











# **Project objectives**

- To understand how human spatial cognition works
  - To develop a theory of human spatial cognition based on solid psychological and neuroscience evidence.
  - To explore how to map the theory onto the ACT-R architecture as an addon spatial module.



#### The concept of space

- Physical space: the boundless extension of the field in which we, and everything else, physically reside and move around.
- Psychological space: representation of physical space in the brain and in the mind.
- The two are not identical: While the physical space appears perfectly three-dimensional, absolute, unified, symmetric, and Euclidean, it is well documented that the psychological space is often distorted, relative, asymmetric, hierarchical, and segmented.







 Spatial performance is determined by the interactions of multiple simultaneously available spatial representation, each with a distinctive FOR, and each containing a partial selection of all possible spatial information.



# **Exp1: Hypotheses**

To memorize object-to-object relations, people select at least one intrinsic reference system, which can be provided by a distinctive object. Then, memory is hierarchically organized according to such reference system.

Predictions: when retrieving the object relations from the memory, the reaction times should show a symmetrical pattern surrounding the anchoring object (hence referred to as "landmark"). Thus, reaction time is not always proportional to the corresponding physical distance. Rather, it is determined by the psychological distance in the hierarchical internal representation.

Salient Landmark	Non-salient Landmark
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	d Ma Sh



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The follo <u>ohysica</u> ncrease	owing groupir I world (for ex es).	ng methods ar kample, "group	re based on sp o number" incr	atial pro eases a	perties in th s "distance"	IE
	Group	# of pairs (28 total)	LM Linked [1]	L-O [2]	Distance (unit)	
	1	4	no	yes	1	
	2	8	no	no	1	
	3	4	no	yes	1.414	
	4	4	no	no	1.414	
	5	2	yes	no	2	
	6	4	no	no	2	
	7	2	yes	no	2.818	





Saliense eneorar group level	Salience	effect	at	"group	level"
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Group Level	Mean Difference (ms)	S.E.	t (13)	p (two-tailed) *
1	240.9	75.37	3.196	.007
3	142.4	53.74	2.650	.020
5	244.7	71.80	3.408	.004
6	290.4	94.54	3.072	.009

\* Comparisons of matched pairs across subjects, no correction for multiple comparisons.



### **Results – cont'd**

Significant differences between groups in pair-wise comparisons (*p* values were after Bonferroni adjustment for multiple comparisons):

Groups	Mean Difference (ms)	S.E.	Sig.
1, 4	- 519.36	89.75	.001
2, 3	324.58	85.72	.048
2, 4	- 314.23	78.03	.030
3, 4	- 638.81	100.78	.001
3, 5	- 263.09	40.74	.000
4, 5	375.72	82.86	.012
4, 6	480.30	81.71	.001
4, 7	531.34	98.76	.003





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	1			1		
Group	# per block	LM Linked [1]	L-0 [2]	Distanc e	Angle [3]	# per 2784 trials [4]
0	1	no	no	2	1	48
1-1 landmark-center	2	no	yes	1	1	96
1-2 vertical	4					192
1-3 horizontal	2					96
2-1 center-side	2	no	no	1	1	96
2-2 side-side	4					192
2-3, corner-side, horizontal	4					192
2-4, corner-side, vertical	4					192
3-1 center	4	yes	yes	1.414	2	192
3-2 corner	4					192
4-1 center	4	no	no	1.414	2	192
2-Apr	4					192
5-1 center-side, horizontal	2	yes	no	2	1	96
5-2, side-side, vertical	2					96
6-1, through center	1	no	no	2	1	48
6-2 corner-side	4					192
6-3 corner-corner	2					96
7	4	yes	no	2.828	2	192
8	2	no	no	2	1	96
9	2	no	no	2.828	2	96
total	58					2784



















Condition	Baseline	Retrieval	Retrieval- Baseline
From- what-to- where	676.1 (40.9)	1333.0 (101.0)	656.9 (89.0)
From- where-to- what	881.7 (46.4)	1796.9 (75.0)	915.2 (90.3)
Difference	-205.6 (46.9)	-463.9 (86.0)	-258.3 (101.0)



- Segregation of processing is a general principle underlying the brain's information processing. The issue is how different processing pathways interact and integrate.
- The experiment results suggest that the underlying symbolic representations of what and where information are not symmetric. Some information is readily retrievable and other may have to be computed online.



















#### Interpretations

- Salience Effect : Updating of object-to-object relations is affected by the behavioral significance of the target objects.
- 2. Salience effect is contingent on the establishment and maintenance of a reference system.
- Updating in intrinsic system is not automatic.
   two sequentially related components:
  - A. Establishing and maintaining a frame of reference.
  - B. Updating the object-to-object relations.











Result	S			
<ul> <li>9 subje</li> </ul>	ects, all co	nflict effe	ects are si	ignificant.
-		dista	ance	-
		dista 18	ance 27	-
		dista 18 675.6	ance 27 660.2	-
	- congru incongru	dista 18 675.6 714.4	ance 27 660.2 684.0	-
-	congru incongru difference	dista 18 675.6 714.4 38.8*	ance 27 660.2 684.0 23.8*	-
-	congru incongru difference	dista 18 675.6 714.4 38.8*	ance 27 660.2 684.0 23.8*	- - -
-	- congru incongru difference	dista 18 675.6 714.4 38.8*	ance 27 660.2 684.0 23.8*	-









			Static	Dynamic
_	Primary learning (Physical exploration		A +Is the cup on the table? +John is standing next to Mary, and Mary is in front of Jack	B *Go buy a cup of coffee and come back *Move forward two steps, turn 180 degrees, move forward five steps, stop, where are you now?
Spatial task	Secondary learning (Spatial artifacts)	Non- immersed	C •On the map, which city, A or B, is closer to city C? •On the radar, where is aircraft 1063 relative to aircraft 2064? After aircraft 2064 moves, what is their relationship?	D Not interesting (i.e., an outside space is stable, independent of the movement of the non- immersed observer).
taxonomy		Immersed	E •Pretend you are a character in a 3D game, point your gun at your enemy. •Pretend you are in the submarine on the radar screen, where is your enemy?	F •Pretend you are a character in a 3D game, go to the room with the fountain, then the control room, and then go back to your starting room. •Pretend you are in the submarine on the radar screen, find a way to reach location A.



