

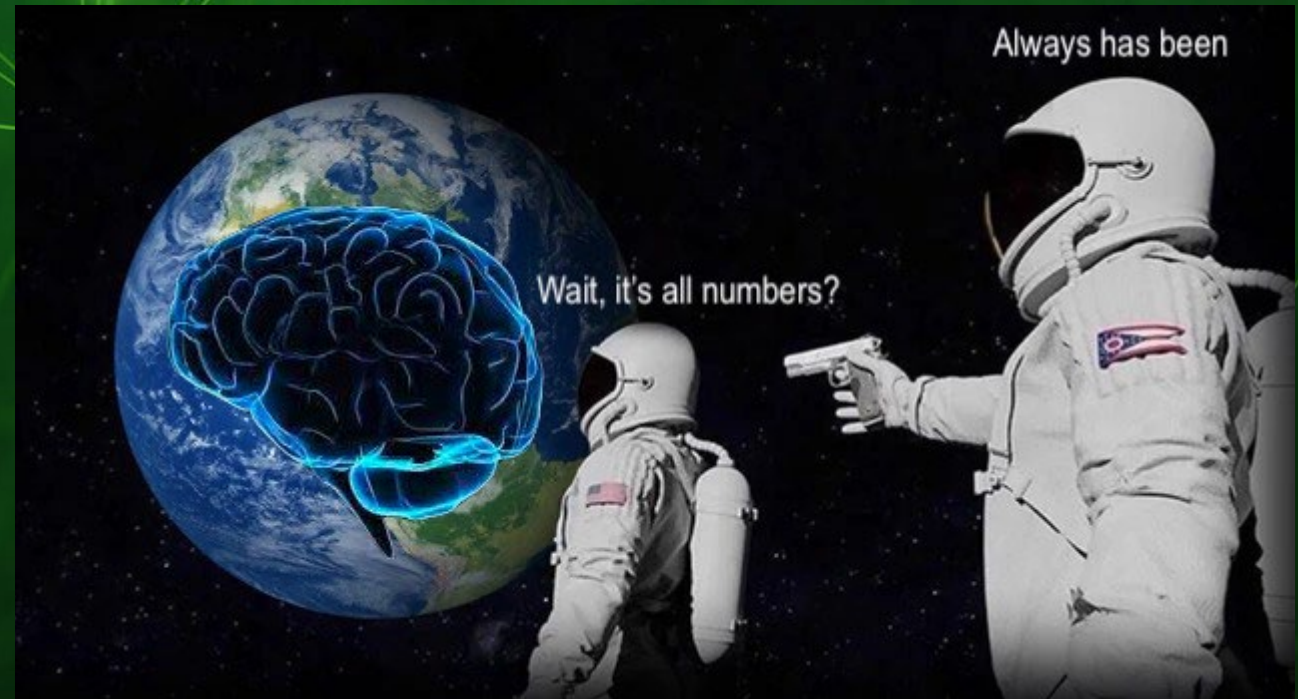
# INTRO TO NEUROIMAGING & DATA SCIENCE: WORKING WITH NUMBERS IN SPACE

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IOWA NEUROIMAGING CONSORTIUM

INC BOOTCAMP 2022

05/23/2022



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THE GOAL OF  
NEUROIMAGING IS  
TO LOOK INSIDE  
SOMEONE'S HEAD,  
AND QUANTIFY  
HOW THE BRAIN IS  
BUILT AND WHAT  
THE BRAIN IS  
DOING - T. KOSCIK



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THE KEY THING TO  
REMEMBER IS THAT  
THIS BRAIN  
ACTIVITY IS JUST  
NUMBERS  
RECORDED BY A  
MACHINE



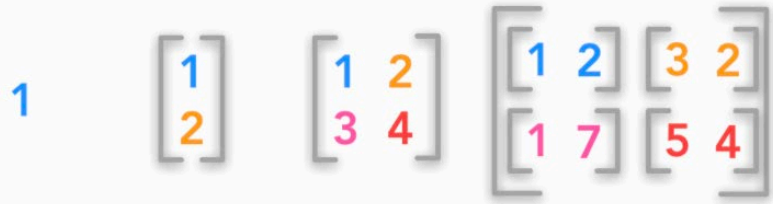
# NUMBERS REPRESENTED IN SPACE

The image is a collage of mathematical content overlaid on a background of a woman's face. The content includes:







- Circle:** A diagram of a circle with radius  $r$ .  
Formulas:  $A = \pi r^2$  and  $C = 2\pi r$ .
- Cone:** A diagram of a cone with radius  $r$  and height  $h$ .  
Formula:  $V = \frac{1}{3} \pi r^2 h$ .
- Cylinder:** A diagram of a cylinder with radius  $r$ .  
Formula:  $V = \pi r^2 h$ .
- Trigonometry Table:**

	30°	45°	60°
sin	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$
cos	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$
tan	$\frac{\sqrt{3}}{3}$	1	$\sqrt{3}$
- Right Triangle:** A right-angled triangle with angles 30°, 45°, and 60°. The sides are labeled  $x$ ,  $x\sqrt{3}$ , and  $x\sqrt{2}$ .
- Integration Formulas:**
  - $\int \sin x dx = -\cos x + C$
  - $\int \frac{dx}{\cos^2 x} = \tan x + C$
  - $\int \tan x dx = -\ln|\cos x| + C$
  - $\int \frac{dx}{\sin x} = \ln|\frac{x}{2}| + C$
  - $\int \frac{dx}{a^2 + x^2} = \frac{1}{a} \arctg \frac{x}{a}$
  - $\int \frac{dx}{x} = \frac{1}{x} \ln|x| + C$
- Graph:** A graph of the tangent function  $\tan(\theta)$  with the vertical axis labeled  $\theta/\text{rad}$ .
- Quadratic Equations:**
  - $ax^2 + bx + c = 0$
  - $a(x^2 + \frac{b}{a}x + \frac{c}{a}) = 0$
  - $x^2 + 2\frac{b}{2a}x + (\frac{b}{2a})^2 - (\frac{b}{2a})^2 + \frac{c}{a} = 0$
  - $(x + \frac{b}{2a})^2 - \frac{b^2 - 4ac}{4a^2} = 0$

Scalar    Vector    Matrix    Tensor



*Difference between a scalar, a vector, a matrix and a tensor*

				Vertices	Edges	Faces	Cells	
0-D	Point	•	○	1				
1-D	Line	—	- -	2	1			
2-D	Square			4	4	1		
3-D	Cube			8	12	6	1	
4-D	Hypercube			16	32	24	8	1

# NUMBERS IN DIFFERENT DIMENSIONS

- Numbers in space can represent data in any dimension
- All of these are tensors
  - E.g. Rank 0 tensor, Rank 1 tensor, etc.

# WHAT CAN NUMBERS IN SPACE REPRESENT

- Anything!



What we see

25 43 11 04 70 87 12 31 43 10 05 77 12 06 45 09 29 30 02  
 56 22 75 03 22 96 45 12 23 03 77 67 81 45 22 04 90 22 21  
 32 45 41 91 87 62 35 02 00 11 62 25 43 11 04 70 87 12 61  
 31 43 10 05 77 12 06 45 09 29 30 56 22 75 03 22 96 45 05  
 12 23 03 77 67 81 45 22 04 90 22 32 45 41 91 87 62 35 44  
 02 00 11 62 25 43 11 04 70 87 12 31 43 10 05 77 12 06 10  
 45 09 29 30 56 22 75 03 22 96 45 12 23 03 77 67 81 45 55  
 22 04 90 22 32 45 41 91 87 62 35 02 00 11 62 25 43 11 80  
 04 70 87 12 31 43 10 05 77 12 06 45 09 29 30 56 22 75 08  
 03 22 96 45 12 23 03 77 67 81 45 22 04 90 22 32 45 41 99  
 91 87 62 35 02 00 11 62 22 01 00 72 65 23 01 00 22 04 30  
 90 22 32 45 41 91 87 62 35 02 00 11 62 25 43 11 04 70 42  
 87 12 31 43 10 05 77 12 06 45 09 29 30 56 22 75 03 22 91  
 96 45 12 23 03 77 67 81 45 22 04 90 22 32 45 41 91 87 40  
 62 35 02 00 11 62 22 01 00 72 65 23 01 00 56 22 75 03 67  
 22 96 45 12 23 03 77 67 81 45 22 04 90 22 32 45 41 91 22

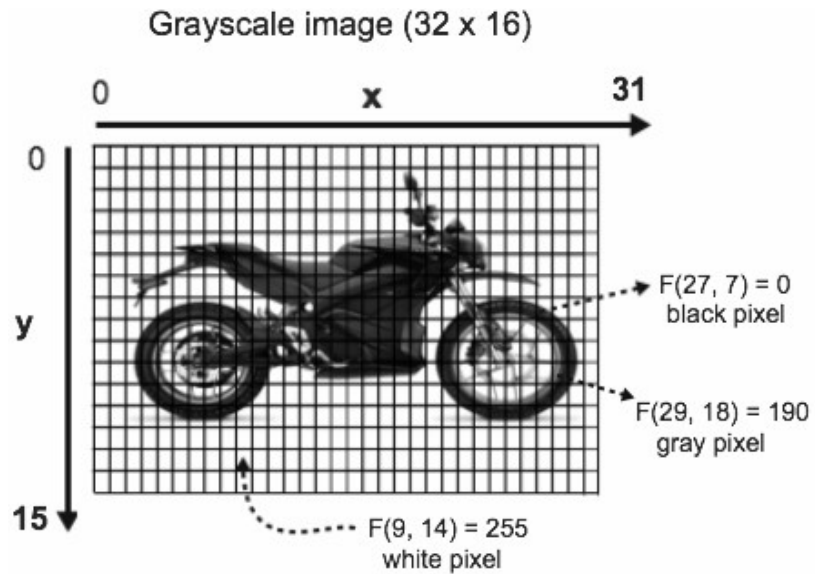
What computers see

	1	2	3	4	5	6	7	8	9	10	
A	10	15	19	21	22	22	21	19	15	10	A
B	15	20	24	26	27	27	26	24	20	15	B
C	19	24	28	30	31	31	30	28	24	19	C
D	21	26	30	32	33	33	32	30	26	21	D
E	22	27	31	33	34	34	33	31	27	22	E
F	22	27	31	33	34	34	33	31	27	22	F
G	21	26	30	32	33	33	32	30	26	21	G
H	19	24	28	30	31	31	30	28	24	19	H
I	15	20	24	26	27	27	26	24	20	15	I
J	10	15	19	21	22	22	21	19	15	10	J
	1	2	3	4	5	6	7	8	9	10	

	A	B	C	D	E	F	G	H	I	J
1								█		
2			█	X	X					
3			█	X						
4			█				█	█	█	█
5										
6	█								X	
7	█							X		
8				█				X		
9										█
10	█	█	█	█						█

# DIFFERENT WAYS NUMBERS CAN REPRESENT IMAGES

## Grayscale

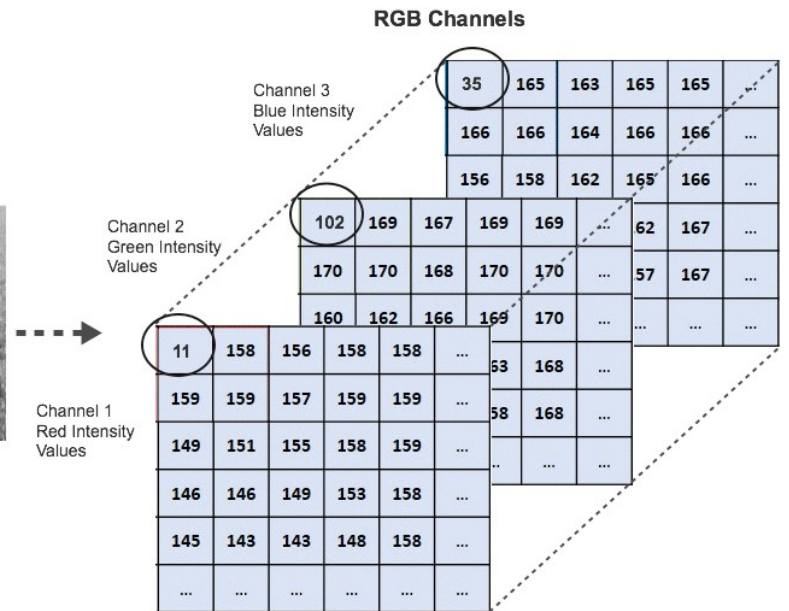


## RGB

$$F(0, 0) = [11, 102, 35]$$



Color Image



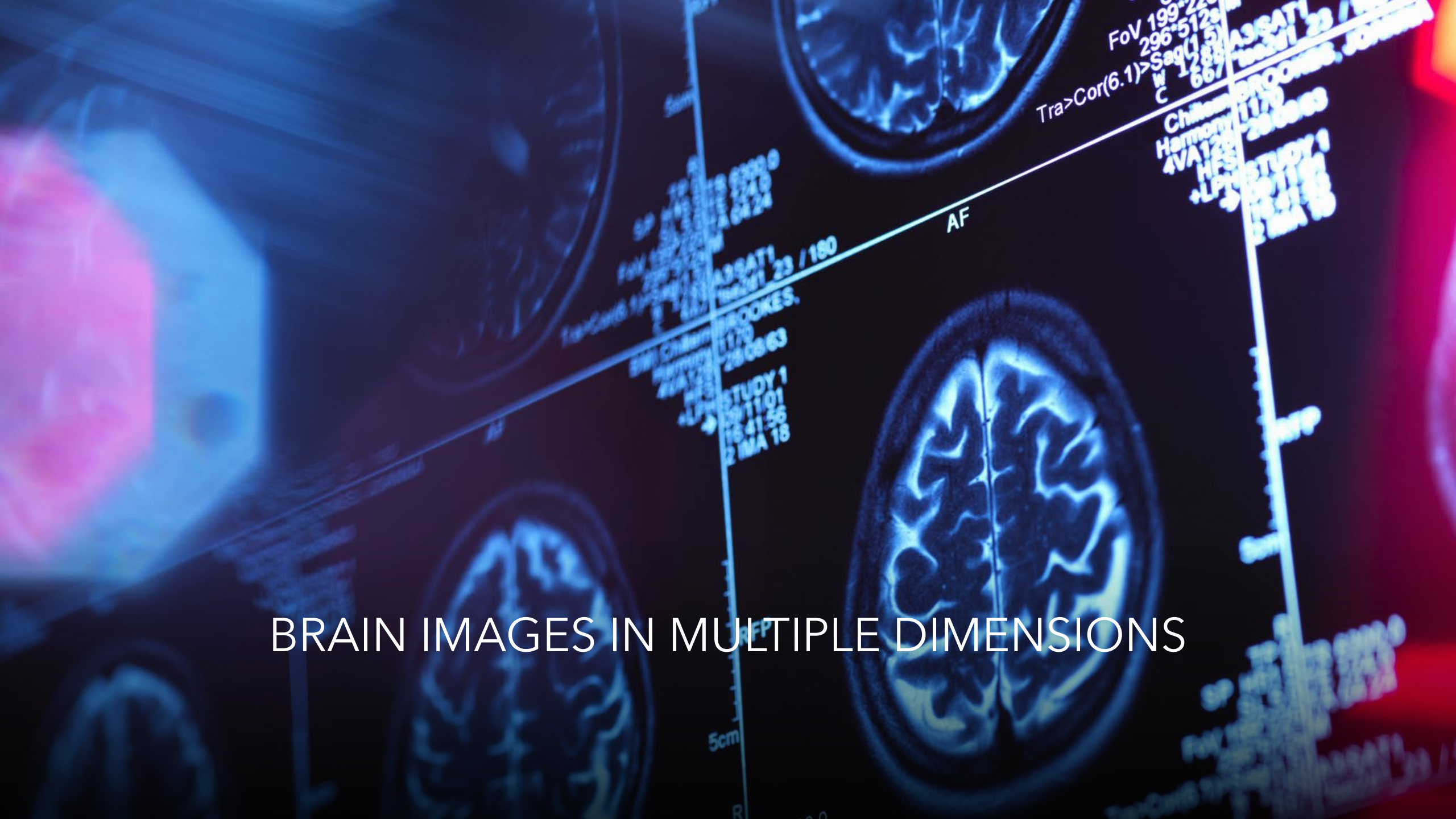
(pretend this pic is in color with green grass, I guess)









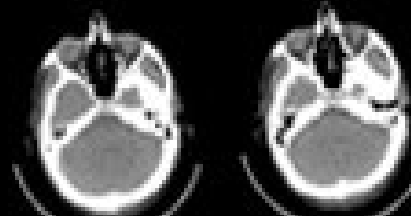
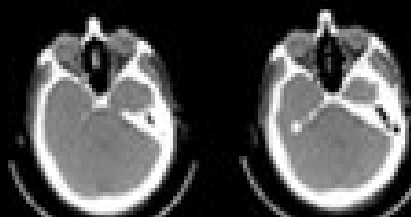
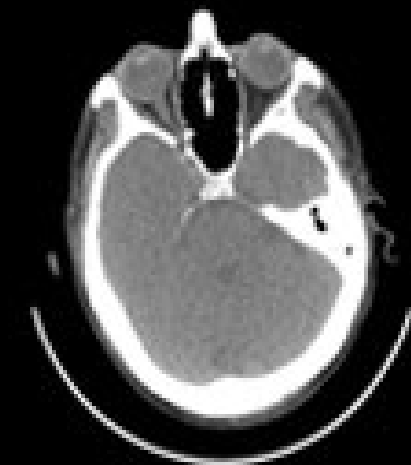


# BRAIN IMAGES IN MULTIPLE DIMENSIONS

## EXAMPLES OF IMAGES IN DIFFERENT DIMENSIONS

- 1d - A line
- 2d - static image of x,y coordinates
- 3d - x,y,z spatial dimensions
- 4d - 3 spatial dims. + time
- 5d & higher - possible

2D



3D



4D

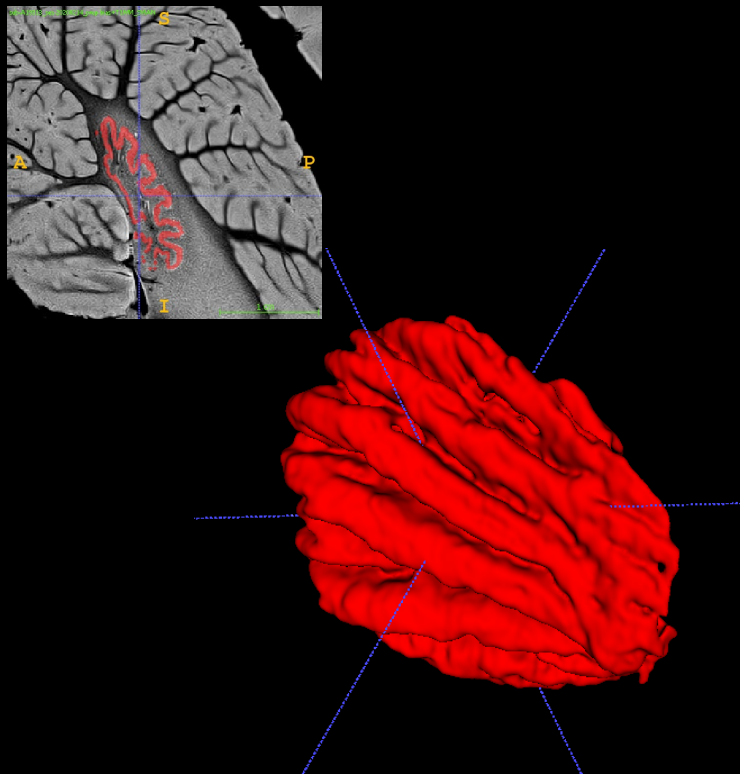


-Time  
-Motion

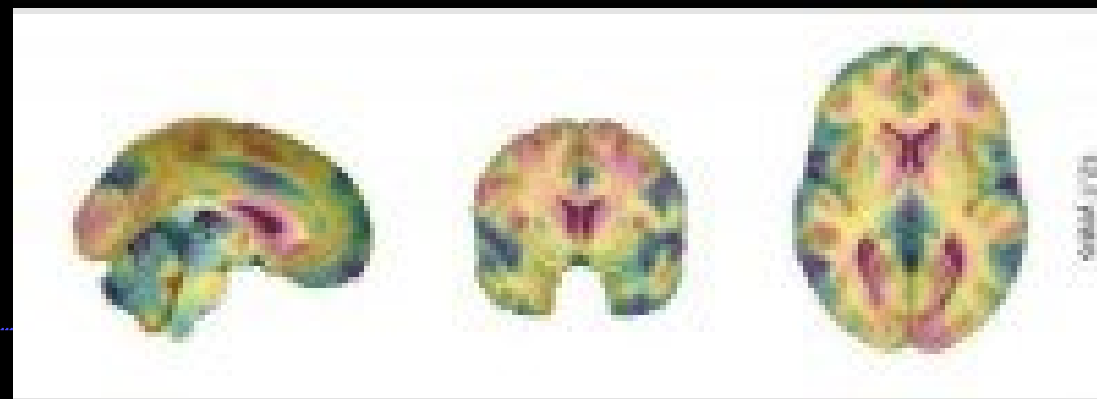
2D projections  
for angiograms

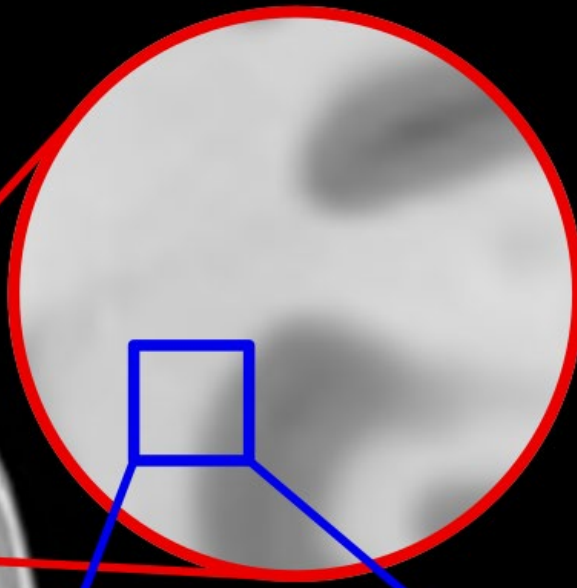
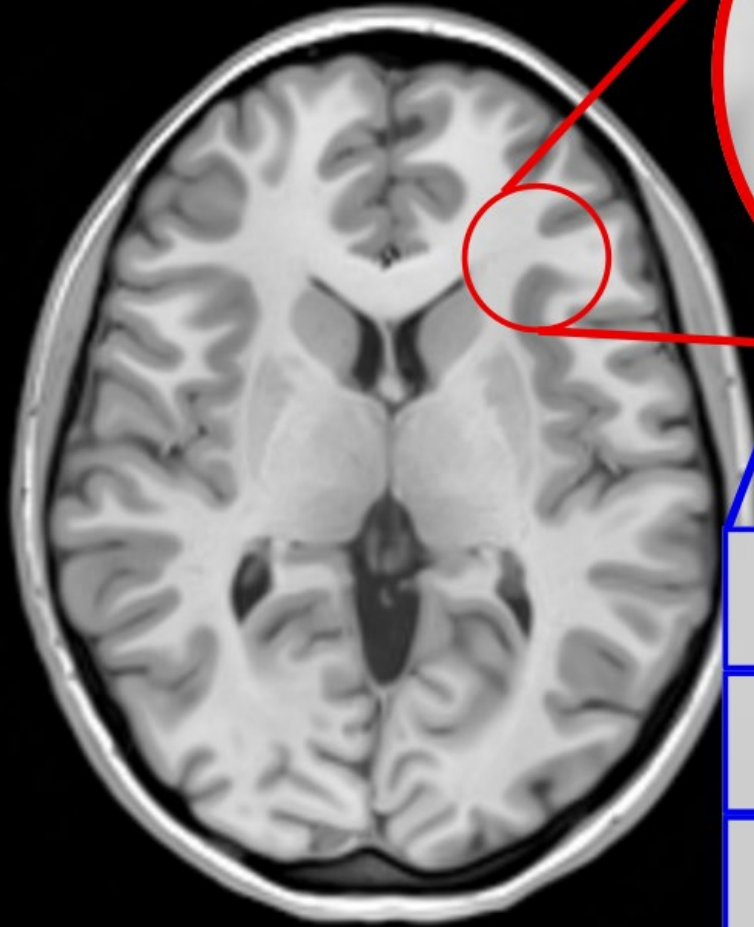


3D reconstruction  
of the Dentate  
Gyrus



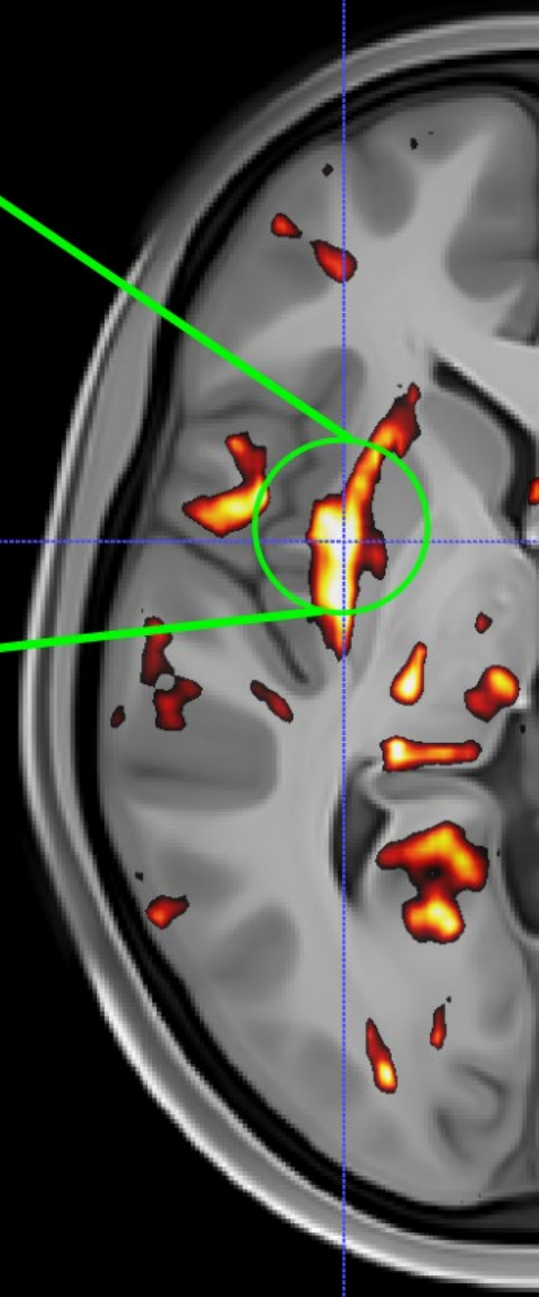
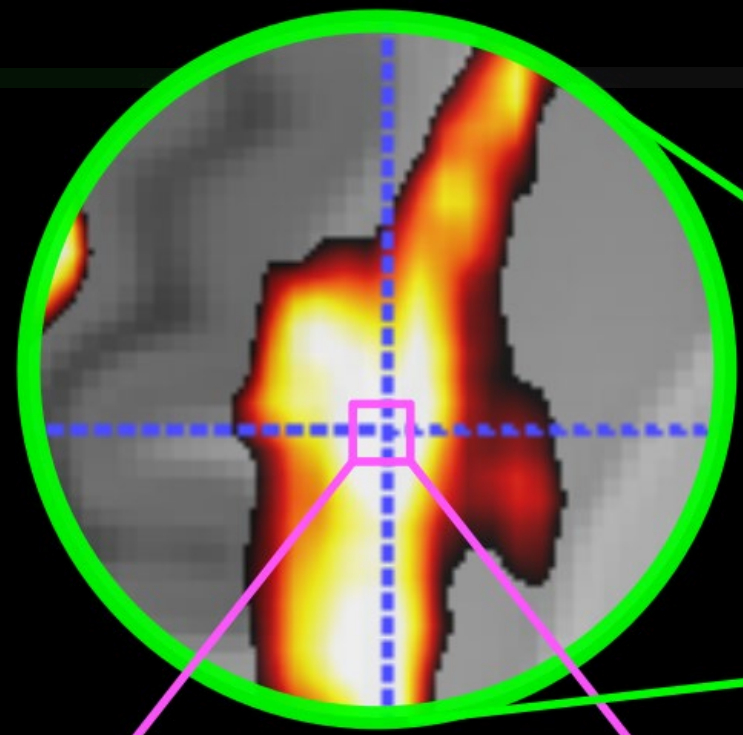
4D representation  
of anatomical  
change with age

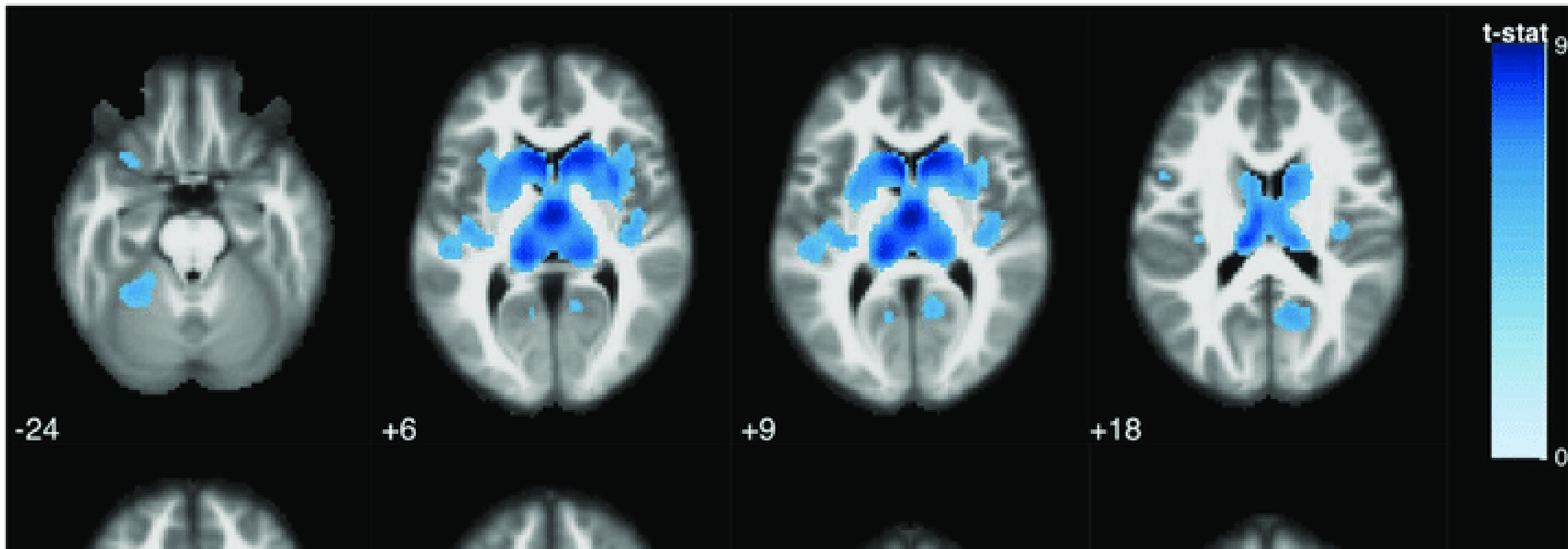




205	202	200	182
206	205	195	151
205	203	174	140
205	201	158	134







VALUES OF A 3D IMAGE  
CAN REPRESENT MANY  
THINGS

- Raw intensity values
- Statistics: t-stats (above), f-stats, p-values
- A parcellated atlas

+20

+33

+57

+52





# TIME FOR AN AWKWARD BRAIN EXAMPLE

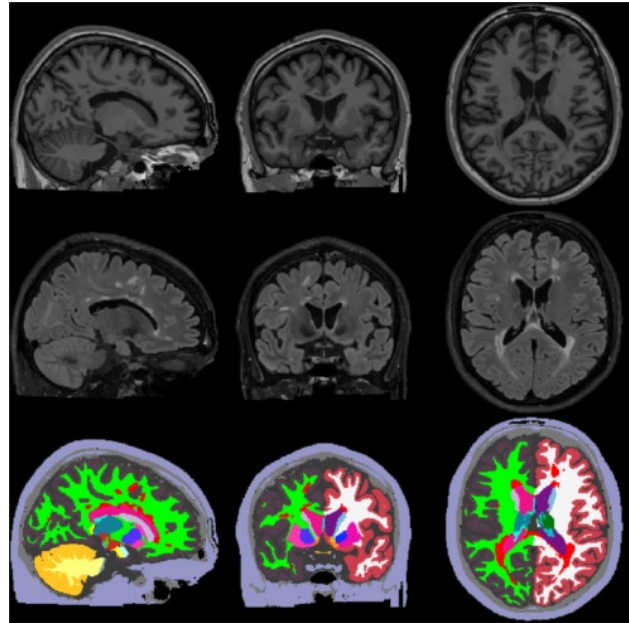
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LOOKING AT DATA IN REAL TIME



# BASIC IMAGING STATISTICS

Statistical analyses are often just paring down multidimensional brain data to single representative values

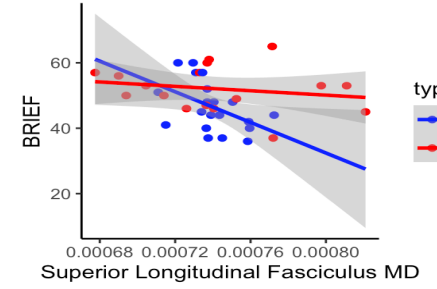
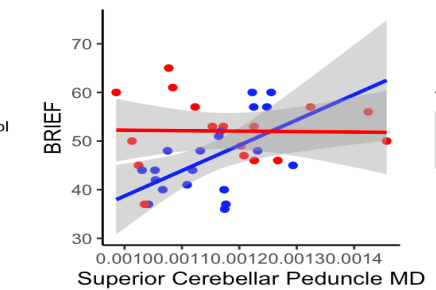
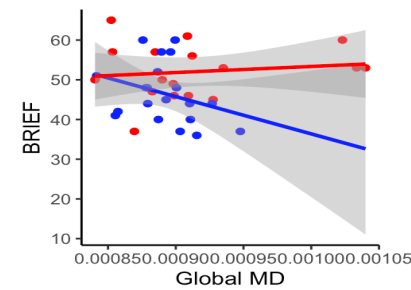


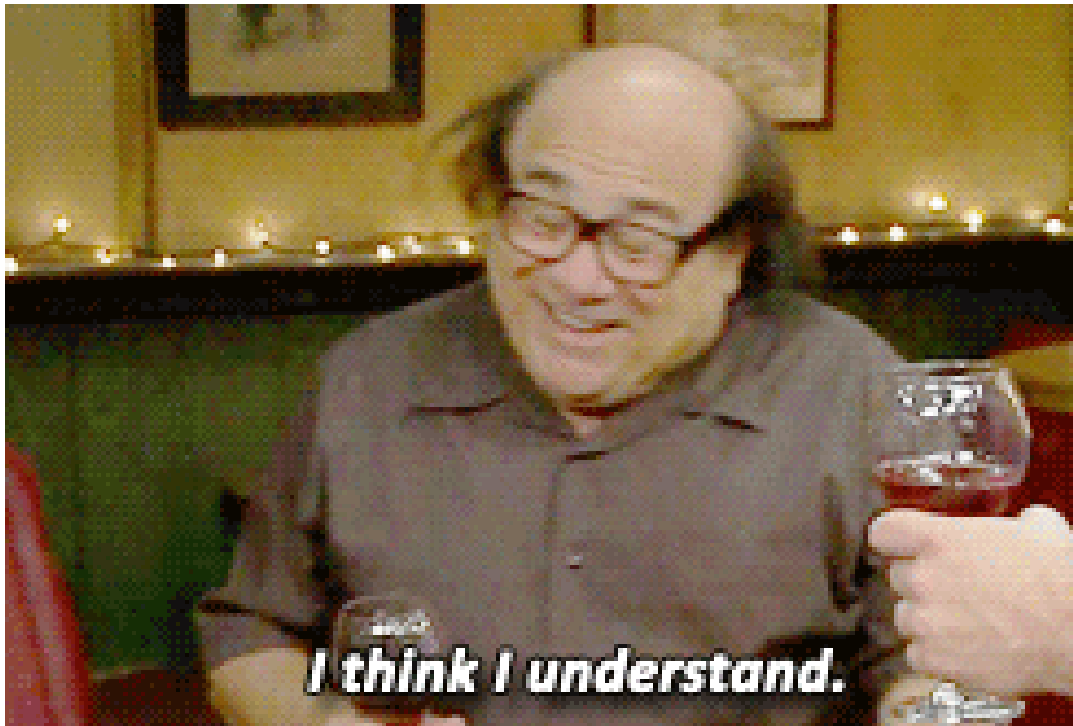
copd\_bids\_volume\_label-sameg

Home Insert Draw Page Layout Formulas Data Review View Tell me

Possible Data Loss Some features might be lost if you save this workbook in the text (.txt) format. To preserve these features, save it in an Excel file format.

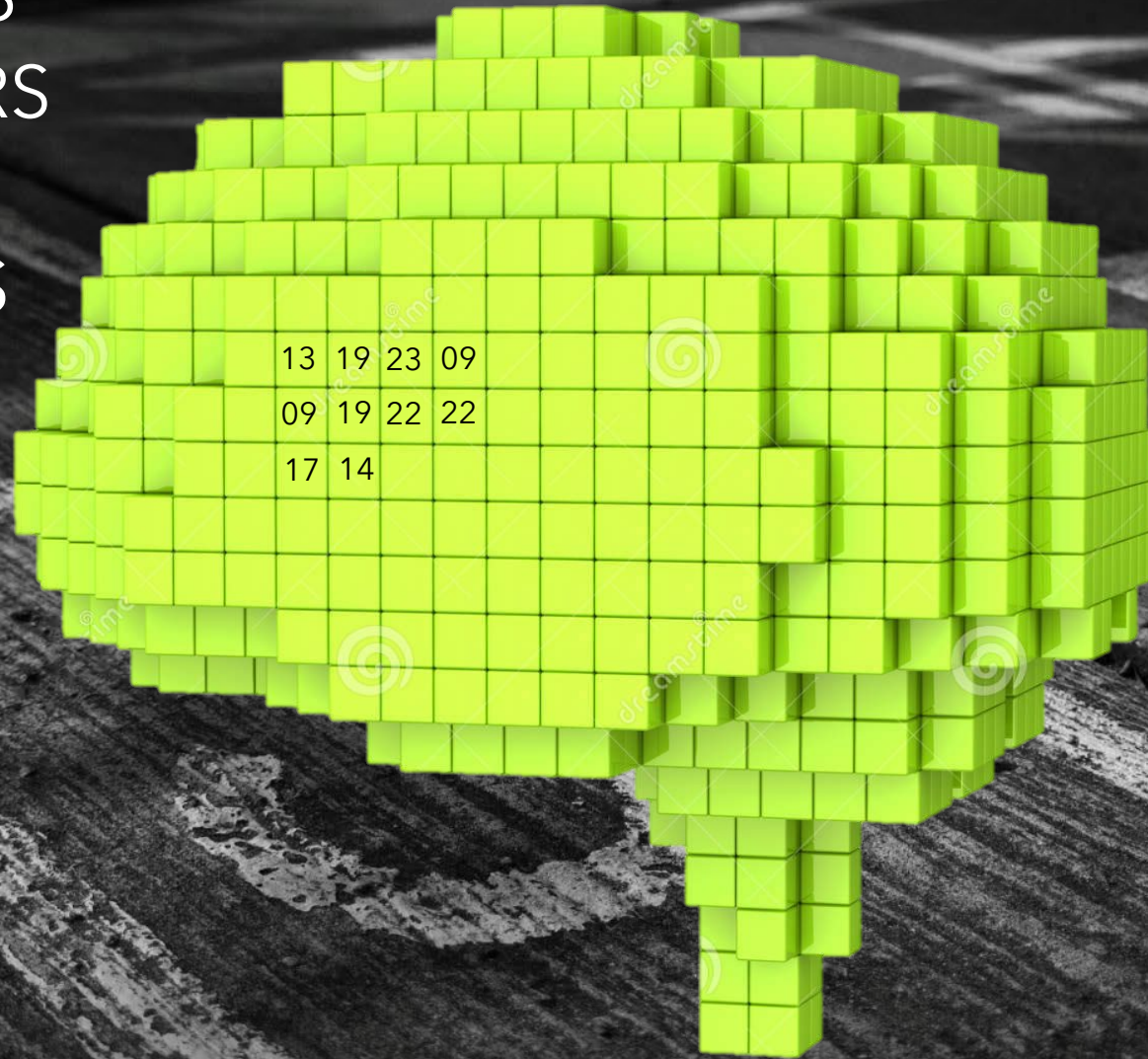
AV1	AM	AN	AO	AP	AQ	AR	AS	AT	AU	AV	AW	AX	AY	AZ	BA	BB	BC	BD	BE	BF	
Hippocampus	Hippocampus	Hippocampus	amygdala	amygdala	ri_ventral	diem_ventral	diem_ventral	diem_brainstem	wm_hypercentensity	optic_chiasm	choroid	plex_choroid	glnx_choroid	plex_vessel	vessel_left	vessel_right	vessel_csf_total	csf_extradur_ventricl			
1	8058	3917	4141	3495	1675	1820	5998	2997	3001	15733	2686	150	3813	1706	2107	159	78	81	363922	340146	2
2	8704	4881	4923	3170	1530	1640	6122	3023	3099	19747	10588	101	1269	472	797	98	29	69	443109	421364	2
3	7193	3534	3659	3325	1517	1808	4888	2480	2408	16972	19054	161	3075	1246	1829	107	68	39	443994	417915	2
4	6795	3242	3553	2703	1322	1381	3764	1869	1895	14412	1881	125	3172	1389	1803	55	21	34	340871	322240	2
5	7881	3807	4074	3351	1652	1699	6118	3016	3102	19507	6501	137	2727	1121	1606	161	81	80	353311	333045	1
6	6275	3169	3106	2370	1138	1242	4054	2240	2214	15016	3123	134	2797	1211	1586	126	47	79	334691	312222	1
7	7955	3992	3963	2759	1301	1458	4935	2490	2445	18179	3420	155	4083	1956	2127	121	65	56	432165	408058	2
8	8118	3464	3354	3264	1552	1712	4985	2462	2523	16292	6218	130	6073	2840	3233	100	58	42	469016	429295	3
9	9592	4723	4869	4270	2029	2241	7433	3589	3844	21917	3876	72	4384	2033	2351	66	38	28	438342	412000	2
10	7899	3517	4382	3226	1888	1888	5248	2578	2670	17630	7833	157	6225	3200	2975	61	48	13	467057	429511	3
11	8818	3464	3354	3264	1552	1712	4985	2462	2523	16292	6218	130	6073	2840	3233	100	58	42	469016	429295	3
12	8602	4097	4505	4269	2066	2203	5884	3078	2906	20780	8266	182	5282	2647	2825	112	53	59	492111	459971	3
13	8593	4322	4271	3532	1729	1803	6296	3233	3063	18906	1355	121	2372	976	1396	109	55	54	419135	400438	1
14	7472	3002	3970	3151	1547	1604	5004	2592	2462	17697	7102	159	6353	3088	2265	63	47	16	480445	443667	3
15	8042	3905	4137	3575	1717	1858	6498	3168	21098	1917	103	3554	1561	1993	113	77	36	472206	462765	2	
16	8369	4100	4269	4035	2076	1959	6684	3425	3259	21586	4216	59	4646	2136	2510	105	84	21	492975	464355	2
17	8887	4288	4599	3825	1876	1949	6540	3374	3166	22367	2424	172	6668	3194	3474	120	57	63	575858	526930	4
18	8511	4115	4396	3806	1847	1959	6680	3370	3310	22456	7608	207	6134	3048	3086	90	62	28	512659	476912	3
19	7721	3664	4057	3257	1573	1684	5659	2884	2775	20505	4347	146	7784	3607	4177	130	58	72	474877	427600	2
20	7566	3820	3746	3120	1640	1480	6066	3185	21883	10300	117	6768	3058	3710	115	70	45	462165	422720	3	
21	7405	3670	3735	3246	1606	1640	4709	2335	2374	16001	1228	117	4846	2350	2596	86	50	39	414611	386293	2
22	8646	4205	4441	3742	1799	1943	5802	2893	2909	20628	2892	184	3810	1779	2031	137	102	35	407273	384344	2
23	9191	4308	4883	3578	1738	1840	6957	3637	3320	22453	4561	194	7590	3352	4238	156	130	426	586889	537585	4
24	7765	3918	3847	3509	1711	1798	4684	2402	2282	17322	4907	144	3355	1412	1938	151	81	70	475928	452877	2
25	7881	3910	3971	3385	1629	1756	4856	2277	2579	17364	1546	121	2825	1375	1450	83	53	30	362787	347505	1
26	8713	4189	4524	3588	1765	1823	5490	2654	2845	16975	4162	169	3255	1439	1815	296	152	54	429336	406466	2
27	8654	4380	4274	3112	1627	1485	6687	3412	3275	20101	12102	138	8468	3761	4707	70	45	25	588390	535358	5
28	8975	4367	4608	3188	1545	1643	6854	3612	3342	22636	2226	134	1799	823	976	20	16	4	350827	334266	1
29	9486	4101	4385	3267	1587	1680	6209	3306	2903	21309	27557	139	7878	3654	4224	74	44	30	578944	51641	5
30	7238	3394	3844	2867	1361	1506	5777	2904	2973	18369	42028	100	2270	988	1282	61	33	28	391906	38223	2
31	7644	3699	3945	3377	1671	1706	5220	2734	2486	18784	3650	141	6468	3104	3364	87	48	39	487144	446336	4
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33	8206	3915	4091	3792	1851	1941	5845	3004	2841	21742	4784	128	9517	4379	5148	102	69	33	510722	502222	6
34	7150	3609	3541	2798	1340	1458	5756	2904	2852	19787	2022	117	4875	2202	2673	50	26	24	463717	430288	2
35	9498	4724	4774	3440	1643	1797	6591	3316	3275	19774	5920	146	1851	761	1090	203	93	110	355373	337839	1
36	8678	4231	4447	3422	1739	1883	6340	3256	3084	19702	2803	169	3365	1361	2004	98	58	40	495840	468139	2
37	7994	4103	3893	3246	1637	1729	6533	3320	3199	19306	8929	174	7286	1009	2517	68	31	37	435143	402962	2





ANY QUESTIONS?

"ALL IT IS IS CUBES  
MADE OF NUMBERS  
MY DUDES." -  
LAUREN HOPKINS



13 19 23 09  
09 19 22 22  
17 14

TAKE HOME MESSAGE