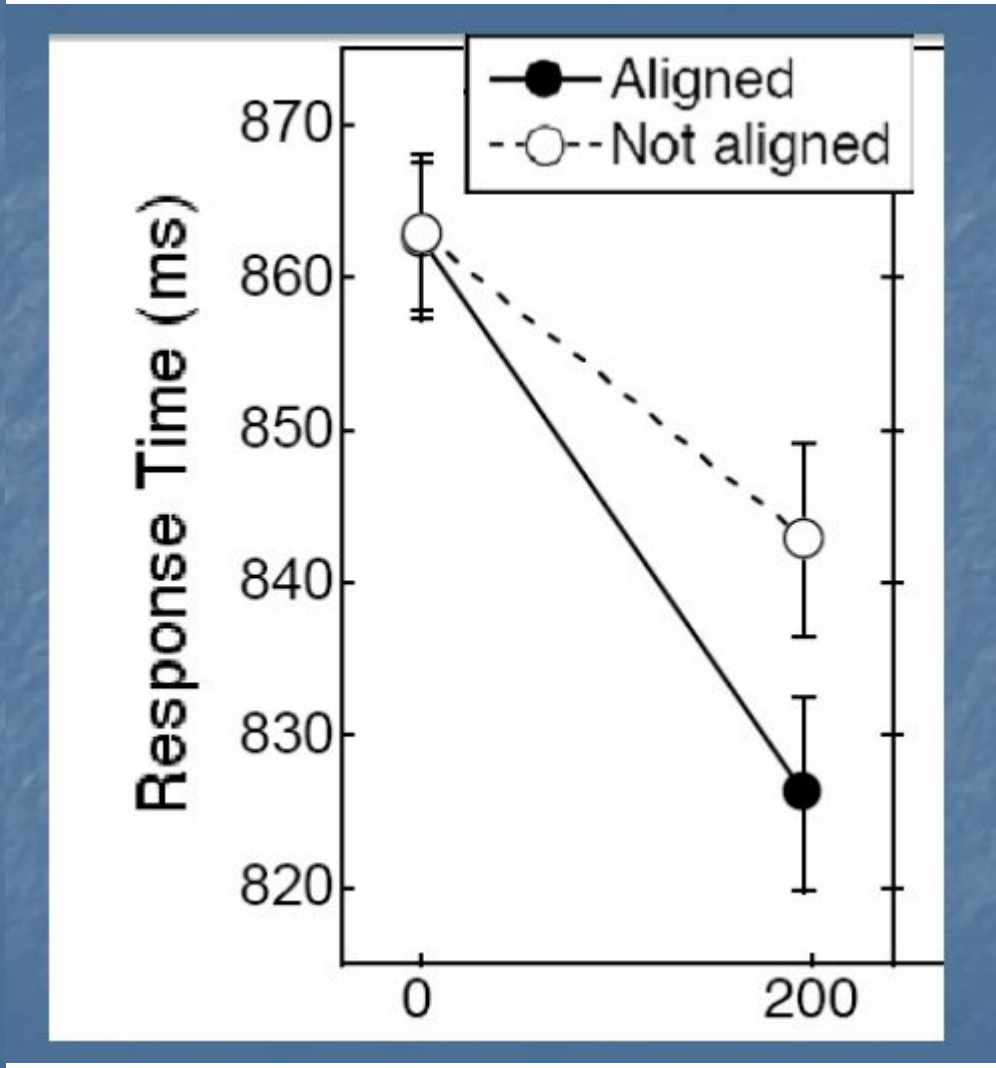
We assume the irrelevant handled object automatically evokes hand action representations.

Competition: The arm producing the intended action conflicts with the side matching the evoked action.

http://thesciencenetwork.org/media/videos/335/Powerpoint.pdf

Alignment paradigm





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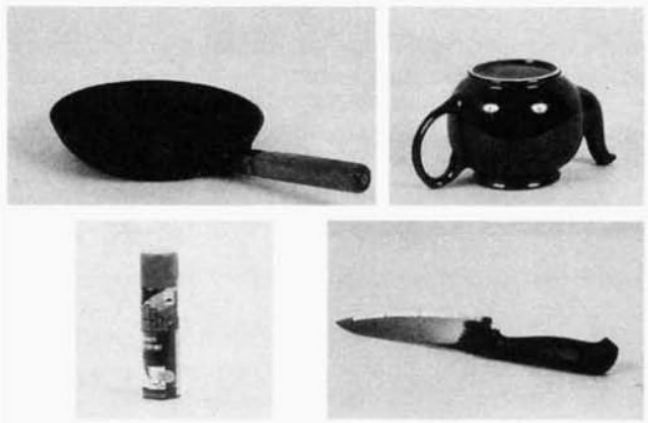
Journal of Experimental Psychology:
Human Perception and Performance
1998, Vol. 24, No. 3, 830–846

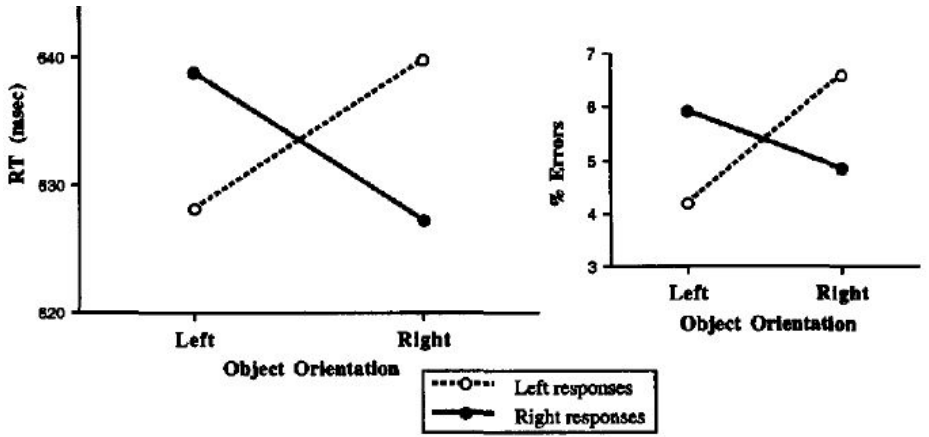
0096-1523/98/$3.00

On the Relations Between Seen Objects and Components of Potential Actions

Mike Tucker and Rob Ellis

- a stimulus-response compatibility paradigm
  - assigning left responses to left stimuli and right responses to right stimuli results in shorter response latencies than does the reverse mapping
- **stimuli**: photographs of common graspable objects
- **task**: as fast as possible whether each object was upright or inverted.
- the **hypothesis** that more than location-based response codes could be activated automatically by visual objects—in particular, that the actions the object affords are automatically potentiated

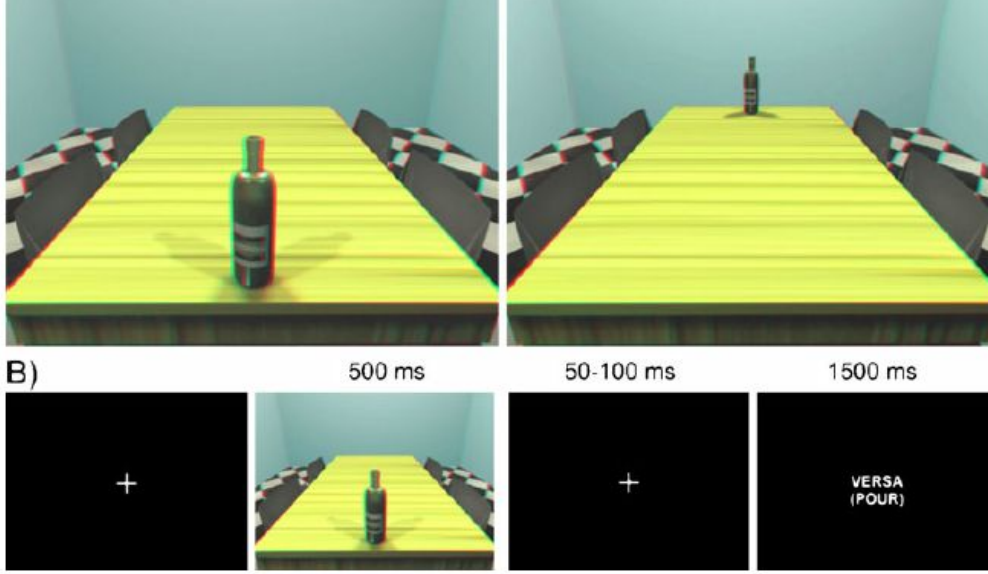




Psychon Bull Rev (2011) 18:302–308
DOI 10.3758/s13423-011-0054-4

When objects are close to me: Affordances in the peripersonal space

Marcello Costantini · Ettore Ambrosini · Claudia Scorolli · Anna M. Borghi



- 3-D pictures of objects located in peripersonal versus extrapersonal space
- Immediately after, they were presented with function, manipulation, or observation verbs (e.g., “to drink,” “to grasp,” “to look at”)
- judge whether the verb was compatible with the presented object.
- both function and manipulation verbs, participants were faster when objects were presented in reachable space
- the fastest response times were recorded when participants read function verbs while objects were presented in the accessible space.

Journal of Experimental Psychology:
Human Perception and Performance
2010, Vol. 36, No. 2, 341–358

0096-1523/10/$12.00 DOI: 10.1037/a0017606

Grasping Beer Mugs: On the Dynamics of Alignment Effects Induced by Handled Objects

Daniel N. Bub and Michael E. J. Masson
University of Victoria

- Left or right handled 3D mugs
- placed in peripersonal or extrapersonal spaces,
- the reaction time in response to a left-/right-hand grasp command is measured

https://tinyurl.com/yb3fxppc

Journal of Experimental Psychology:
Human Perception and Performance
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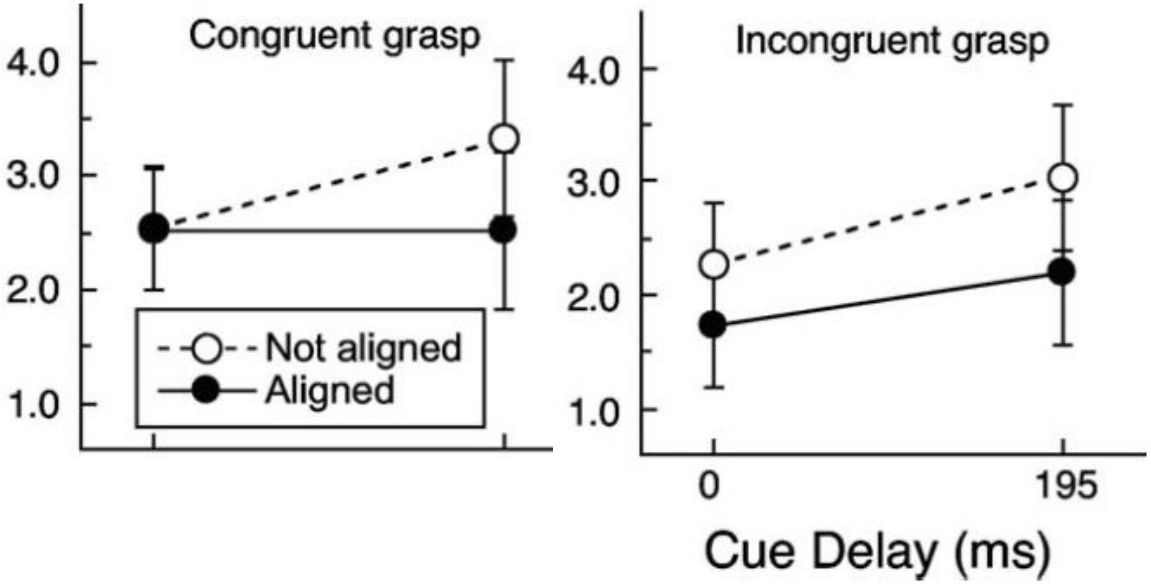
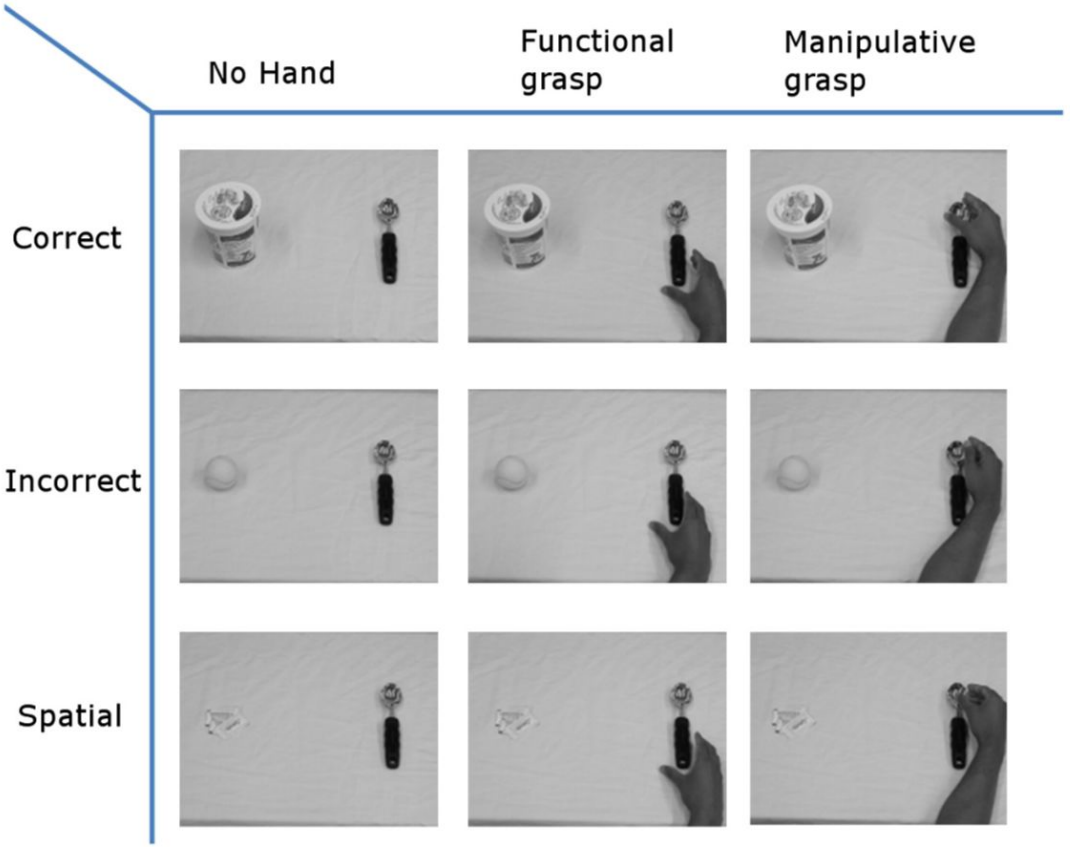
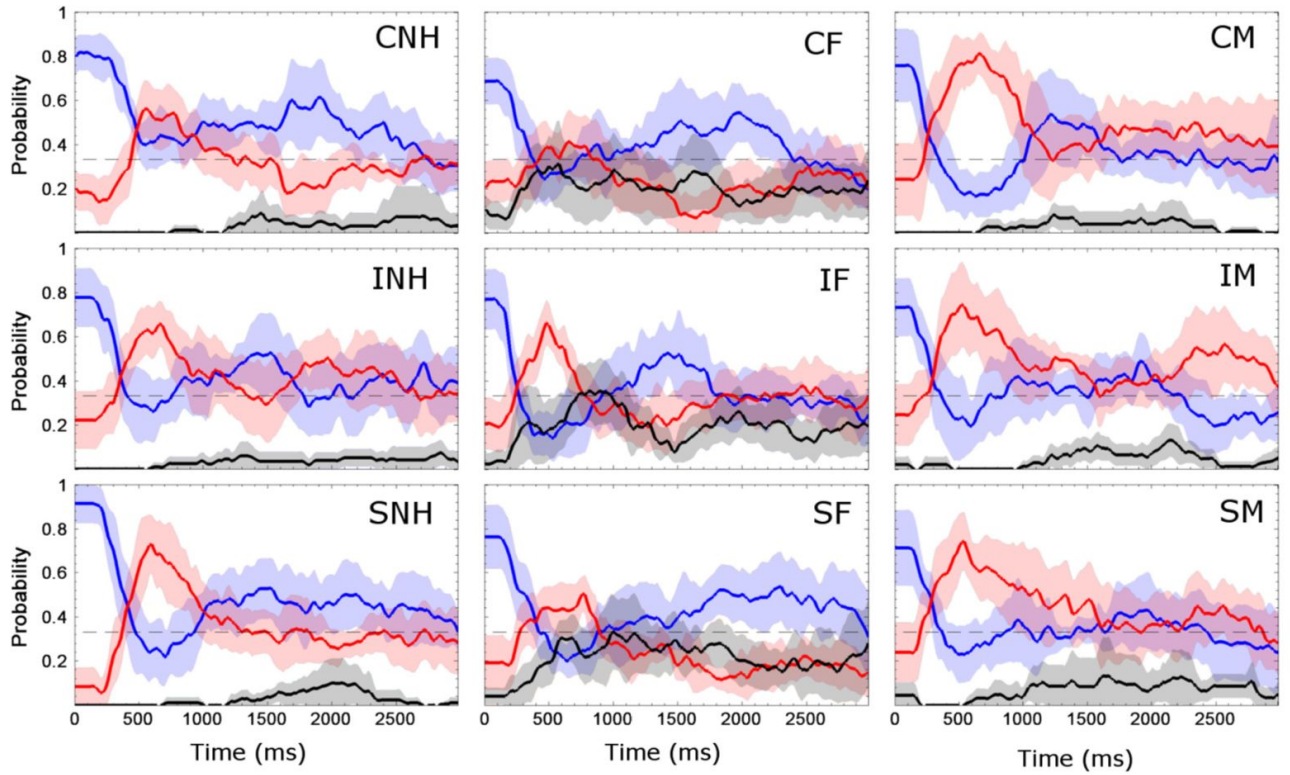


The Visual Encoding Of Tool-Object Affordances

- The three contexts :
    - Correct context (hammer-nail)
    - Incorrect context (hammer-paper)
    - A spatial context (hammer-wood)
- The four grasp postures :
    - No hand
    - A static hand at the bottom equidistant from the tool and object
    - A functional grasp-posture (grasp hammer handle)
    - A non-functional/manipulative grasp-posture (grasp hammer head)

- Passively evaluate the appropriateness of tool use


No Hand
Functional grasp
Manipulative grasp
Correct
Incorrect
Spatial



CNH Correct context, No hand
CF Correct context, Functional grasp
CM Correct context, Manipulative grasp

INH Incorrect context, No Hand
IF Incorrect context, Functional grasp
IM Incorrect context, Manipulative grasp

SNH Spatial context, No hand
SF Spatial context, Functional grasp
SM Spatial context, Manipulative grasp

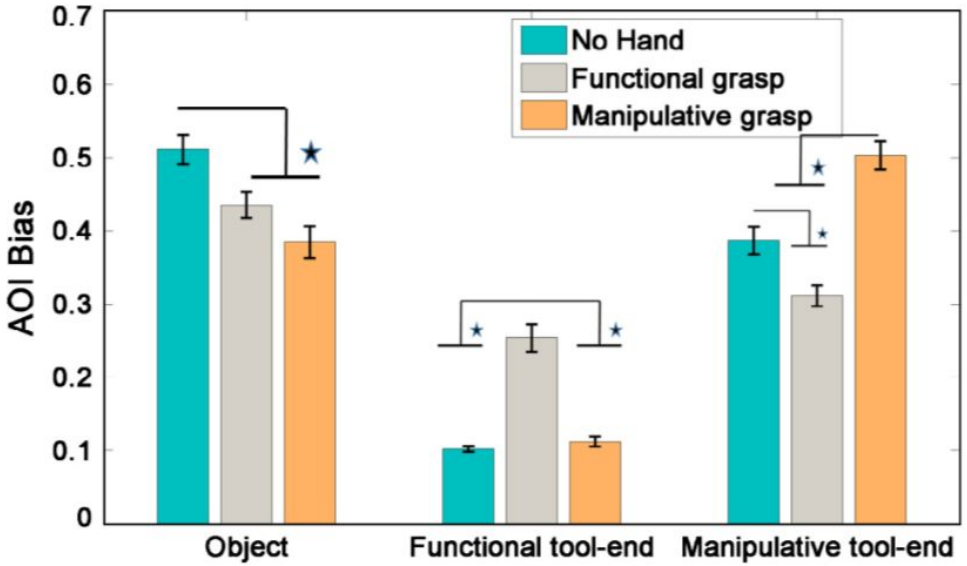
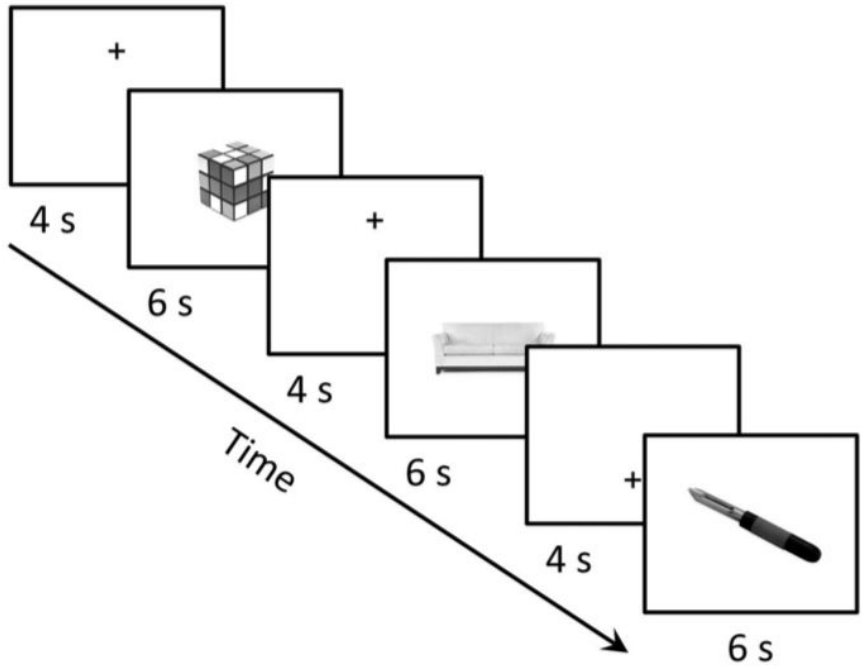


Fig. 5. (A–C) Mean foveal bias (with S.E bars) toward each AOI across the three Hand conditions (no hand, functional grasp, manipulative grasp). Data were collapsed across Context in line with the clustering results of Fig. 4B. Significant differences are marked with the star sign.

Body Posture Effect


+
4 s
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+
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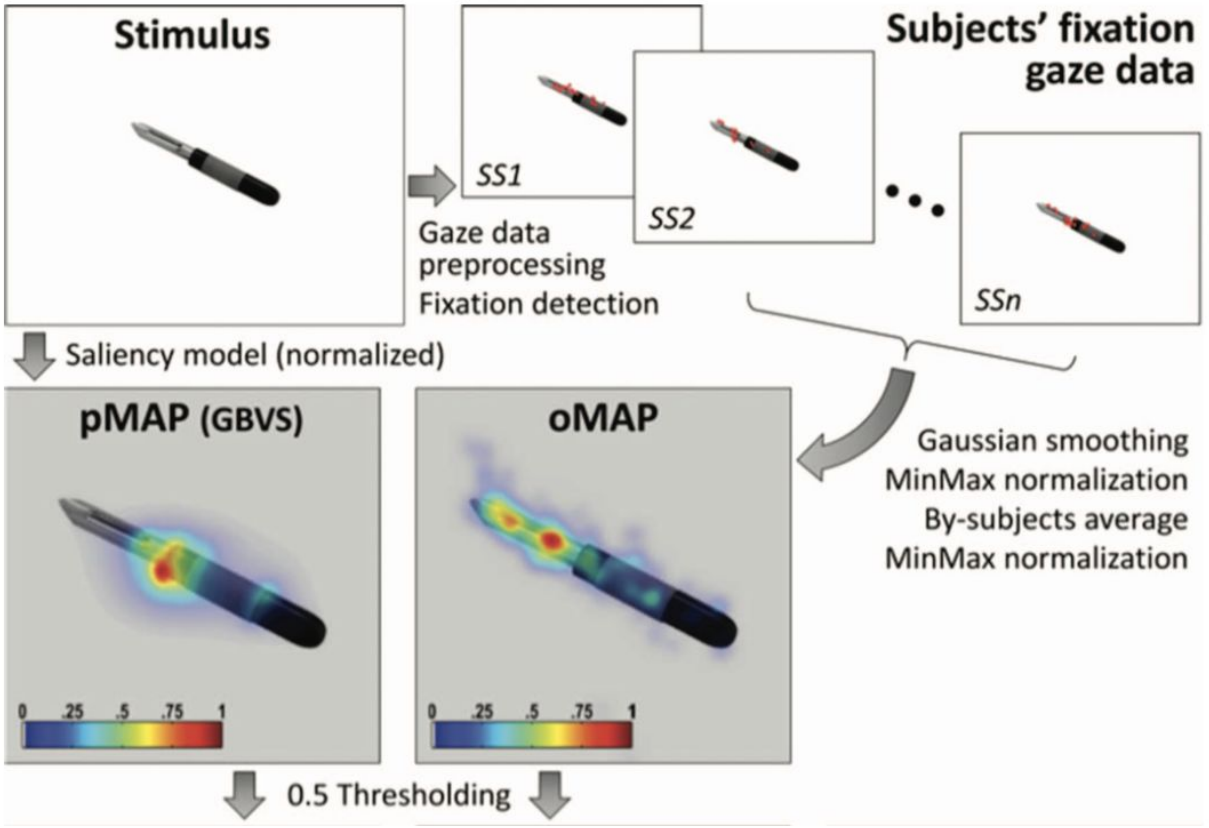
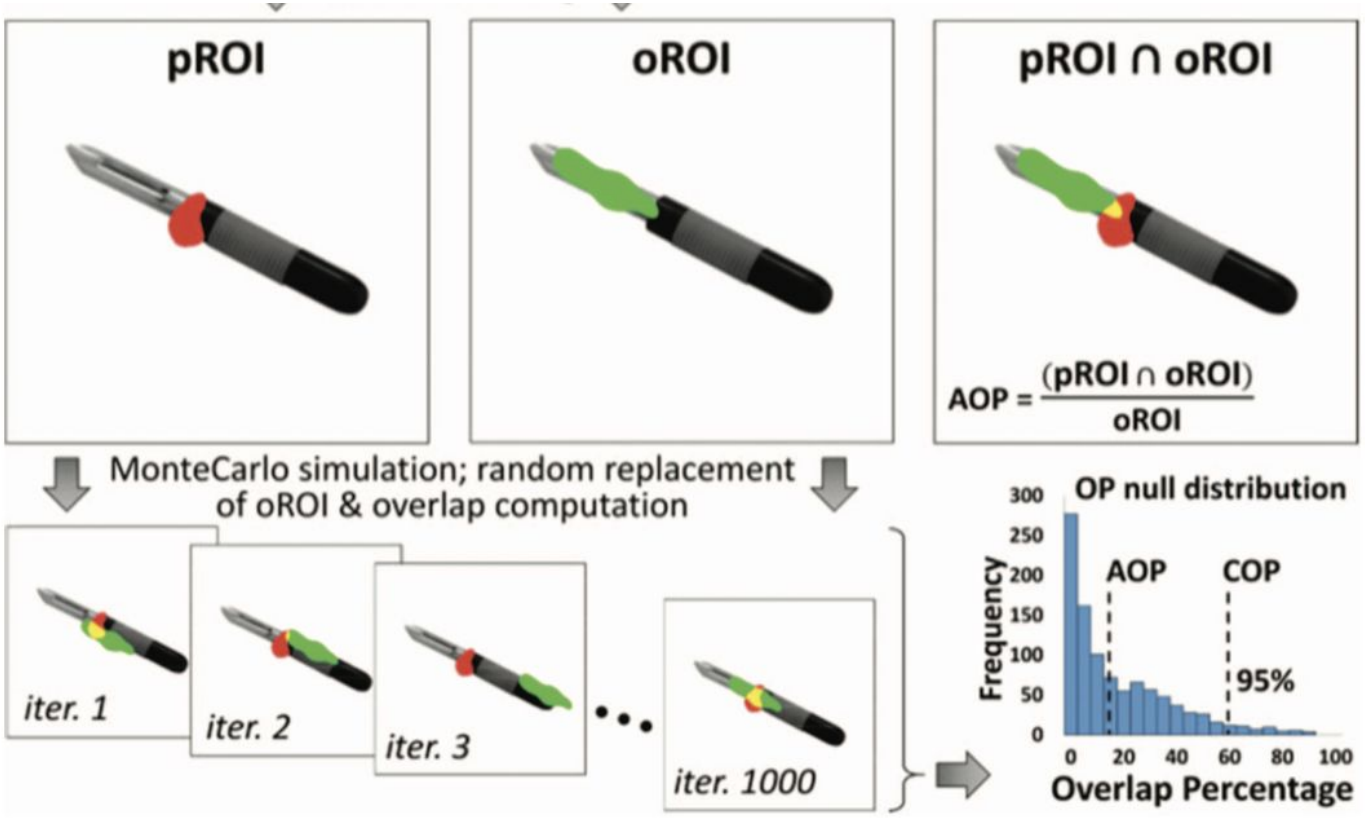
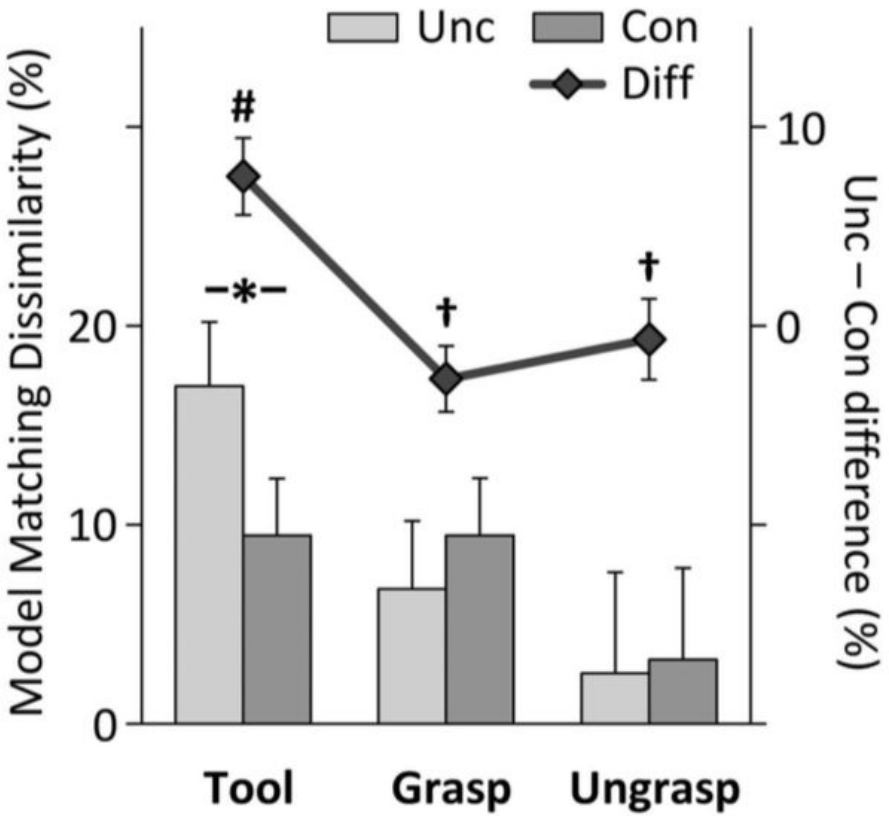
+
4 s
6 s
Time


Stimulus
SS1
SS2
SSn
Subjects' fixation gaze data
Gaze data preprocessing
Fixation detection
Saliency model (normalized)
pMAP (GBVS)
oMAP
0 .25 .5 .75 1
0 .25 .5 .75 1
Gaussian smoothing
MinMax normalization
By-subjects average
MinMax normalization
0.5 Thresholding


pROI
oROI
pROI ∩ oROI
AOP = (pROI ∩ oROI) / oROI
MonteCarlo simulation; random replacement of oROI & overlap computation
iter. 1
iter. 2
iter. 3
iter. 1000
OP null distribution
Frequency
AOP
COP
95%
Overlap Percentage
0
50
100
150
200
250
300
0
20
40
60
80
100


Unc
Con
Diff
Model Matching Dissimilarity (%)
Unc – Con difference (%)
0
10
20
10
0
#
–*–
†
†
Tool
Grasp
Ungrasp

Anticipatory eye fixations reveal tool knowledge for tool interaction

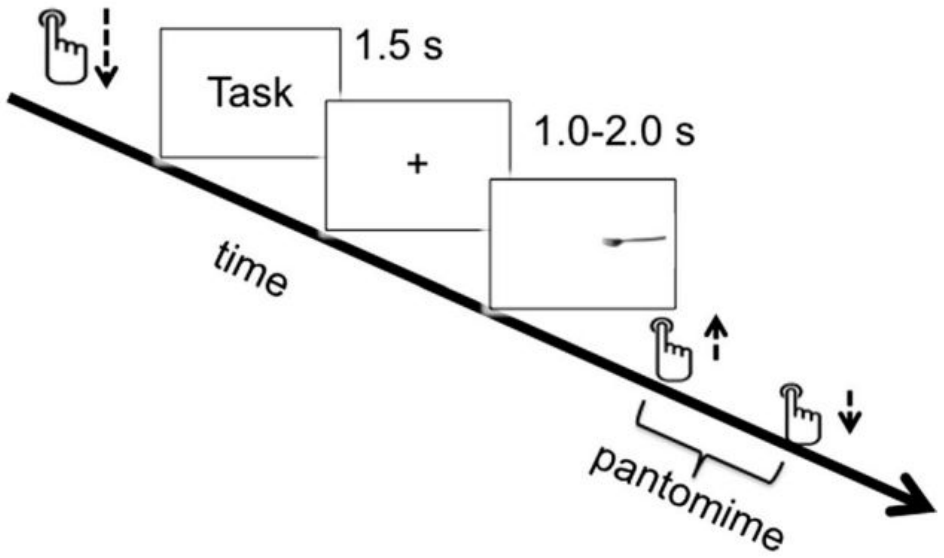


Fig. 1 Time line of each trial. When the subject is pressing the space bar, the current task appears, followed by the fixation cross and then the stimulus image. The subjects can then release the space bar (reaction time) and execute the appropriate movement. Returning to the space bar signals the end of the task

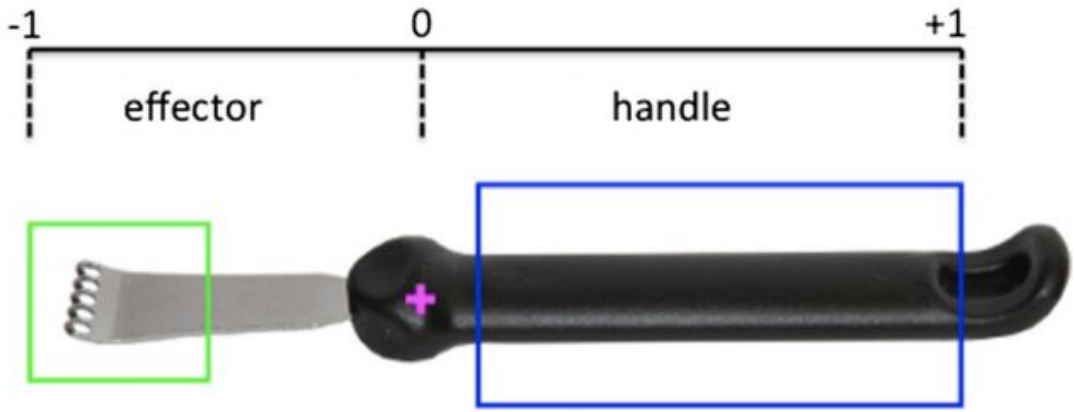
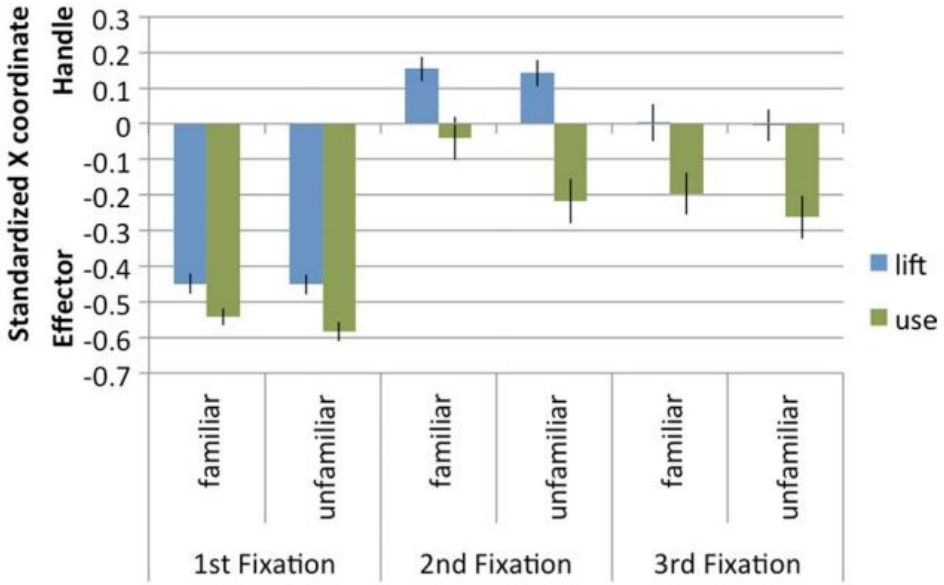
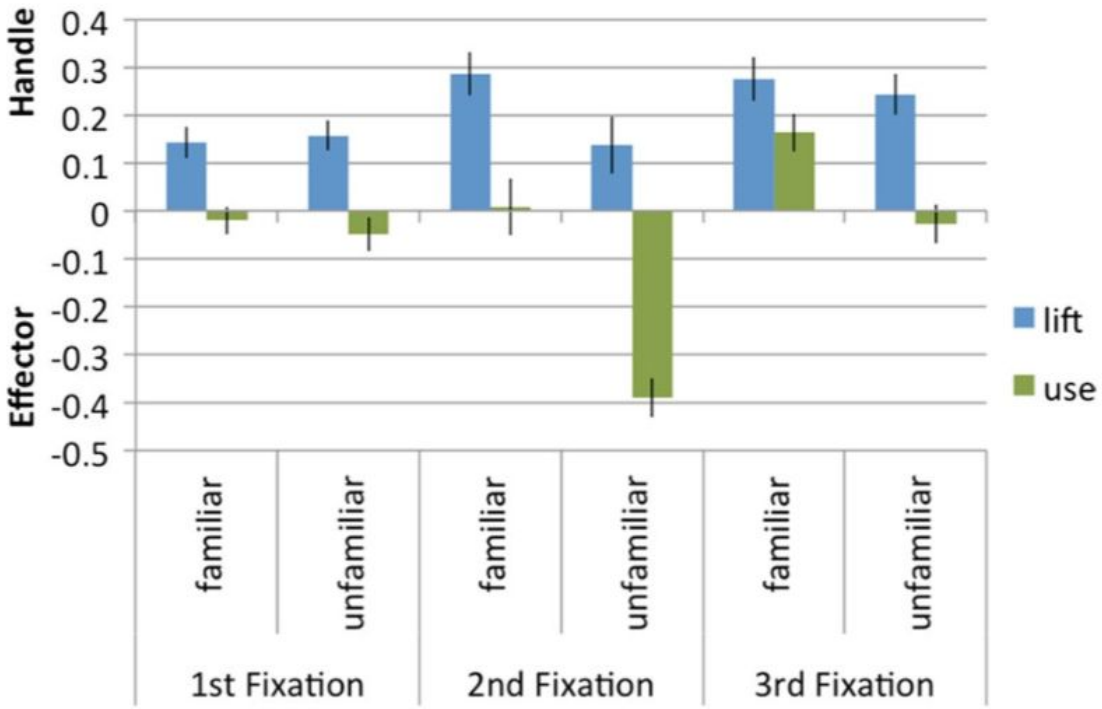


Fig. 2 Effector (*green*) and handle (*blue*) ROIs for one of the unfamiliar objects (*zester*). The *x* coordinate of each fixation was standardized according to the axis centered on the midpoint between the two ROI's centers (*magenta cross*) (color figure online)

Objects shown at the level of fixation cross



Objects shown at the upper level of fixation cross



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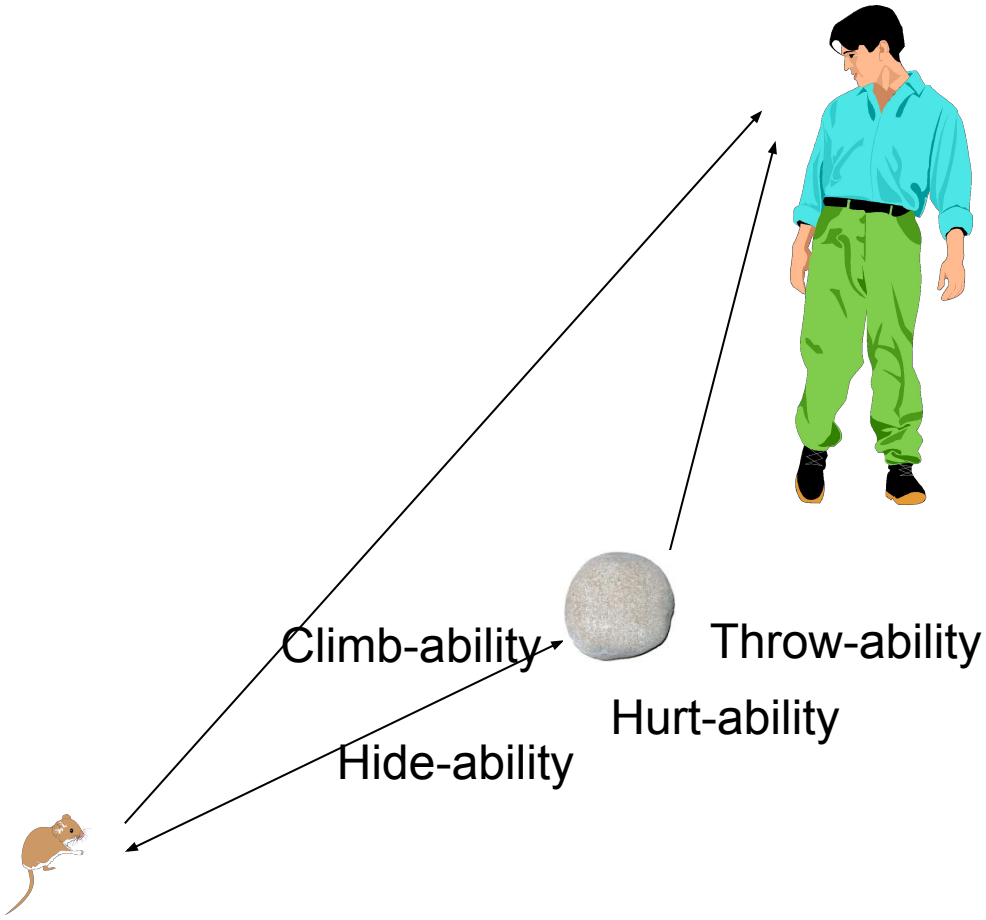
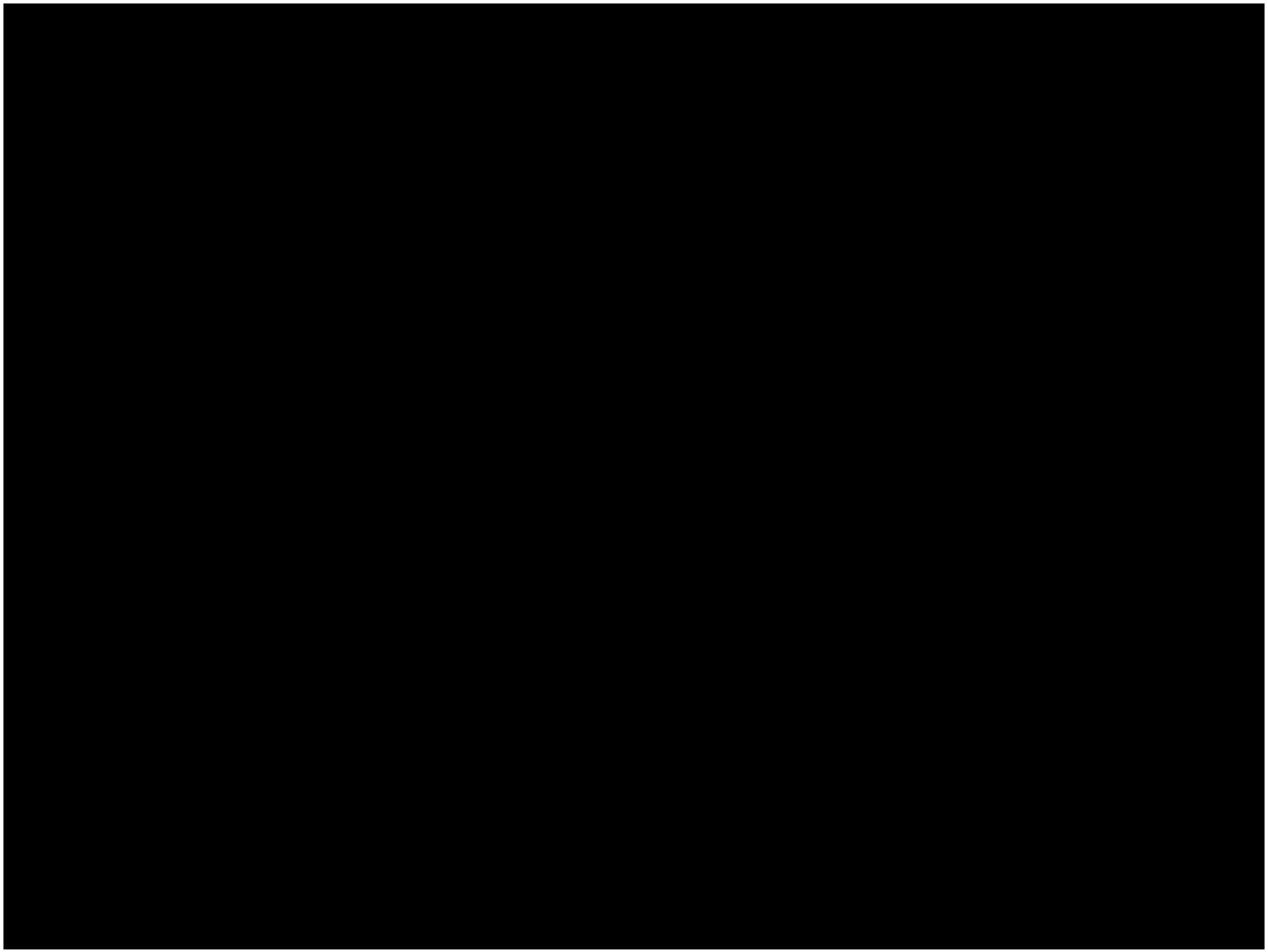
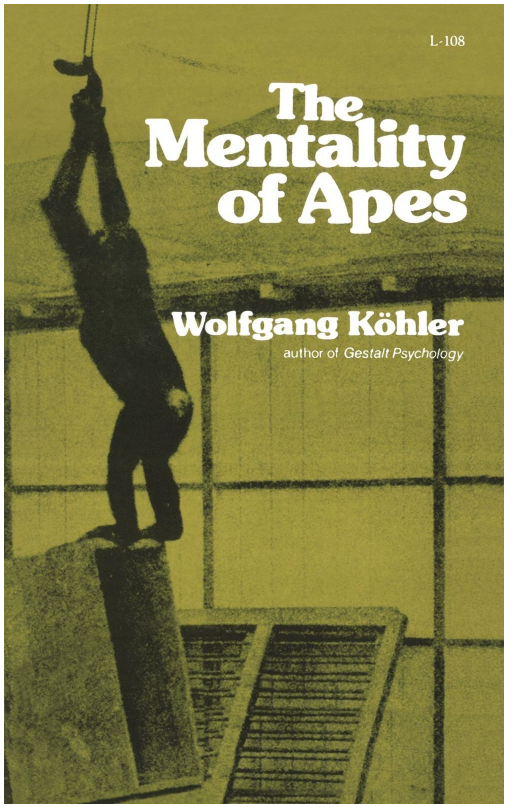
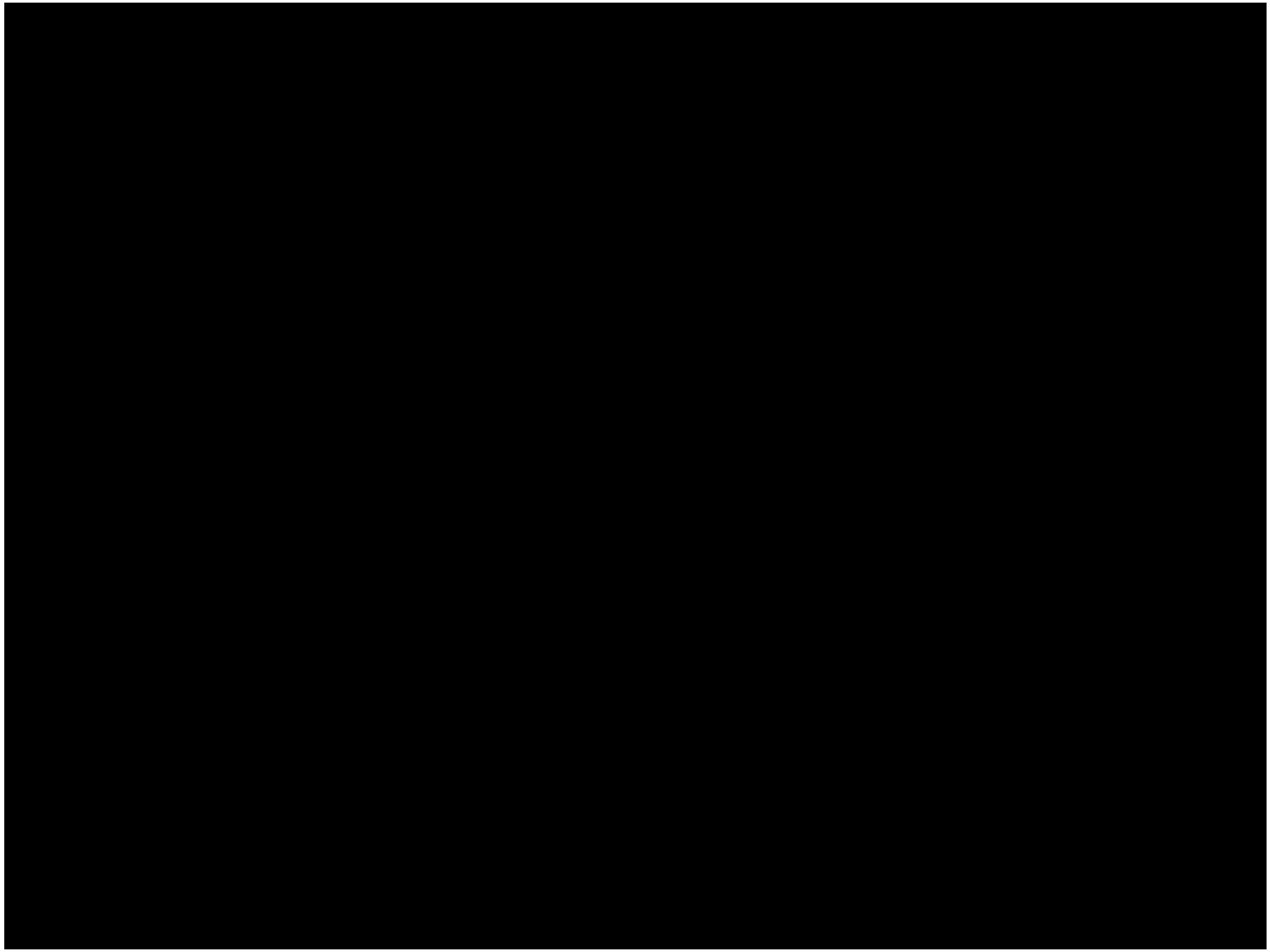
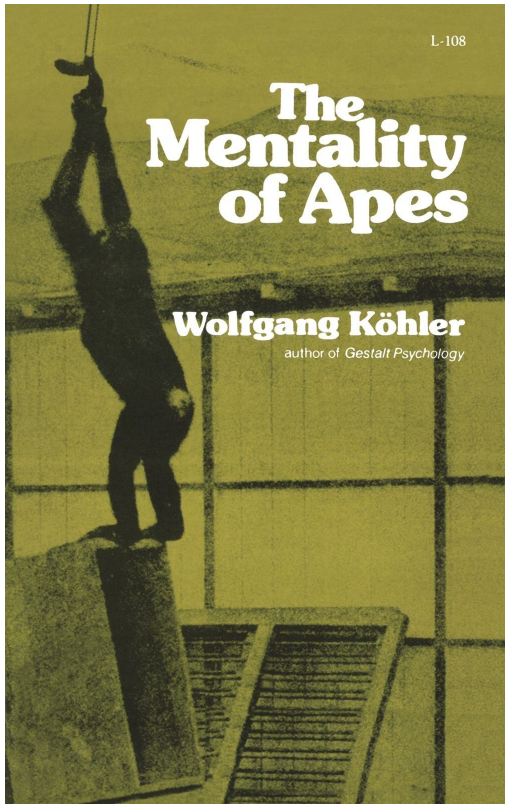
Affordances are defined in animal-environment system






L-108
The Mentality of Apes
Wolfgang Köhler
author of Gestalt Psychology

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The Mentality of Apes
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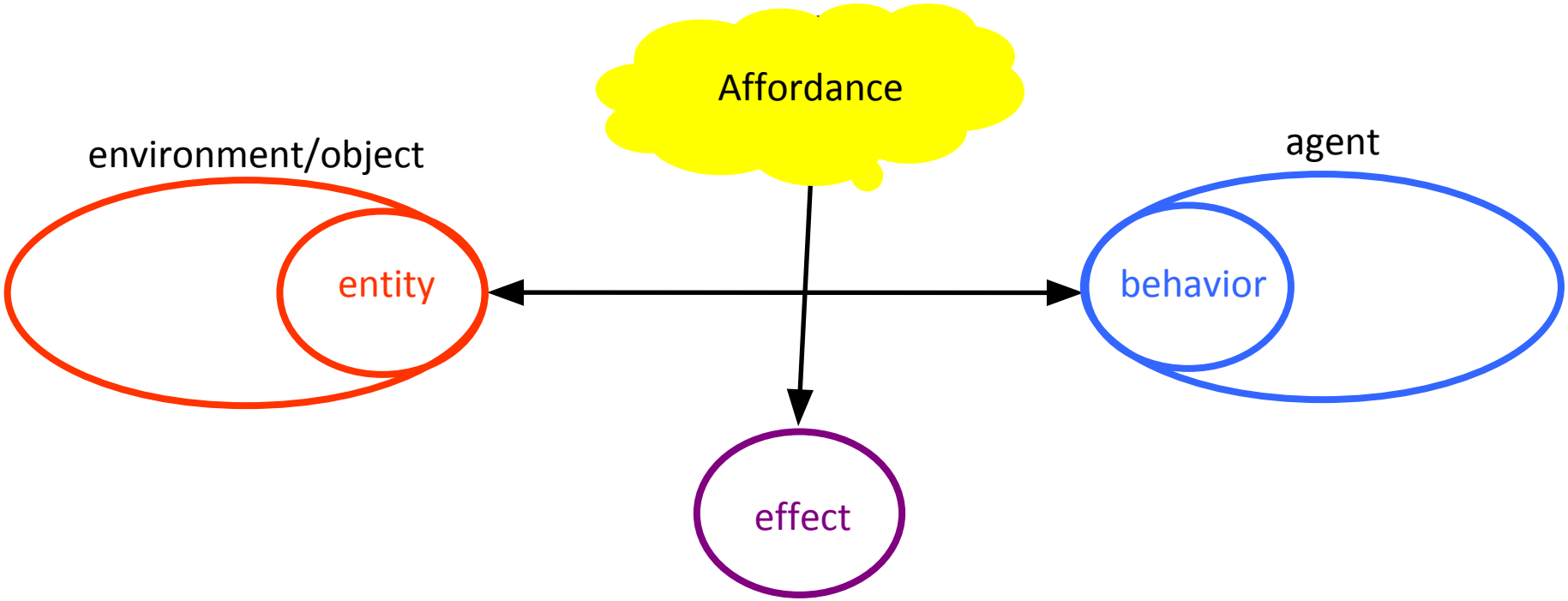
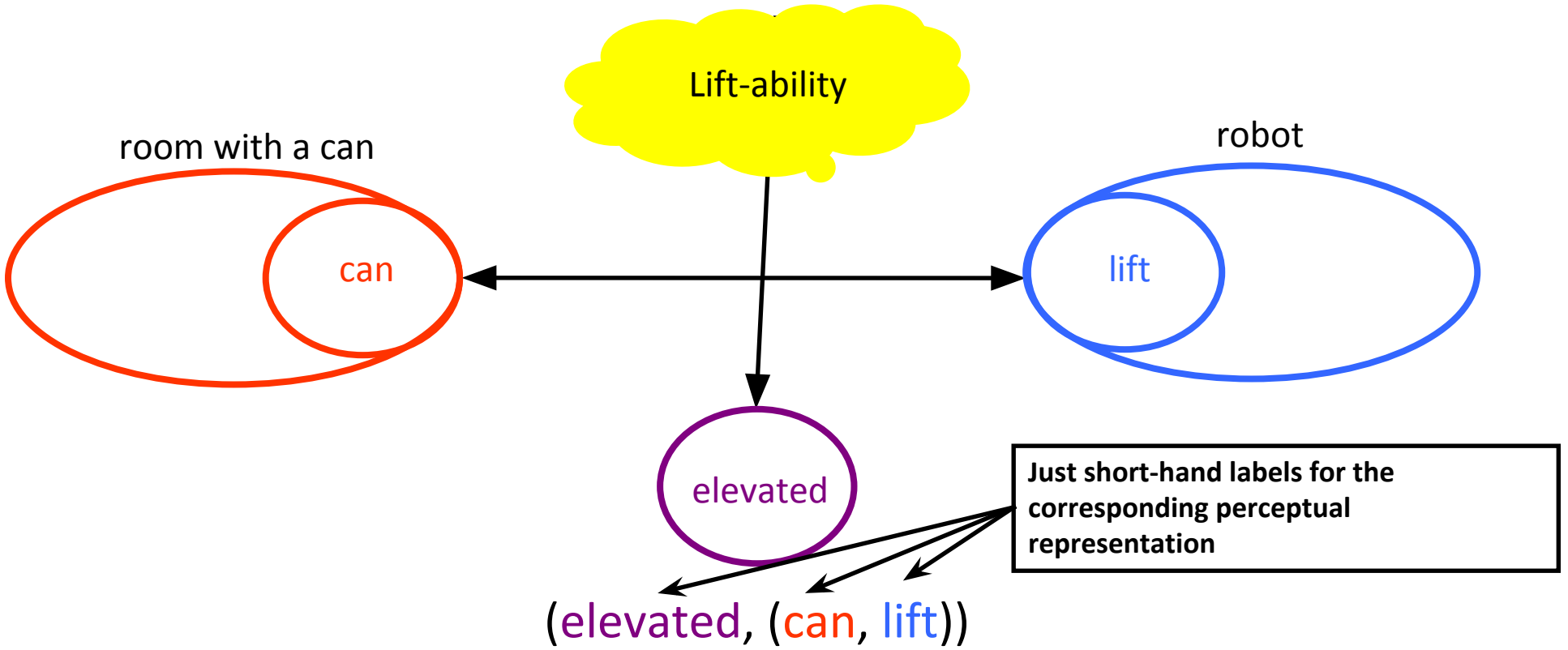
Formalize affordances for robot control



(effect, (entity, behavior))

Definition: An affordance is an acquired relation between a behavior of an agent and an entity in the environment such that the application of the behavior on the entity generates a certain effect.

Formalize affordances for robot control

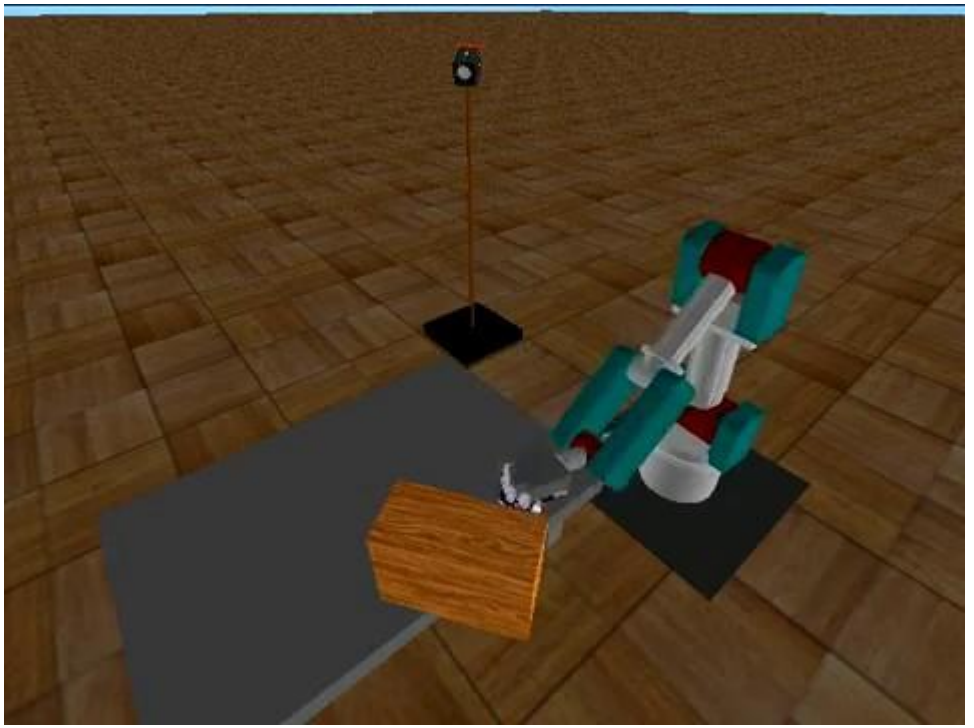


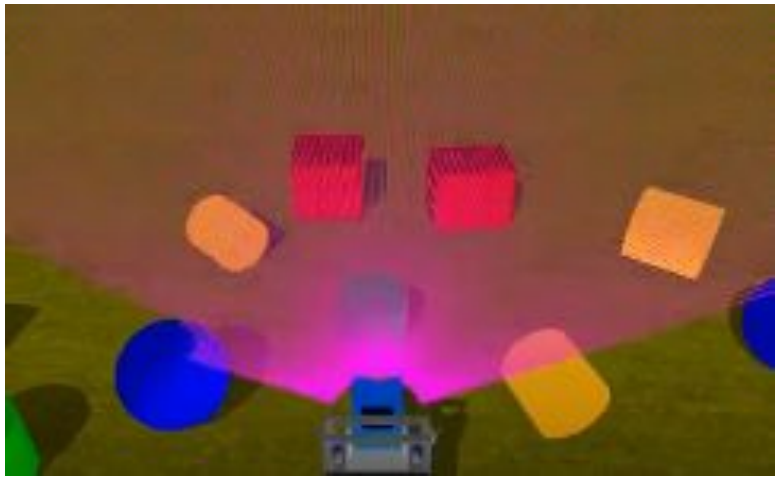
The robot applied its lift behavior on the can and obtained the elevated effect.
Can: The perceptual representation of the can as seen by the robot
Lift: The behavior executed by the robot
Elevated: The effect of the behavior on the environment as perceived by the robot.

Learning affordances in animals

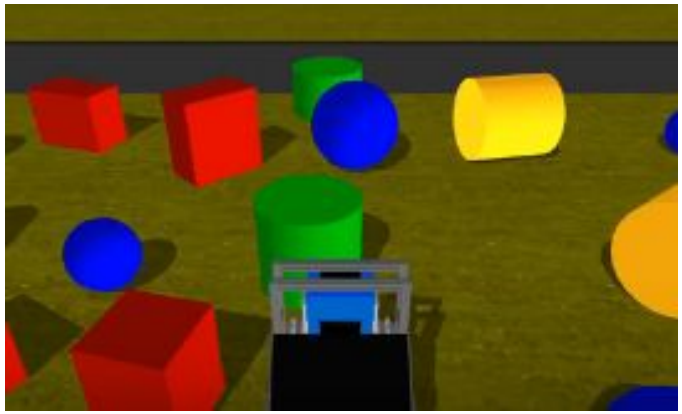
- With primitives,
- Self-exploration,
- Physical interaction,
- Instrinsic motivated,
- Observe & learn

Learning of navigation and manipulation affordances in robots





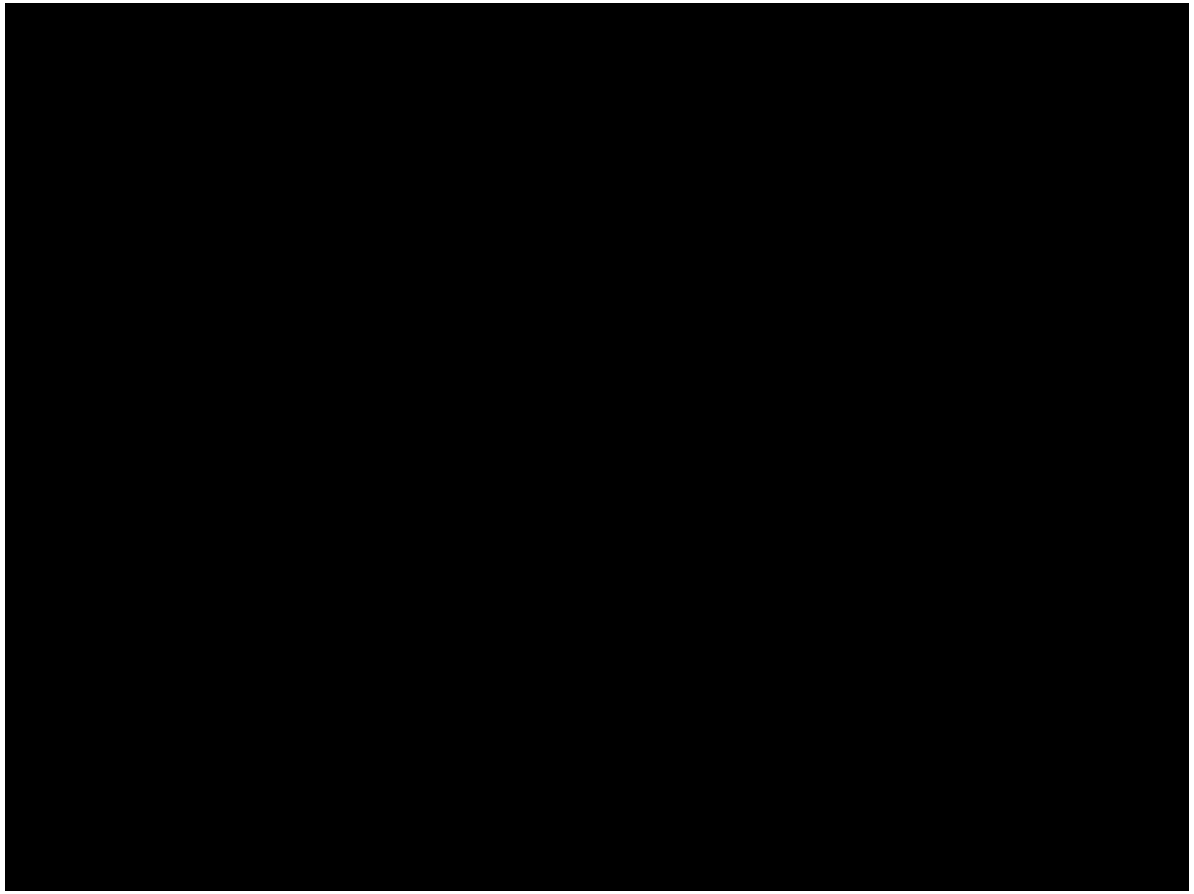
Use of locomotion affordances

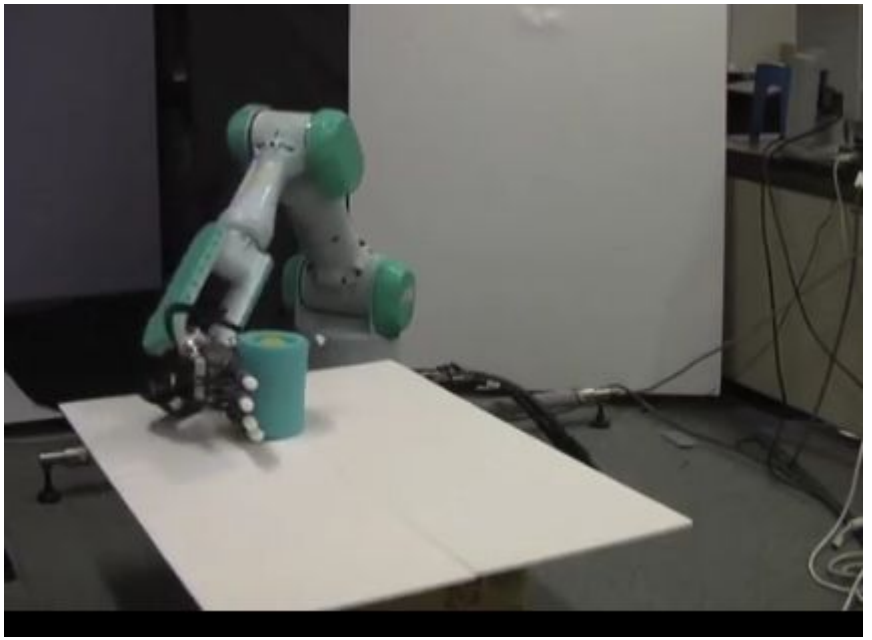


Use of locomotion affordances

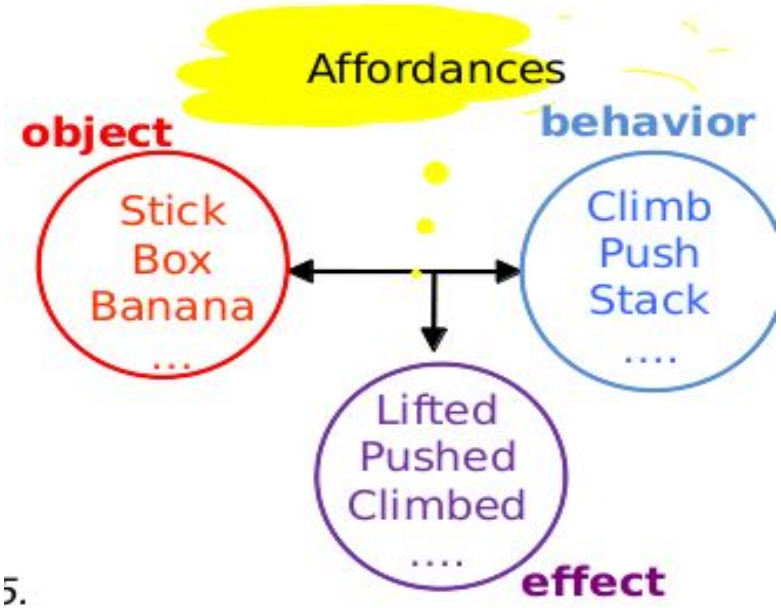
Use of locomotion affordances

Use of manipulation affordances





Formalize affordances for robot control



5.

Affordance-Based Altruistic Robotic Architecture for Human-Robot Collaboration (COGSCI lecture version)

M.Sc. Thesis: Mert Imre
Supervisor: Assist. Prof. Emre Ugur

Computer Engineering Department,
Bogazici University

13.11.2018

Outline

Introduction : Altruism in Primates

- **Altruism** “altrui” -> “somebody else” (Italian)
  “alteri huic” -> “to this other” (Latin)
  The concern for other people regardless of self-concern of an individual.[1]
- Observed in chimpanzees and infants.

[1] Oxford Living Dictionaries
https://en.oxforddictionaries.com/definition/altruism accessed: June 2018

Introduction : Altruism in Primates

 [2]

This task requires:

- stackability and insertability.
- forward models (target pred. and goal inference).
- error minimization (exp. and cur. outcome).
- own action repertoire.

[2] Warneken, F. & Tomasello, M. (2006). *Altruistic helping in human infants and young chimpanzees*. Science, 311, 1301-1303.

Introduction : Altruism in Primates

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[3] Warneken, F. & Tomasello, M. (2006). *Altruistic helping in human infants and young chimpanzees*. Science, 311, 1301-1303.

Introduction : Altruism in Primates

 [4]

- empathy vs error minimization
  - affordance detection.
  - forward models (target pred and goal inference).
  - error minimization (exp. and cur. outcome).
  - own action repertoire.

[4] Kenward, Ben, & Gustaf Gredebäck. (2013). *Infants help a non-human agent*. PloS one 8, no. 9

Introduction

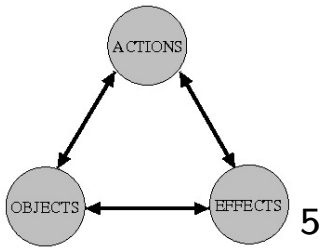
- Our claim: basic sensorimotor processes over deliberate cognitive processes.
- Novelty of work:
  1. a biologically realistic model. (Implementation)
  2. altruistic robot with affordance learning.
  3. altruistic partner HRI experiments.

Outline

Outline

Background : Affordance

- "Affordance" - J.J. Gibson from (1966 - 1979) [Gibson, 1966, Gibson, 2014].
- Perceived action capabilities for an animal in an environment.
- Certain effect and certain (agent, (object, action)) [Şahin et al., 2007].
- Two categories in robotics
  1. Enhanced classifier : e.g SVM
     object features -> affordance class
  2. Bayesian Networks :



[5]

[5] Montesano, L., Lopes, M., Bernardino, A. and Santos-Victor, J. (2007). *Modeling affordances using bayesian networks*. IROS 2007 Proceedings, 4102-4107.

Outline

Background : Goal Inference

- Track ongoing action to infer the goal.
- Goal inference and motor abilities developmentally correspondent [Sommerville, 2005, Kanakogi Y, 2011, Terje et al., 2006].
- The movement of the subject hand towards an object [Hamlin et al., 2009].

Outline

Background : Altruistic Help in Robotics

- Morton et al. for better collaboration between the robotic agents [Morton et al., 2009].
- Baraglia et al. [Baraglia et al., 2016] by use of error minimization.

Outline

Altruistic Help Model

- Biologically inspired from the sensorimotor processing of primate brain.
- Integrates
  - Affordance Detection
  - Goal Inference with Forward Modeling
  - Error Minimization
  - Action Execution
- Composed of modules that are active in both *action generation* and *action observation*

Altruistic Help Model

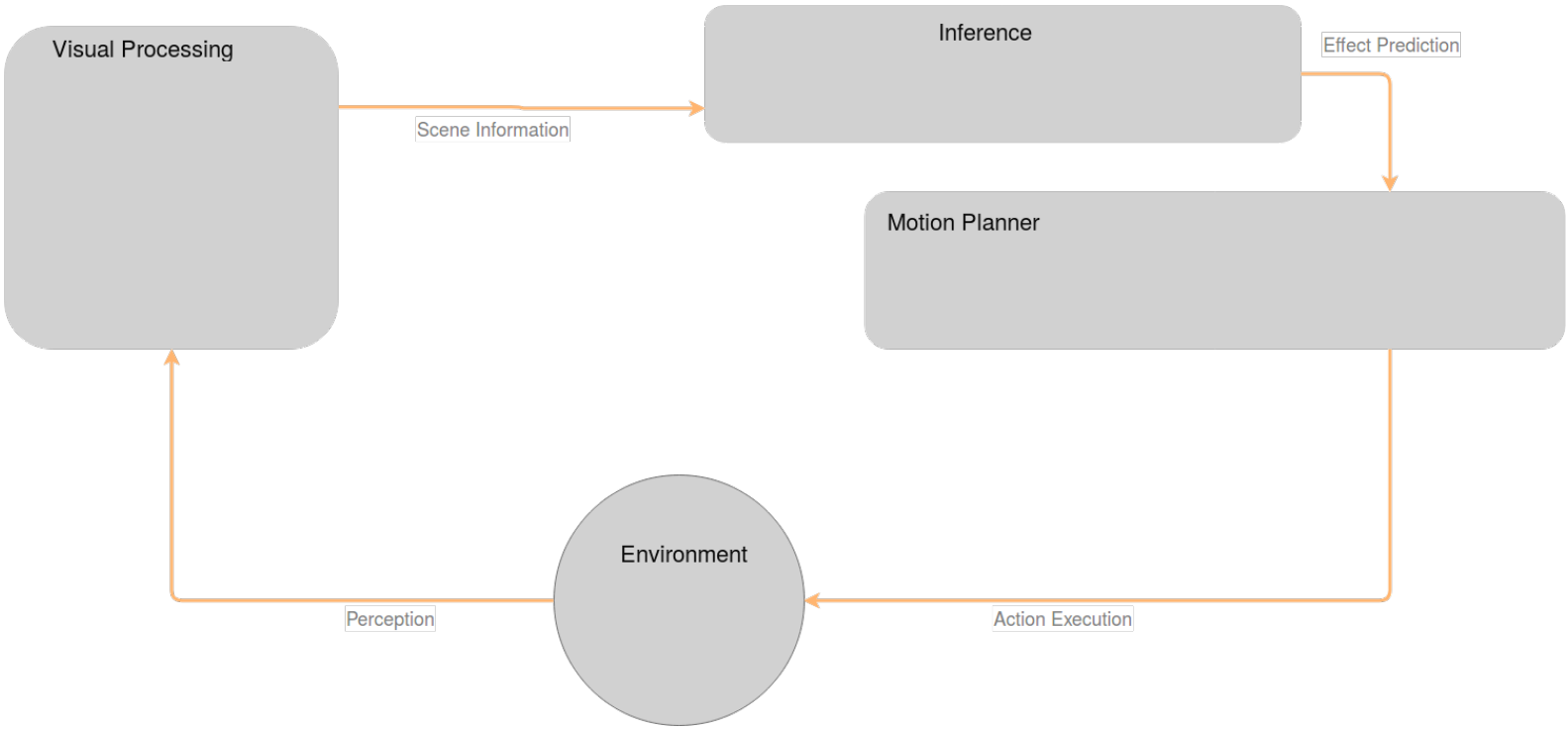


Figure 1: Model Overview

Altruistic Help Model

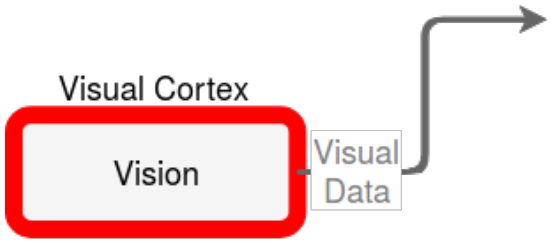


Figure 2: Vision Module

- Kinect perception
- Filter the region of interest.
- Detection of objects
- Visual features

Altruistic Help Model

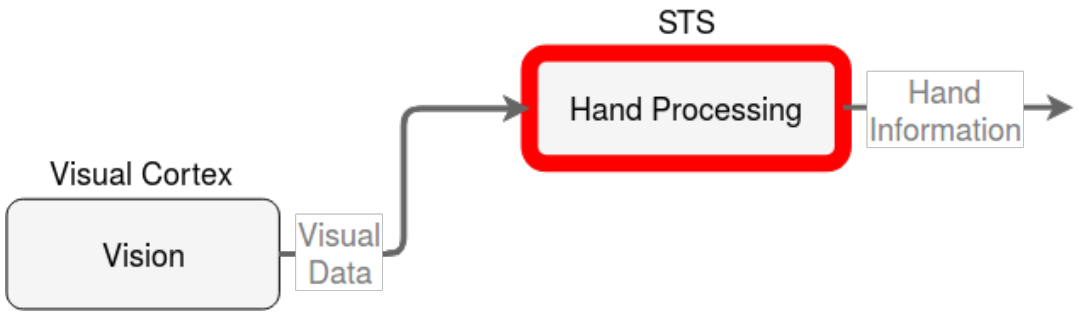


Figure 3: Hand Trajectory Module

- Detection of the hand.
- Tracks the hand trajectory.

Altruistic Help Model

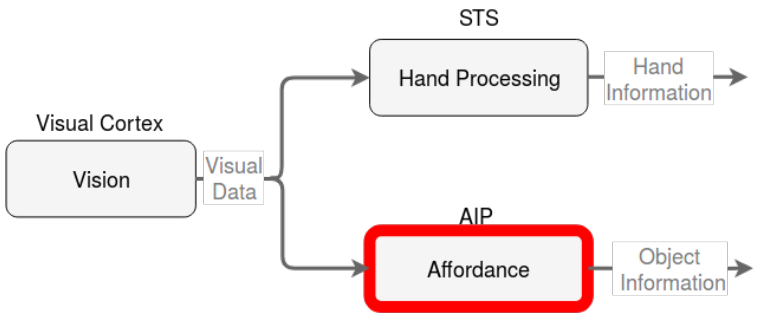
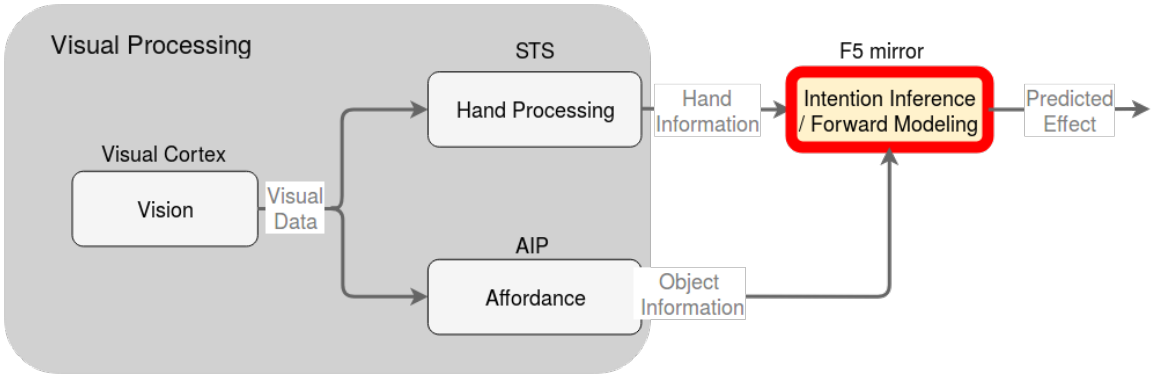


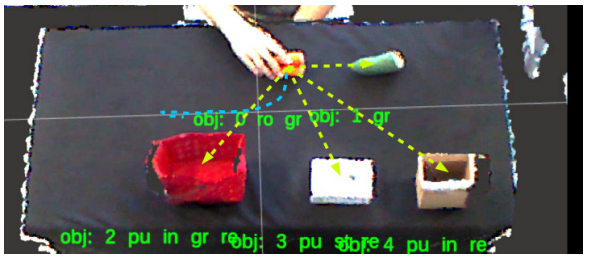
Figure 4: Affordance Module

- Affordance detection from visual features.

Altruistic Help Model



(a) Forward Modeling Module



(b) DTW Usage

Figure 5: Forward Modeling Module

- Search over each (object, action) pair
- Reasonable affordance
- Goal inference

Altruistic Help Model

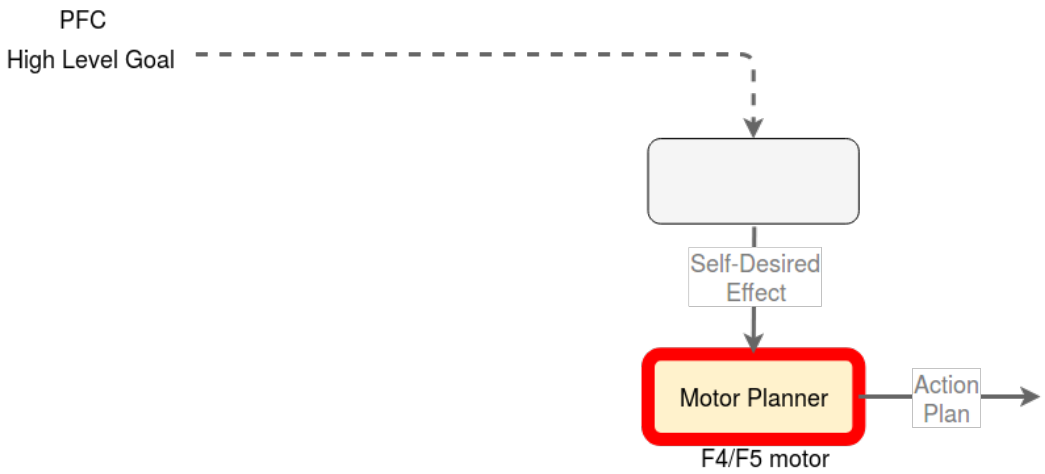


Figure 6: Motor Planner

- High level planning
- Aim :minimizing the difference between the self desired effect and current scene.

Altruistic Help Model

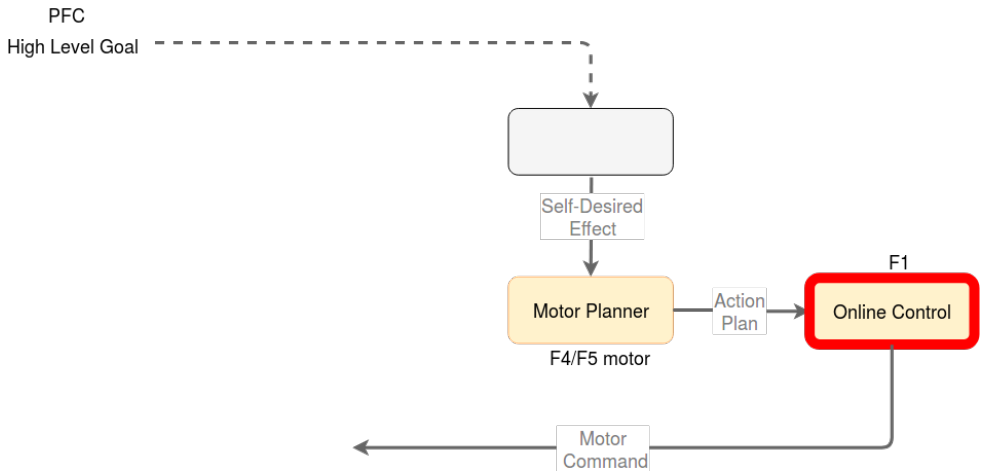


Figure 7: Online Control

- Low level motor command generation
- Position control with inverse kinematics.

Altruistic Help Model

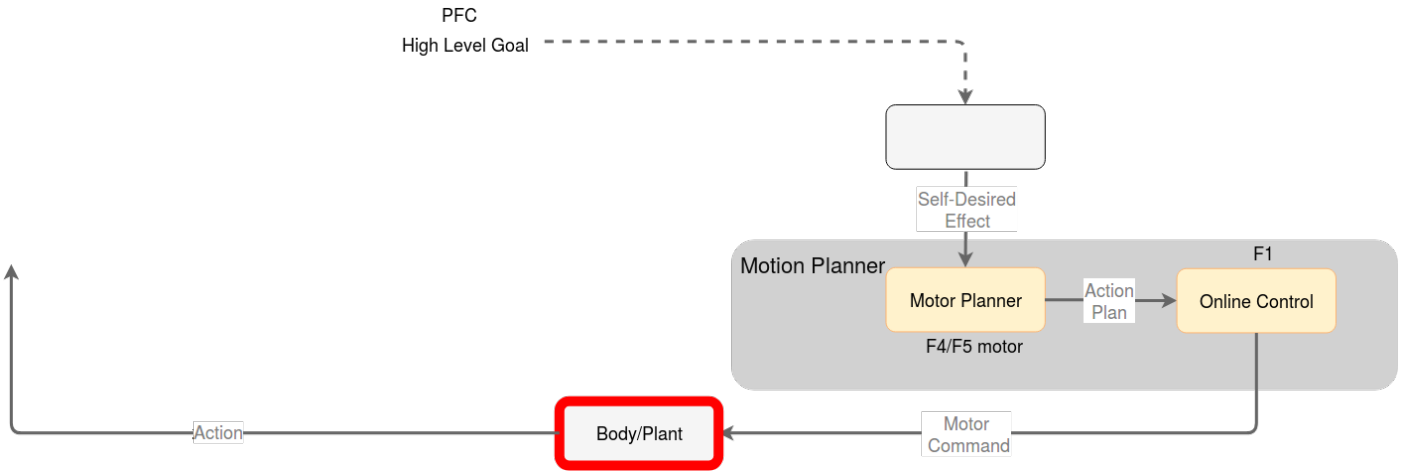


Figure 8: Body/Plant

- Embodiment of the system.
- Execution of commands

Altruistic Help Model

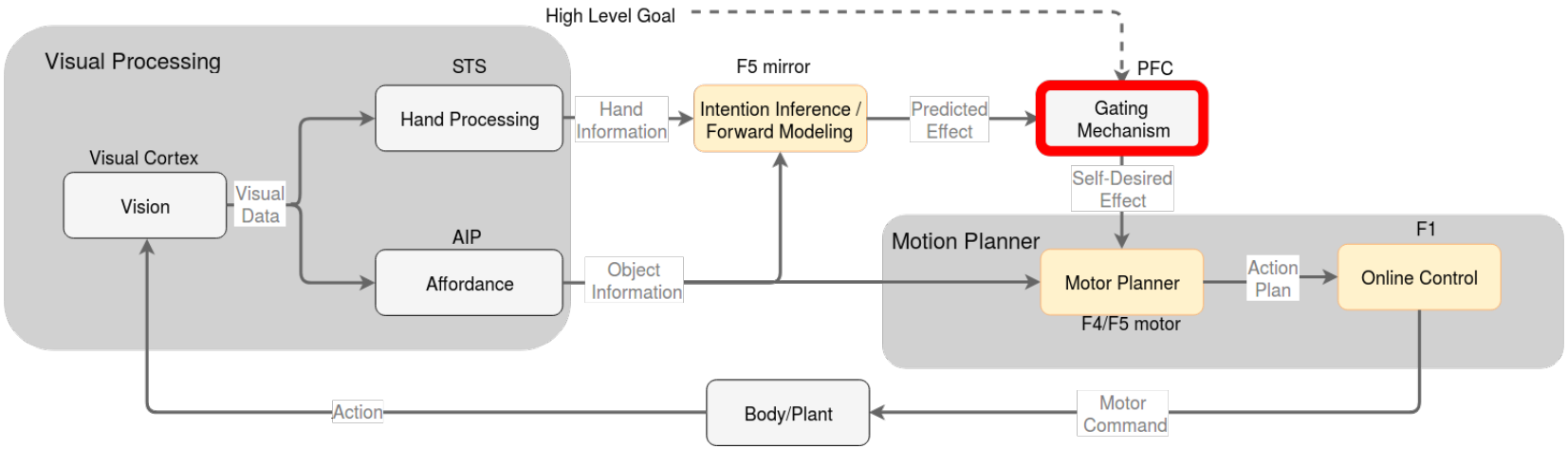


Figure 9: Gating Mechanism

- Turning high level goal into self-desired effect
- Inhibition of the predicted goal (observation)
- Stopping inhibition for altruistic behavior emergence.

Altruistic Help Model

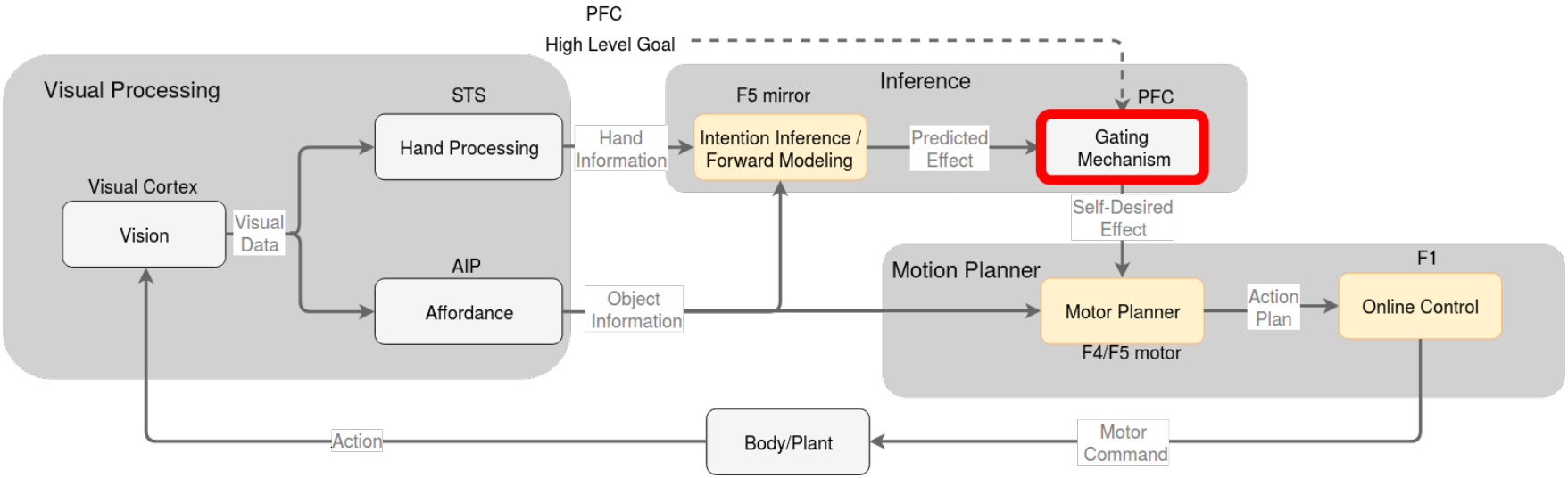
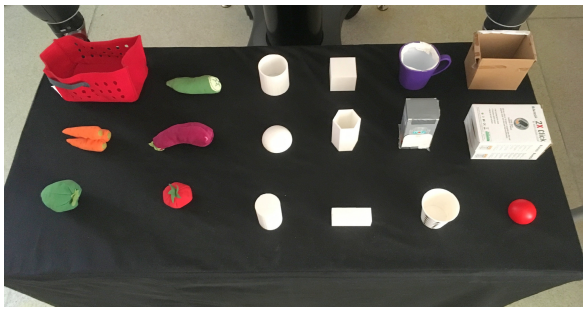


Figure 10: Altruistic Helping Model

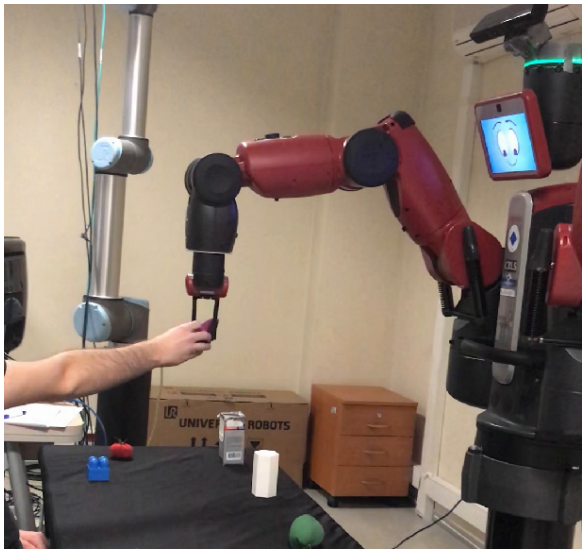
Model on Robot

Outline

(a) Baxter with kinect attached on its head



(b) Object Examples



(c) Example scene from the experiments

Figure 11: Experimental Setup and General Scenario

- 6 affordances :graspability (gr.), insertability (in.), pushability (pu.), reachability (re.), rollability (ro.), stackability(st.)

HRI with Naïve Subject

- Aim : Evaluating the success of the robot in natural interaction task.
- 10 volunteer subjects. (age 20-30, student)
- Consent is taken.
- No prior information.
- 1-minute video.
- Avg time: 45 minutes.
- Video recording.
- Subject grading and expert evaluation.

HRI with Naïve Subject

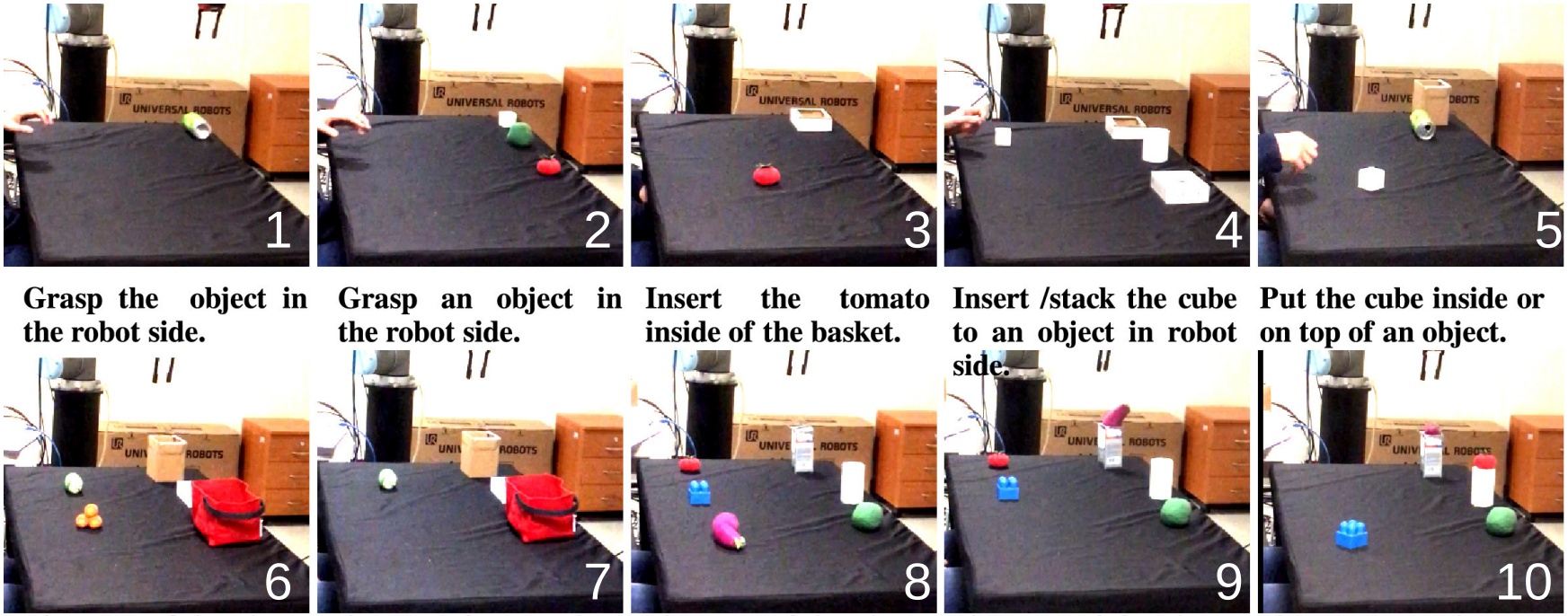


Figure 12: Example table setups.

Introduction : Altruism in Primates

HRI with Naïve subjects

Table 1: Grading of naïve subjects in the experiments on the altruistic helping behavior of the robot.

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	TM	TV
T1	5	5	5	5	4	5	3	4	5	4	4.5	0.71
T2	4	5	5	4	1	1	4	3	5	5	3.7	1.57
T3	4	4	5	5	5	4	4	5	3	1	4.0	1.25
T4	2	5	1	5	1	1	2	5	5	1	2.8	1.93
T5	3	2	5	5	1	5	4	2	3	2	3.2	1.48
T6	1	5	4	5	4	3	2	3	4	3	3.4	1.26
T7	5	4	2	3	5	3	2	4	5	1	3.4	1.43
T8	3	1	1	2	1	3	1	4	5	1	2.2	1.48
T9	2	5	5	5	4.5	5	3	2	5	4	4.05	1.26
T10	4	1	5	4	1	1	4	2	3	3	2.8	1.48
SM	3.3	3.7	3.8	4.3	2.7	3.1	2.9	3.4	4.3	2.5		
SV	1.3	1.7	1.7	1.0	1.8	1.6	1.1	1.1	0.9	1.5		

- High (4+) : 55%.
- Average (3): 15%.
- Low (2-): 30%.

- inference and help: 3.90 ± 0.91.
- speed and behavior: 2.75 ± 0.91.

HRI with naïve subjects

Table 2: Expert evaluation results of naïve HRI experiments.

Reason	**Naïve Subject Experiment Success Rates**
Successful execution	68.0%
Failure in affordance computation	1.00%
Failure in predicting the 1st obj	0.00%
Failure in predicting the 2nd obj	4.00%
Failure in planning	0.00%
Failure in execution	19.0%
Failure in human collaboration	8.0%

Outline

Conclusions

- HRI experiments : success in goal inference and autonomous completion of predicted action.
- Our results support our thesis. Altruistic behavior may emerge through basic sensorimotor processes

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- JST CREST "Cognitive Mirroring: Assisting people with developmental disorders by means of self-understanding and social sharing of cognitive processes", Japan (Grant No: JPMJCR16E2)
- Bogazici Research Fund (BAP) project IMAGINE-COG (Grant No: 12721)