GDC | March 20-24, 2023
San Francisco, CA

"GOOD NUMBERS"
IN GAME DESIGN

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#GDC23 *Game Developer's Conference, March 24th 2023*

AGENDA

- Games are filled with *numbers* (& why that might be)
- Numbers have their own distinct aesthetic qualities
- We can make deliberate choices about the numbers in our games (and should do so)
- Some practical examples thereof to use in your own work

Tommy (1975)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	Rarity	Effect	Notes	Rank 0	Rank 1	Rank 2	Rank 3	Rank 4	Rank 5	Rank 6	Rank 7	Rank 8	Rank 9	Rank 10	Rank 11	Rank 12	Rank 13	Rank 14	Rank
2	Common	Speed	Change these to match	1	1	3	4	7	14	30	68	160	396	1024	2048	4096	8192	16384	327
3	Common	Payout		1	2	3	4	7	14	30	68	160	396	1024	2048	4096	8192	16384	327
4	Epic	Speed	Effect all generators	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	7E+07	3E+08	1E+
5	Epic	Payout	Effect all generators	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	7E+07	3E+08	1E+
6	Epic	Discount	Effect all generators	1	2	4	8	16	32	64	128	256	512	1024	2048	4096	7E+07	3E+08	1E+
7	Rare	Click		0	0.4	0.8	1.2	1.6	2	3	4	6	9	13	18	24	31	39	
8	Rare	Payout	1 card per class (moons	1	4	8	16	32	64	128	256	512	1024	2048	4096	8192	2E+06	5E+06	1E+
9	Rare	Payout - Sol	Solar Winds Only	1	4	8	16	32	64	128	256	512	1024	2048	4096	8192	1E+09	6E+09	3E+
10																			
11				1	5	25	125	625	3125	15625	78125	390625	2E+06	1E+07	5E+07	2E+08	1E+09	6E+09	3E+
12																			
13				1	2	4	8	16	32	64	128	256	512	1024	2048	4096	8192	16384	327
14																			

HOW DO YOU PICK SOME GOOD NUMBERS TO START WITH?

GOOD NUMBERS

GOOD NUMBERS TO START WITH

Mission ID codes | CB Pricing | SpeedCalc | ValuePerType | Rank Amts | Constellations TODO | progressions | how many rank ups | card economy | economy map | expo scrap | how

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W
25																							
26																7.860596884							
27																							
28																							
29																							
30																							
31																							
32				1	5	15	35	70	126	210	330	495	715	1001	1365	1820	2380	3060	3876	4845	5985	7315	8855
33																							
34																							
35																							
36				0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
37			2^x	1	2	4	8	16	32	64	128	256	512	1,024	2,048	4,096	8,192	16,384	32,768	65,536	131,072	262,144	524,288
38			3^x	1	3	9	27	81	243	729	2,187	6,561	19,683	59,049	177,147	531,441	1,594,323	4,782,969	14,348,907	43,046,721	129,140,163	387,420,489	1,162,261,467
39			4^x	1	4	16	64	256	1,024	4,096	16,384	65,536	262,144	1,048,576	4,194,304	16,777,216	67,108,864	268,435,456	1,073,741,824	4,294,967,296	17,179,869,184	68,719,476,736	274,877,906,944
40			5^x	1	5	25	125	625	3,125	15,625	78,125	390,625	1,953,125	9,765,625	48,828,125	244,140,625	1,220,703,125	6,103,515,625	30,517,578,125	152,587,890,625	762,939,453,125	3,814,697,265,625	19,073,486,328,125
41			x^2	-	1	4	9	16	25	36	49	64	81	100	121	144	169	196	225	256	289	324	361
42			x^3	-	1	8	27	64	125	216	343	512	729	1,000	1,331	1,728	2,197	2,744	3,375	4,096	4,913	5,832	6,859
43			x^4	-	1	16	81	256	625	1,296	2,401	4,096	6,561	10,000	14,641	20,736	28,561	38,416	50,625	65,536	83,521	104,976	130,321
44			x^5	-	1	32	243	1,024	3,125	7,776	16,807	32,768	59,049	100,000	161,051	248,832	371,293	537,824	759,375	1,048,576	1,419,857	1,889,568	2,476,099
45																							
46																							
47	Constant	a, ar, ar^2, ar^3, ar^4 … wl			23.131	26.6	30.59023	35.1787629	40.45557736	46.52391396	53.50250105	61.52787621	70.75705764	81.37061629	93.57620874	107.61264	123.7545361	142.3177165	163.6653739	188.21518	216.447457	248.9145756	286.2517619
48	Constant	An = Am + (n-m)d, or for r			1	3	5	7	9	11	13	15	17	19	21	23	25	27	29	31	33	35	37
49	Triangular				1	3	6	10	15	21	28	36	45	55	66	78	91	105	120	136	153	171	190
50	Tetrahedr	(a pyramid)			1	4	10	20	35	56	84	120	165	220	286	364	455	560	680	816	969	1140	1330
51	Pentatope (further powers are pasc				1	5	15	35	70	126	210	330	495	715	1001	1365	1820	2380	3060	3876	4845	5985	7315
52	Square Numbers				1	4	9	16	25	36	49	64	81	100	121	144	169	196	225	256	289	324	361
53	Pentagonal Number				1	5	12	22	35	51	70	92	117	145	176	210	247	287	330	376	425	477	532
54	Hexagonal Number				1	6	15	28	45	66	91	120	153	190	231	276	325	378	435	496	561	630	703
55	Septogonal Numbers				1	7	18	34	55	81	112	148	189	235	286	342	403	469	540	616	697	783	874
56	Pronic				2	6	12	20	30	42	56	72	90	110	132	156	182	210	240	272	306	342	380

GOOD NUMBERS TO START WITH

Level Up Rewards Table

Note: "Chapters" here refers to the unit EXP is measured in. It's not the same as literal 'chapters completed' because you get bonus chapters for completing volumes (see tab EXP_ChapterPayoutAmounts)

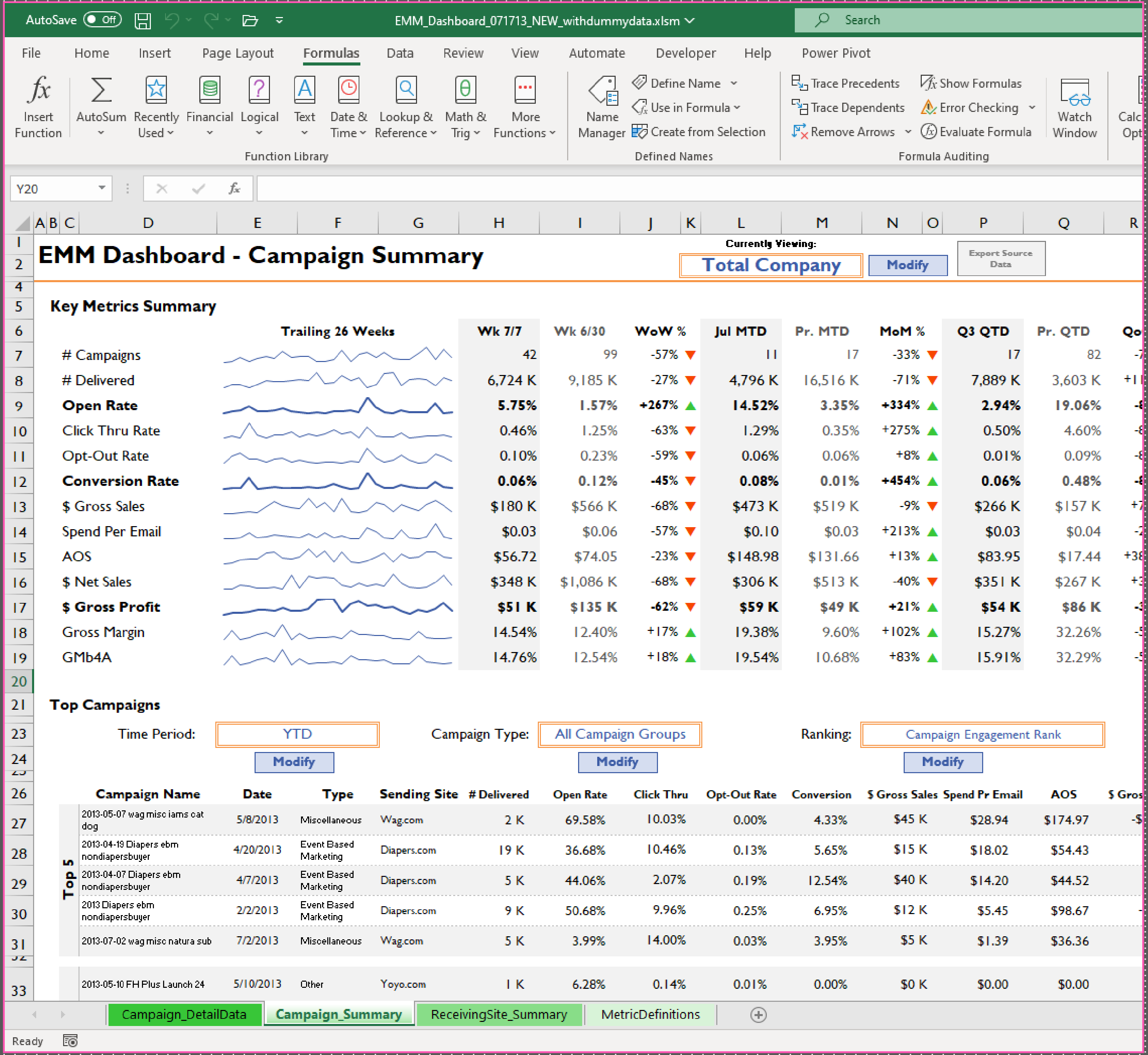
Note: Player starts at level 1, with FILL unlocked.

Player Level	Incremental Chapters (Chapters to Reach Thi	Cumulative Chapters (Total Chapters to Reac	Unlocks Puzzle Mode	Unlock Type	Ink Reward
1	0	0	FILL	Puzzle	
2	2	2	REARRANGE	Puzzle	
3	3	5	SWAP	Puzzle	
4	3	8	SPELLCHECK	Puzzle	
5	4	12		Ink	4,000
6	4	16		Ink	2,000
7	4	20	SEQUENCE	Puzzle	
8	4	24		Ink	750
9	4	28	CROSSOUT	Puzzle	
10	4	32		Ink	500
11	4	36	FILL TWO	Puzzle	
12	6	42		Ink	500

CODE FOR PETER

```
all.append(LWPlayerRank(rank: 1, xp: 0, rewardType: .MODE, modeUnlocked: .FILL, inkAmount: 0))
all.append(LWPlayerRank(rank: 2, xp: 2, rewardType: .MODE, modeUnlocked: .REARRANGE, inkAmount: 0))
all.append(LWPlayerRank(rank: 3, xp: 5, rewardType: .MODE, modeUnlocked: .WORD_SWAP, inkAmount: 0))
all.append(LWPlayerRank(rank: 4, xp: 8, rewardType: .MODE, modeUnlocked: .SPELLCHECK, inkAmount: 0))
all.append(LWPlayerRank(rank: 5, xp: 12, rewardType: .INK, modeUnlocked: nil, inkAmount: 4000))
all.append(LWPlayerRank(rank: 6, xp: 16, rewardType: .INK, modeUnlocked: nil, inkAmount: 2000))
all.append(LWPlayerRank(rank: 7, xp: 20, rewardType: .MODE, modeUnlocked: .SEQUENCE, inkAmount: 0))
all.append(LWPlayerRank(rank: 8, xp: 24, rewardType: .INK, modeUnlocked: nil, inkAmount: 750))
all.append(LWPlayerRank(rank: 9, xp: 28, rewardType: .MODE, modeUnlocked: .CROSSOUT, inkAmount: 0))
all.append(LWPlayerRank(rank: 10, xp: 32, rewardType: .INK, modeUnlocked: nil, inkAmount: 500))
all.append(LWPlayerRank(rank: 11, xp: 36, rewardType: .MODE, modeUnlocked: .FILL2, inkAmount: 0))
all.append(LWPlayerRank(rank: 12, xp: 42, rewardType: .INK, modeUnlocked: nil, inkAmount: 500))
```

ALEXANDER KING


EMM_Dashboard_071713_NEW_withdummydata.xlsm

EMM Dashboard - Campaign Summary

Currently Viewing: Total Company

Key Metrics Summary

	Trailing 26 Weeks	Wk 7/7	Wk 6/30	WoW %	Jul MTD	Pr. MTD	MoM %	Q3 QTD	Pr. QTD
# Campaigns		42	99	-57%	11	17	-33%	17	82
# Delivered		6,724 K	9,185 K	-27%	4,796 K	16,516 K	-71%	7,889 K	3,603 K
Open Rate		**5.75%**	**1.57%**	**+267%**	**14.52%**	**3.35%**	**+334%**	**2.94%**	**19.06%**
Click Thru Rate		0.46%	1.25%	-63%	1.29%	0.35%	+275%	0.50%	4.60%
Opt-Out Rate		0.10%	0.23%	-59%	0.06%	0.06%	+8%	0.01%	0.09%
Conversion Rate		**0.06%**	**0.12%**	**-45%**	**0.08%**	**0.01%**	**+454%**	**0.06%**	**0.48%**
$ Gross Sales		$180 K	$566 K	-68%	$473 K	$519 K	-9%	$266 K	$157 K
Spend Per Email		$0.03	$0.06	-57%	$0.10	$0.03	+213%	$0.03	$0.04
AOS		$56.72	$74.05	-23%	$148.98	$131.66	+13%	$83.95	$17.44
$ Net Sales		$348 K	$1,086 K	-68%	$306 K	$513 K	-40%	$351 K	$267 K
$ Gross Profit		**$51 K**	**$135 K**	**-62%**	**$59 K**	**$49 K**	**+21%**	**$54 K**	**$86 K**
Gross Margin		14.54%	12.40%	+17%	19.38%	9.60%	+102%	15.27%	32.26%
GMb4A		14.76%	12.54%	+18%	19.54%	10.68%	+83%	15.91%	32.29%

Top Campaigns

Time Period: YTD | Campaign Type: All Campaign Groups | Ranking: Campaign Engagement Rank

	Campaign Name	Date	Type	Sending Site	# Delivered	Open Rate	Click Thru	Opt-Out Rate	Conversion	$ Gross Sales	Spend Pr Email	AOS
Top 5	2013-05-07 wag misc iams cat dog	5/8/2013	Miscellaneous	Wag.com	2 K	69.58%	10.03%	0.00%	4.33%	$45 K	$28.94	$174.97
	2013-04-19 Diapers ebm nondiapersbuyer	4/20/2013	Event Based Marketing	Diapers.com	19 K	36.68%	10.46%	0.13%	5.65%	$15 K	$18.02	$54.43
	2013-04-07 Diapers ebm nondiapersbuyer	4/7/2013	Event Based Marketing	Diapers.com	5 K	44.06%	2.07%	0.19%	12.54%	$40 K	$14.20	$44.52
	2013 Diapers ebm nondiapersbuyer	2/2/2013	Event Based Marketing	Diapers.com	9 K	50.68%	9.96%	0.25%	6.95%	$12 K	$5.45	$98.67
	2013-07-02 wag misc natura sub	7/2/2013	Miscellaneous	Wag.com	5 K	3.99%	14.00%	0.03%	3.95%	$5 K	$1.39	$36.36
	2013-05-10 FH Plus Launch 24	5/10/2013	Other	Yoyo.com	1 K	6.28%	0.14%	0.01%	0.00%	$0 K	$0.00	$0.00

Campaign_DetailData | Campaign_Summary | ReceivingSite_Summary | MetricDefinitions

NUMBERS IN GAME DESIGN

- Games are full of *numbers*

Are you using Cinderglacier > Fallen Crusader in your MH or you doing weapon swapping? @Sarthe
its insane
i was doing 11k as Feral and i look over to our locks and magos doing 15k
The Observation Ring
Layer 1
11:07
Auriaya
1128
5573
5
Andersemjr
Copedogx
Stelthy
Sekpad
Feral Defender activates
Sonic Screech
Unholy Strength
Death and Decay
Sarthegirl (2)...
Boss 100%
[00:47] Damage Done
1. Psychod 561K 11.7K
2. Sarthegi 524K 10.9K
3. Prefert 478K 9.9K
4. Imlomud 454K 9.6K
5. Sekpad 451K 9.4K
6. Navadoo 446K 9.3K
7. Takanoto 445K 9.3K

NUMBERS IN GAME DESIGN

- Games are full of *numbers*

Longform Rock Paper Shotgunned

Arithmophobia

JOEL GOODWIN SEPTEMBER 14, 2016 8 MIN READ 19

Tony Van was the producer in charge of localizing a Japanese RPG called *The Story of Thor: Hikari wo Tsugu Mono* (Ancient, 1994) for Western audiences, but received a badly translated copy of the story


Equipment
Select item to equip
LB‹ ›RB
Astora's Straight Sword
:Select
Equipment
Select item to equip
LB‹ ›RB
Tower Kite Shield
:Select
Status
Check status
LB‹ ›RB
Road
Covenant Way of White
Level 26
Souls 0
Vitality 20
Attunement 10
Endurance 14
Strength 13
Dexterity 16
Resistance 11
Intelligence 9
Faith 14
Humanity 0
HP 793/793
Stamina 98
Equip Load 34.5/54.0
R Weapon 1 184
R Weapon 2 97
L Weapon 1 67
L Weapon 2 20
Physical Def. 150(49)
VS strike 145
VS slash 166
VS thrust 148
Magic DEF 97(54)
Flame DEF 98(48)
Lightning DEF 83(50)
Poise 46
Bleed Resist 110
Poison Resist 72
Curse Resist 30
Item Discovery 100
Attunement Slots 1
:Toggle Display B:Close BACK:Explanation


LB
RB
Player Status
Lv 15
400
1049
16370
Attributes
VGR 7
END 8
VIT 6
ATN 5
STR 15
DEX 12
ADP 5
INT 5
FTH 5
Performance
HP 873
Stamina 96
Equip load 47.5
Slot 0
Cast speed 45
ATK: Str 68
ATK: Dex 61
Magic BNS 51
Fire BNS 61
Lghtng BNS 53
Dark BNS 61
Poison BNS 57
Bleed BNS 57
Phys DEF 80
Magic DEF 55
Fire DEF 55
Lghtng DEF 55
Dark DEF 55
Poison RES 55
Bleed RES 55
Petrify RES 55
Curse RES 55
AGL 85
Poise 1.5
Right Weapon
R Weapon1 189
R Weapon2 188
R Weapon3 53
Left Weapon
L Weapon1 85
L Weapon2 53
L Weapon3 53
Defense
VS strike 271
VS slash 285
VS thrust 272
Poise 6.5
29.2 / 47.5
61.5%
400
Check status.
B : Back : Help

NUMBERS ARE ABSTRACT REPRESENTATIONS


9
Ceci n'est pas une **neuf**
Magritte

NUMBERS ARE ABSTRACT REPRESENTATIONS OF MEASUREMENT

Game Development > Learning Guides

Numbers Getting Bigger

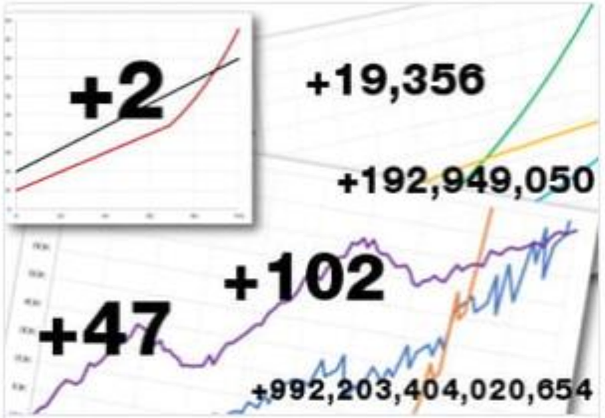
Incremental games are fascinating and perplexing. Marked by minimal player agency and periods of inactivity, they seem to defy conventional logic about good game design, and yet nonetheless have attracted a substantial player base. In this series, we examine them in more detail, and explore why that is.

Posts in this series

Numbers Getting Bigger: What Are Incremental Games, and Why Are They Fun?

Incremental games are fascinating and perplexing. Marked by minimal player agency and periods of inactivity, they seem to defy conventional logic about good...

Alexander King
22 May 2015
GAME DESIGN



Numbers Getting Bigger: The Design and Math of Incremental Games

Incremental games, despite their simple mechanics and limited player interaction, present interesting challenges to a game designer. We'll examine some core...

Alexander King
30 Jun 2015
GAME DESIGN

Numbers Getting Even Bigger: The Growing Appeal of Incremental Games

Incremental games are fascinating and perplexing. Marked by minimal player agency and periods of inactivity, they seem to defy conventional logic about good...

Alexander King
13 Sep 2016
GAME DESIGN

NUMBERS IN GAME DESIGN

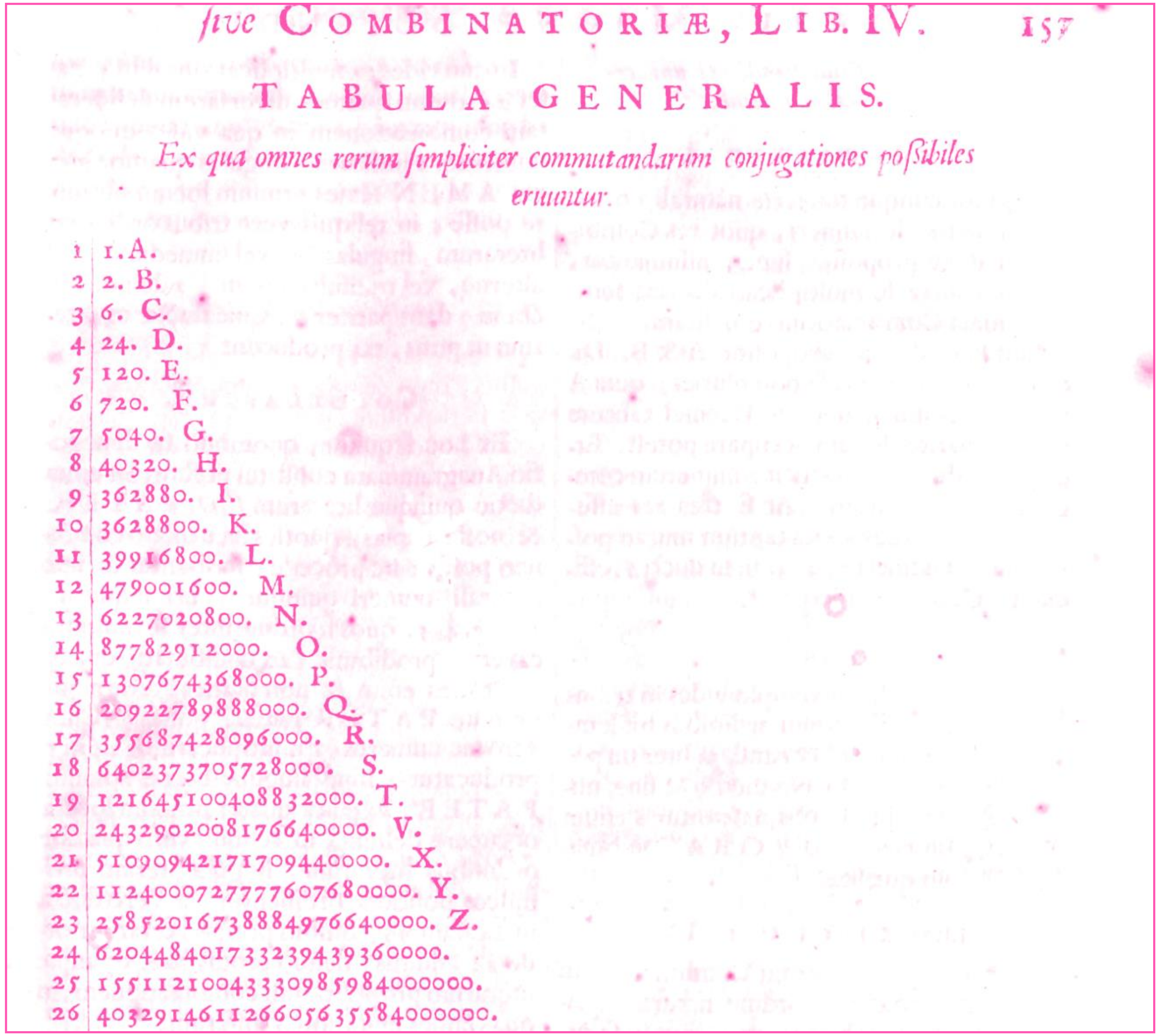
- Games are full of *numbers*
- But there aren't a lot of best practices of what those numbers should be
- What are "good" numbers to use in games?

WHAT IS "GOOD"?

- Use-case and genre agnostic
- Appropriate for the occasion, "feel right"
- Interesting, have some aesthetic qualities to them
- Easy to produce

WHAT IS "GOOD"?

- So, here are the good numbers!
- Grab a pen.


ſive COMBINATORIÆ, LIB. IV. 157

TABULA GENERALIS.

Ex qua omnes rerum ſimpliciter commutandarum conjugationes poſsibiles eruuntur.

1	1. A.
2	2. B.
3	6. C.
4	24. D.
5	120. E.
6	720. F.
7	5040. G.
8	40320. H.
9	362880. I.
10	3628800. K.
11	39916800. L.
12	479001600. M.
13	6227020800. N.
14	87782912000. O.
15	1307674368000. P.
16	20922789888000. Q.
17	355687428096000. R.
18	6402373705728000. S.
19	121645100408832000. T.
20	2432902008176640000. V.
21	51090942171709440000. X.
22	1124000727777607680000. Y.
23	25852016738884976640000. Z.
24	620448401733239439360000.
25	15511210043330985984000000.
26	403291461126605635584000000.

Gr.	M.	log sin.	D.1"	log tang.	G.D.1"	log cotg.	log cos.	D.1"	'	°
23	0	9,59 188	0,50	9,62 785	0,59	10,37 215	9,96 403	0,09	0	67
	1	9,59 218	0,50	9,62 820	0,59	10,37 180	9,96 397	0,09	59	
	2	9,59 247	0,50	9,62 855	0,59	10,37 145	9,96 392	0,09	58	
	3	9,59 277	0,50	9,62 890	0,58	10,37 110	9,96 387	0,09	57	
	4	9,59 307	0,49	9,62 926	0,58	10,37 074	9,96 381	0,09	56	
	5	9,59 336	0,49	9,62 961	0,58	10,37 039	9,96 376	0,09	55	
	6	9,59 366	0,49	9,62 996	0,58	10,37 004	9,96 370	0,09	54	
	7	9,59 396	0,49	9,63 031	0,58	10,36 969	9,96 365	0,09	53	
	8	9,59 425	0,49	9,63 066	0,58	10,36 934	9,96 360	0,09	52	
	9	9,59 455	0,49	9,63 101	0,58	10,36 899	9,96 354	0,09	51	
23	10	9,59 484	0,49	9,63 135	0,58	10,36 865	9,96 349	0,09	50	66
	11	9,59 514	0,49	9,63 170	0,58	10,36 830	9,96 343	0,09	49	
	12	9,59 543	0,49	9,63 205	0,58	10,36 795	9,96 338	0,09	48	
	13	9,59 573	0,49	9,63 240	0,58	10,36 760	9,96 333	0,09	47	
	14	9,59 602	0,49	9,63 275	0,58	10,36 725	9,96 327	0,09	46	
	15	9,59 632	0,49	9,63 310	0,58	10,36 690	9,96 322	0,09	45	
	16	9,59 661	0,49	9,63 345	0,58	10,36 655	9,96 316	0,09	44	
	17	9,59 690	0,49	9,63 379	0,58	10,36 621	9,96 311	0,09	43	
	18	9,59 720	0,49	9,63 414	0,58	10,36 586	9,96 305	0,09	42	
	19	9,59 749	0,49	9,63 449	0,58	10,36 551	9,96 300	0,09	41	
23	20	9,59 778	0,49	9,63 484	0,58	10,36 516	9,96 294	0,09	40	66
	21	9,59 808	0,49	9,63 519	0,58	10,36 481	9,96 289	0,09	39	
	22	9,59 837	0,49	9,63 553	0,58	10,36 447	9,96 284	0,09	38	
	23	9,59 866	0,49	9,63 588	0,58	10,36 412	9,96 278	0,09	37	
	24	9,59 895	0,49	9,63 623	0,58	10,36 377	9,96 273	0,09	36	
	25	9,59 924	0,49	9,63 657	0,58	10,36 343	9,96 267	0,09	35	
	26	9,59 954	0,49	9,63 692	0,58	10,36 308	9,96 262	0,09	34	
	27	9,59 983	0,49	9,63 726	0,58	10,36 274	9,96 256	0,09	33	
	28	9,60 012	0,48	9,63 761	0,58	10,36 239	9,96 251	0,09	32	
	29	9,60 041	0,48	9,63 796	0,58	10,36 204	9,96 245	0,09	31	
23	30	9,60 070		9,63 830		10,36 170	9,96 240		30	66
°	'	log cos.	D.1"	log cotg.	G.D.1"	log tang.	log sin.	D.1"	M.	Gr.

Gr.	M.	log sin.	D.1"	log tang.	G.D.1"	log cotg.	log cos.	D.1"	'	°
23	30	9,60 070	0,48	9,63 830	0,58	10,36 170	9,96 240	0,09	30	66
	31	9,60 099	0,48	9,63 865	0,58	10,36 135	9,96 234	0,09	29	
	32	9,60 128	0,48	9,63 899	0,58	10,36 101	9,96 229	0,09	28	
	33	9,60 157	0,48	9,63 934	0,57	10,36 066	9,96 223	0,09	27	
	34	9,60 186	0,48	9,63 968	0,57	10,36 032	9,96 218	0,09	26	
	35	9,60 215	0,48	9,64 003	0,57	10,35 997	9,96 212	0,09	25	
	36	9,60 244	0,48	9,64 037	0,57	10,35 963	9,96 207	0,09	24	
	37	9,60 273	0,48	9,64 072	0,57	10,35 928	9,96 201	0,09	23	
	38	9,60 302	0.48	9,64 106	0,57	10,35 894	9,96 196	0,09	22	
	39	9,60 331	0,48	9,64 140	0,57	10,35 860	9,96 190	0,09	21	
23	40	9,60 359	0,48	9,64 175	0,57	10,35 825	9,96 185	0,09	20	66
	41	9,60 388	0,48	9,64 209	0,57	10,35 791	9,96 179	0,09	19	
	42	9,60 417	0,48	9,64 243	0,57	10,35 757	9,96 174	0,09	18	
	43	9,60 446	0,48	9,64 278	0,57	10,35 722	9,96 168	0,09	17	
	44	9,60 474	0,48	9,64 312	0,57	10,35 688	9,96 162	0,09	16	
	45	9,60 503	0,48	9,64 346	0,57	10,35 654	9,96 157	0,09	15	
	46	9,60 532	0,48	9,64 381	0,57	10,35 619	9,96 151	0,09	14	
	47	9,60 561	0,48	9,64 415	0,57	10,35 585	9,96 146	0,09	13	
	48	9,60 589	0,48	9,64 449	0,57	10,35 551	9,96 140	0,09	12	
	49	9.60 618	0,48	9,64 483	0,57	10,35 517	9,96 135	0,09	11	
23	50	9,60 646	0,48	9,64 517	0,57	10,35 483	9,96 129	0,09	10	66
	51	9,60 675	0,48	9,64 552	0,57	10,35 448	9,96 123	0,09	9	
	52	9,60 704	0,48	9,64 586	0,57	10,35 414	9,96 118	0,09	8	
	53	9,60 732	0,48	9,64 620	0,57	10,35 380	9,96 112	0,09	7	
	54	9,60 761	0,48	9,64 654	0,57	10,35 346	9,96 107	0,09	6	
	55	9,60 789	0,48	9,64 688	0.57	10,35 312	9,96 101	0,09	5	
	56	9,60 818	0,47	9,64 722	0.57	10,35 278	9,96 095	0,09	4	
	57	9,60 846	0,47	9,64 756	0,57	10,35 244	9,96 090	0,09	3	
	58	9,60 875	0,47	9,64 790	0,57	10,35 210	9,96 084	0,09	2	
	59	9,60 903	0,47	9,64 824	0,57	10,35 176	9,96 079	0,09	1	
24	0	9,60 931		9,64 858		10,35 142	9,96 073		0	66
°	'	log cos.	D.1"	log cotg.	G.D.1"	log tang.	log sin.	D.1"	M.	Gr.

A "GOOD NUMBERS" TOOLBOX

- What we really want are methods that produce numbers
- Find yourself some good numbers to start with
- My solution is a spreadsheet tab with interesting progressions

														7.860596884	
		1	5	15	35	70	126	210	330	495	715	1001	1365	1820	
		0	1	2	3	4	5	6	7	8	9	10	11	12	
	2^x	1	2	4	8	16	32	64	128	256	512	1,024	2,048	4,096	
	3^x	1	3	9	27	81	243	729	2,187	6,561	19,683	59,049	177,147	531,441	1,59
	4^x	1	4	16	64	256	1,024	4,096	16,384	65,536	262,144	1,048,576	4,194,304	16,777,216	67,10
	5^x	1	5	25	125	625	3,125	15,625	78,125	390,625	1,953,125	9,765,625	48,828,125	244,140,625	1,220,70
	x^2	-	1	4	9	16	25	36	49	64	81	100	121	144	
	x^3	-	1	8	27	64	125	216	343	512	729	1,000	1,331	1,728	
	x^4	-	1	16	81	256	625	1,296	2,401	4,096	6,561	10,000	14,641	20,736	2
	x^5	-	1	32	243	1,024	3,125	7,776	16,807	32,768	59,049	100,000	161,051	248,832	37
ar^2, ar^3, ar^4 … wl			23.131	26.6	30.59023	35.1787629	40.45557736	46.52391396	53.50250105	61.52787621	70.75705764	81.37061629	93.57620874	107.61264	123.7
Am + (n-m)d, or for r			1	3	5	7	9	11	13	15	17	19	21	23	
			1	3	6	10	15	21	28	36	45	55	66	78	
ramid)			1	4	10	20	35	56	84	120	165	220	286	364	
her powers are pasc			1	5	15	35	70	126	210	330	495	715	1001	1365	

A "GOOD NUMBERS" TOOLBOX

- What we really want are methods that produce numbers
- Find yourself some good numbers to start with
- My solution is a spreadsheet tab with interesting progressions
- When I need good numbers, I "play" around with them till I find a good set

													7.860596884	
	1	5	15	35	70	126	210	330	495	715	1001	1365	1820	
	0	1	2	3	4	5	6	7	8	9	10	11	12	
2^x	1	2	4	8	16	32	64	128	256	512	1,024	2,048	4,096	
3^x	1	3	9	27	81	243	729	2,187	6,561	19,683	59,049	177,147	531,441	1,59
4^x	1	4	16	64	256	1,024	4,096	16,384	65,536	262,144	1,048,576	4,194,304	16,777,216	67,10
5^x	1	5	25	125	625	3,125	15,625	78,125	390,625	1,953,125	9,765,625	48,828,125	244,140,625	1,220,70
x^2	-	1	4	9	16	25	36	49	64	81	100	121	144	
x^3	-	1	8	27	64	125	216	343	512	729	1,000	1,331	1,728	
x^4	-	1	16	81	256	625	1,296	2,401	4,096	6,561	10,000	14,641	20,736	2
x^5	-	1	32	243	1,024	3,125	7,776	16,807	32,768	59,049	100,000	161,051	248,832	37
ar^2, ar^3, ar^4 … wl		23.131	26.6	30.59023	35.1787629	40.45557736	46.52391396	53.50250105	61.52787621	70.75705764	81.37061629	93.57620874	107.61264	123.7
Am + (n-m)d, or for r		1	3	5	7	9	11	13	15	17	19	21	23	
		1	3	6	10	15	21	28	36	45	55	66	78	
ramid)		1	4	10	20	35	56	84	120	165	220	286	364	
her powers are pasc		1	5	15	35	70	126	210	330	495	715	1001	1365	

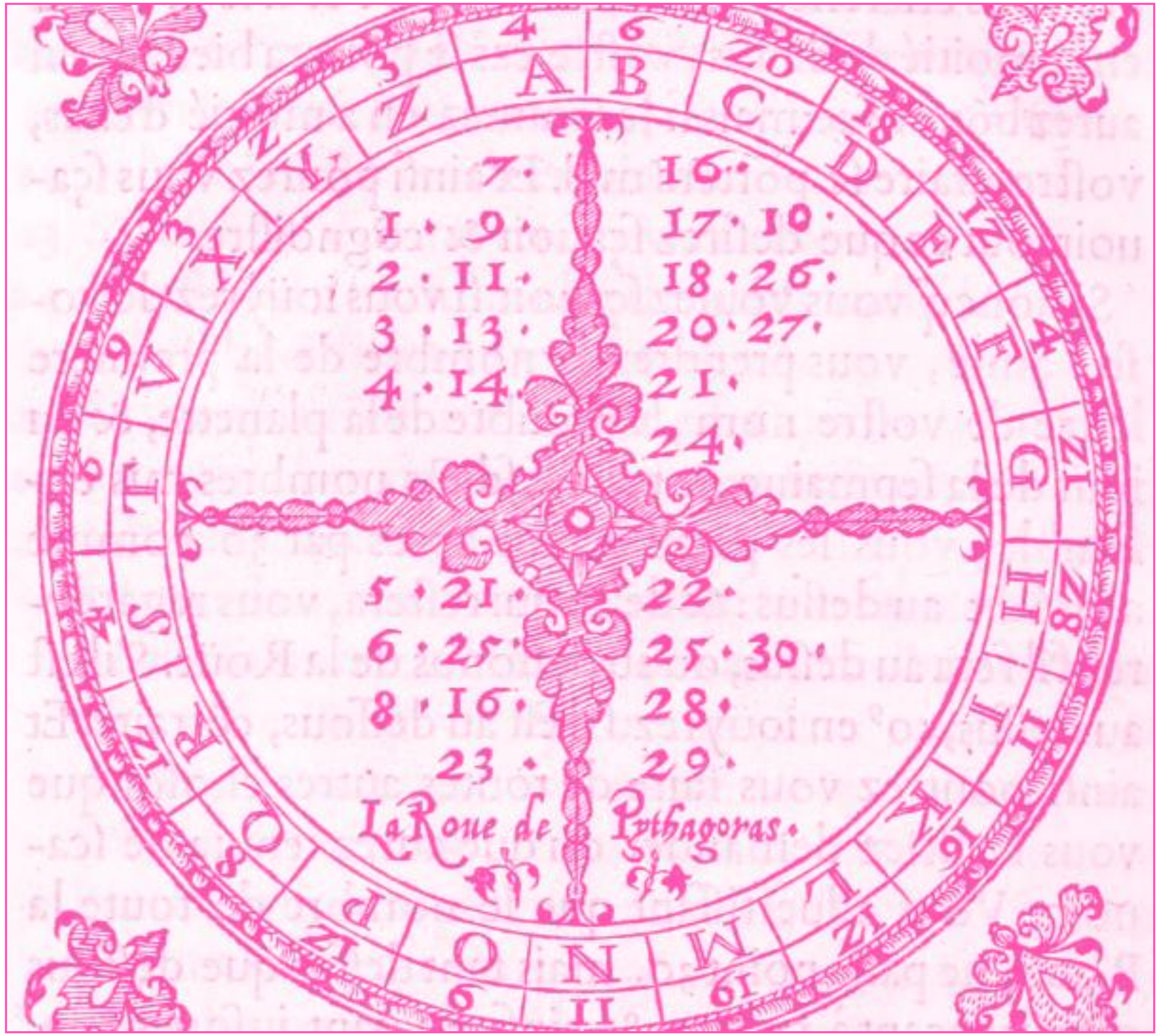
A "GOOD NUMBERS" TOOLBOX

- A 'toolbox' of good numbers let's you reuse what 'feels right'
- How to build your own

													7.860596884	
	1	5	15	35	70	126	210	330	495	715	1001	1365	1820	
	0	1	2	3	4	5	6	7	8	9	10	11	12	
2^x	1	2	4	8	16	32	64	128	256	512	1,024	2,048	4,096	
3^x	1	3	9	27	81	243	729	2,187	6,561	19,683	59,049	177,147	531,441	1,59
4^x	1	4	16	64	256	1,024	4,096	16,384	65,536	262,144	1,048,576	4,194,304	16,777,216	67,10
5^x	1	5	25	125	625	3,125	15,625	78,125	390,625	1,953,125	9,765,625	48,828,125	244,140,625	1,220,70
x^2	-	1	4	9	16	25	36	49	64	81	100	121	144	
x^3	-	1	8	27	64	125	216	343	512	729	1,000	1,331	1,728	
x^4	-	1	16	81	256	625	1,296	2,401	4,096	6,561	10,000	14,641	20,736	2
x^5	-	1	32	243	1,024	3,125	7,776	16,807	32,768	59,049	100,000	161,051	248,832	37
ar^2, ar^3, ar^4 … wl		23.131	26.6	30.59023	35.1787629	40.45557736	46.52391396	53.50250105	61.52787621	70.75705764	81.37061629	93.57620874	107.61264	123.7
Am + (n-m)d, or for r		1	3	5	7	9	11	13	15	17	19	21	23	
		1	3	6	10	15	21	28	36	45	55	66	78	
ramid)		1	4	10	20	35	56	84	120	165	220	286	364	
her powers are pasc		1	5	15	35	70	126	210	330	495	715	1001	1365	

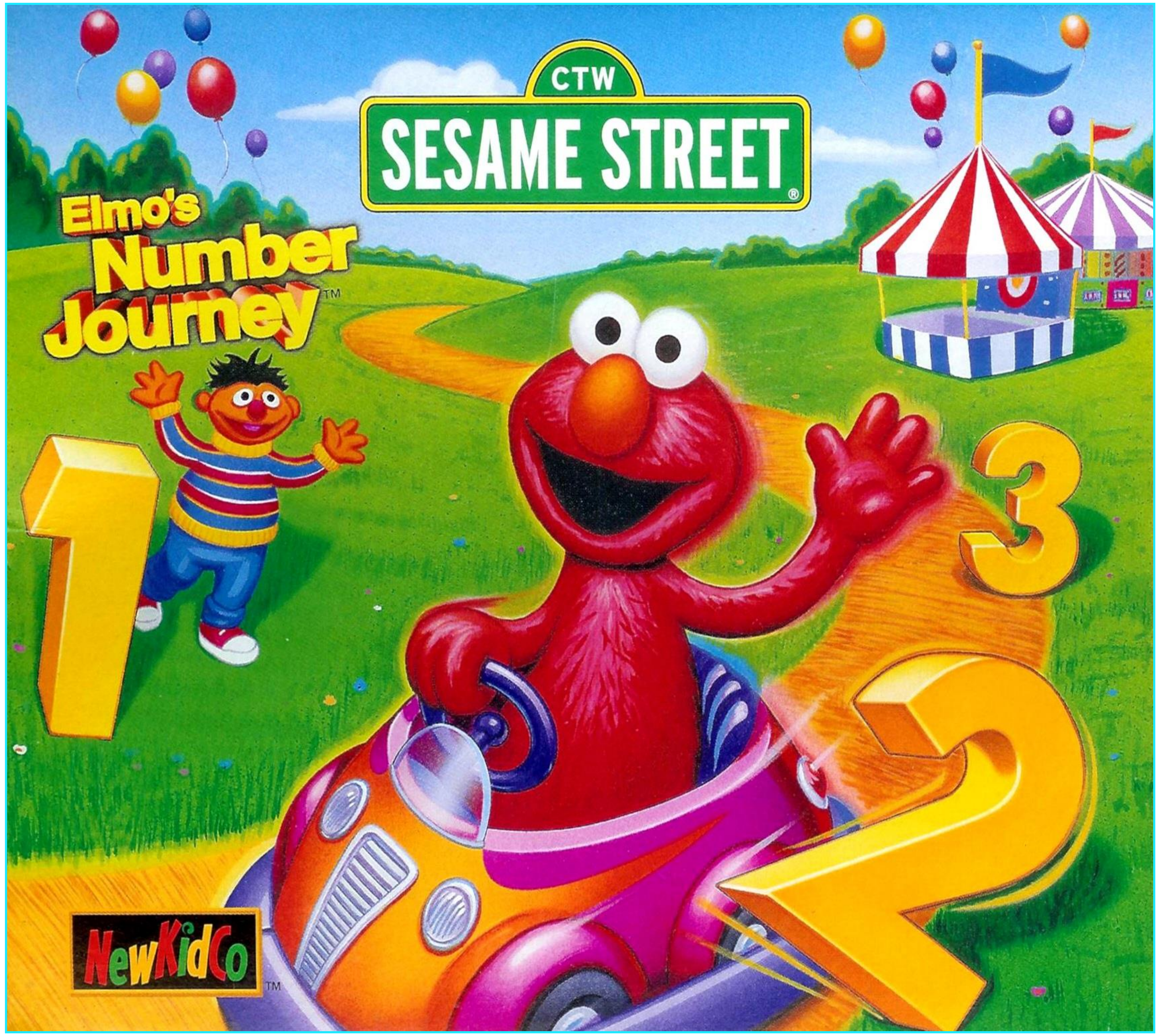
INTERESTING SETS

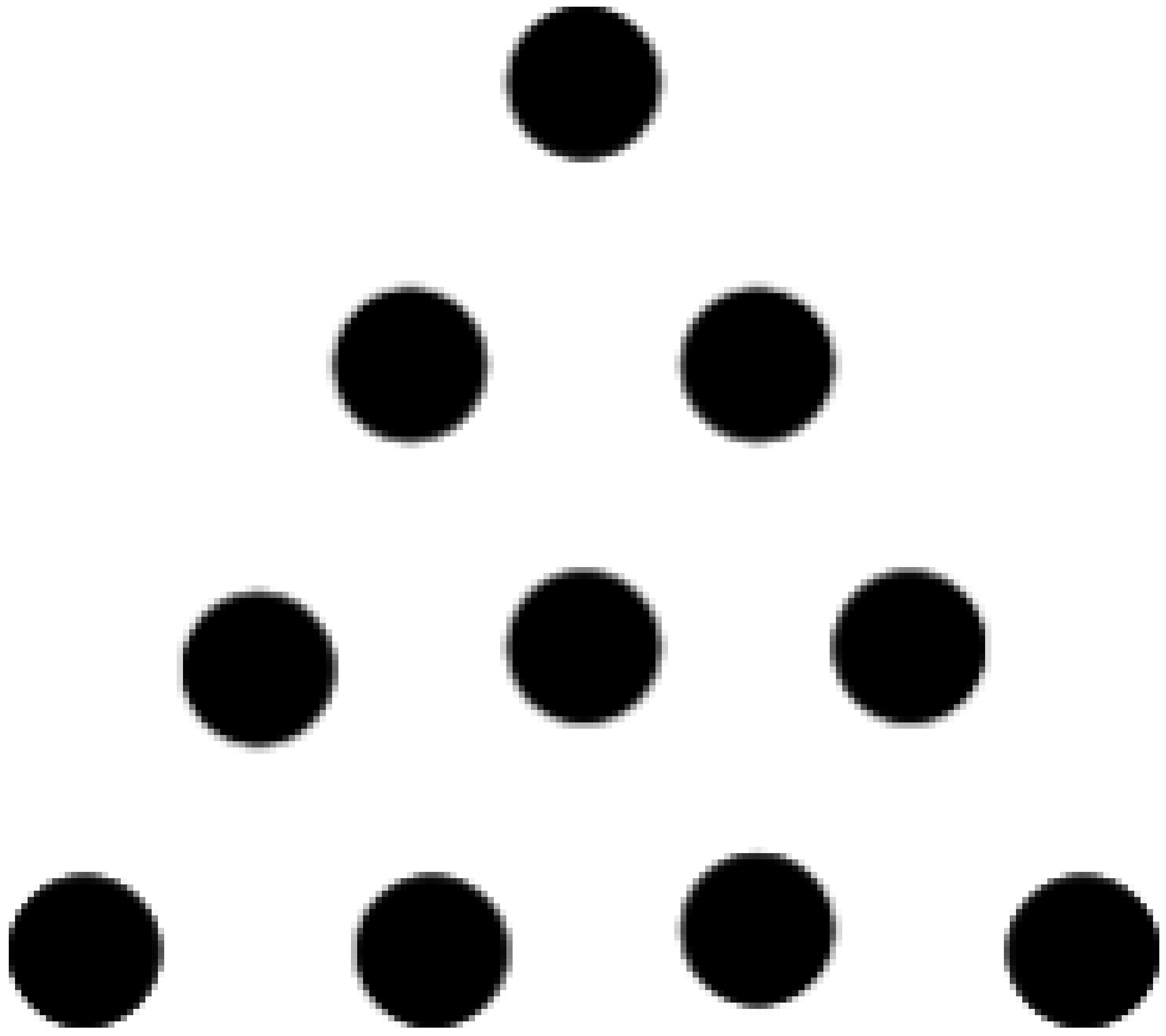
- Why are they interesting
- Why are they useful
- What is aesthetically pleasing about them.



1,2,3,4

- Never use a complex solution when the most basic will do
- Simplest series actually has great proportions





1

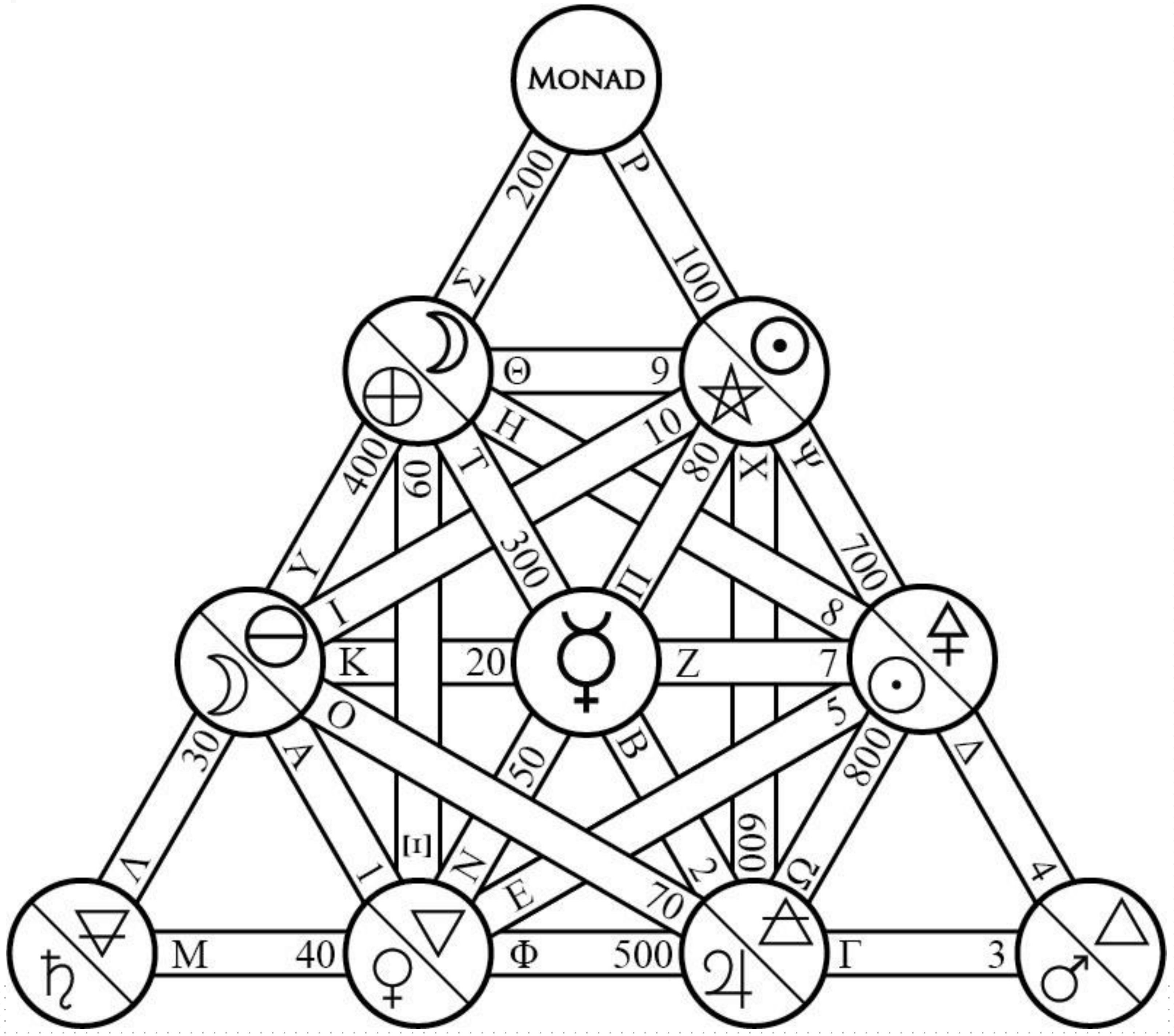
2

3

4

10

MUSICAL HARMONY


MONAD
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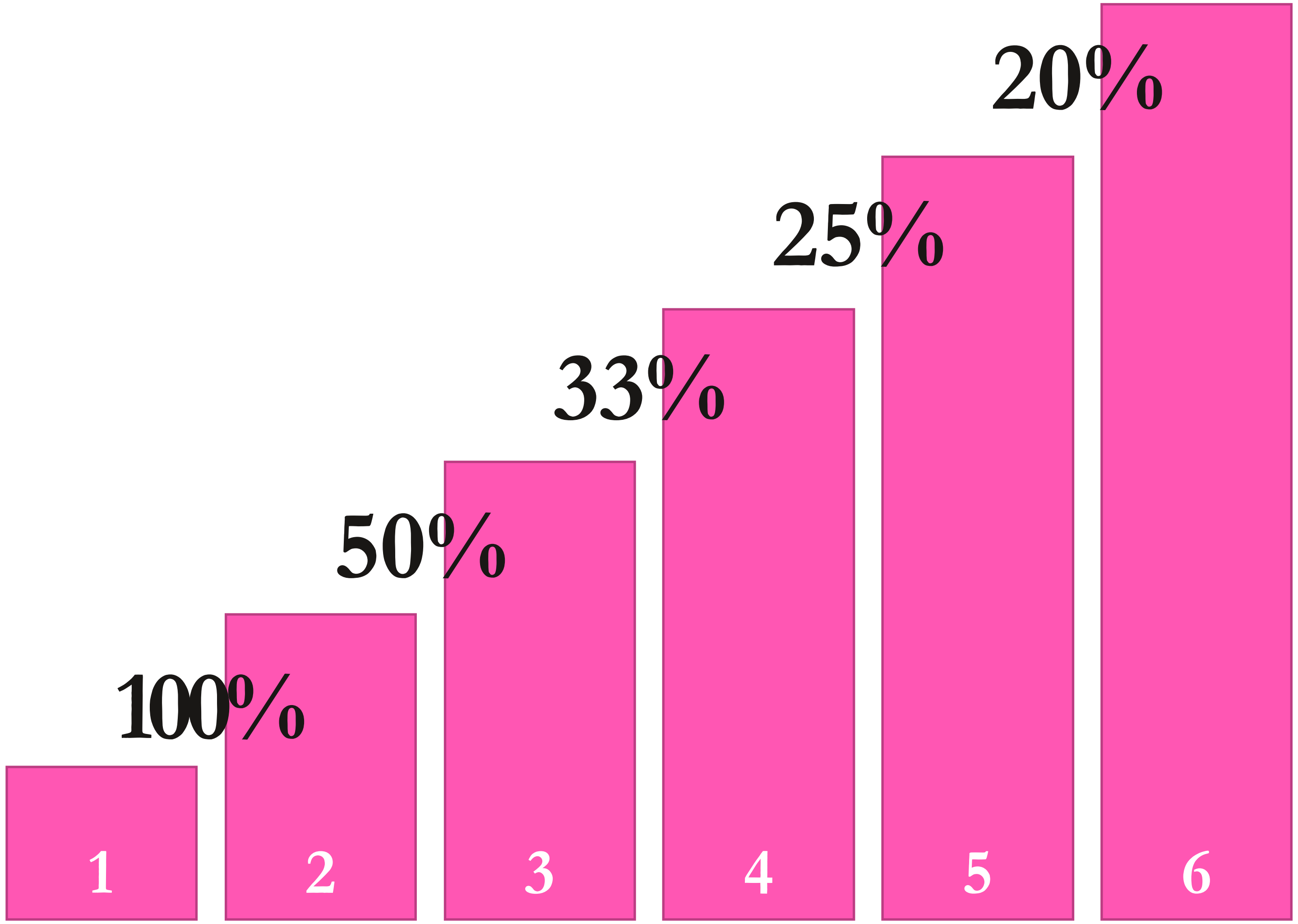
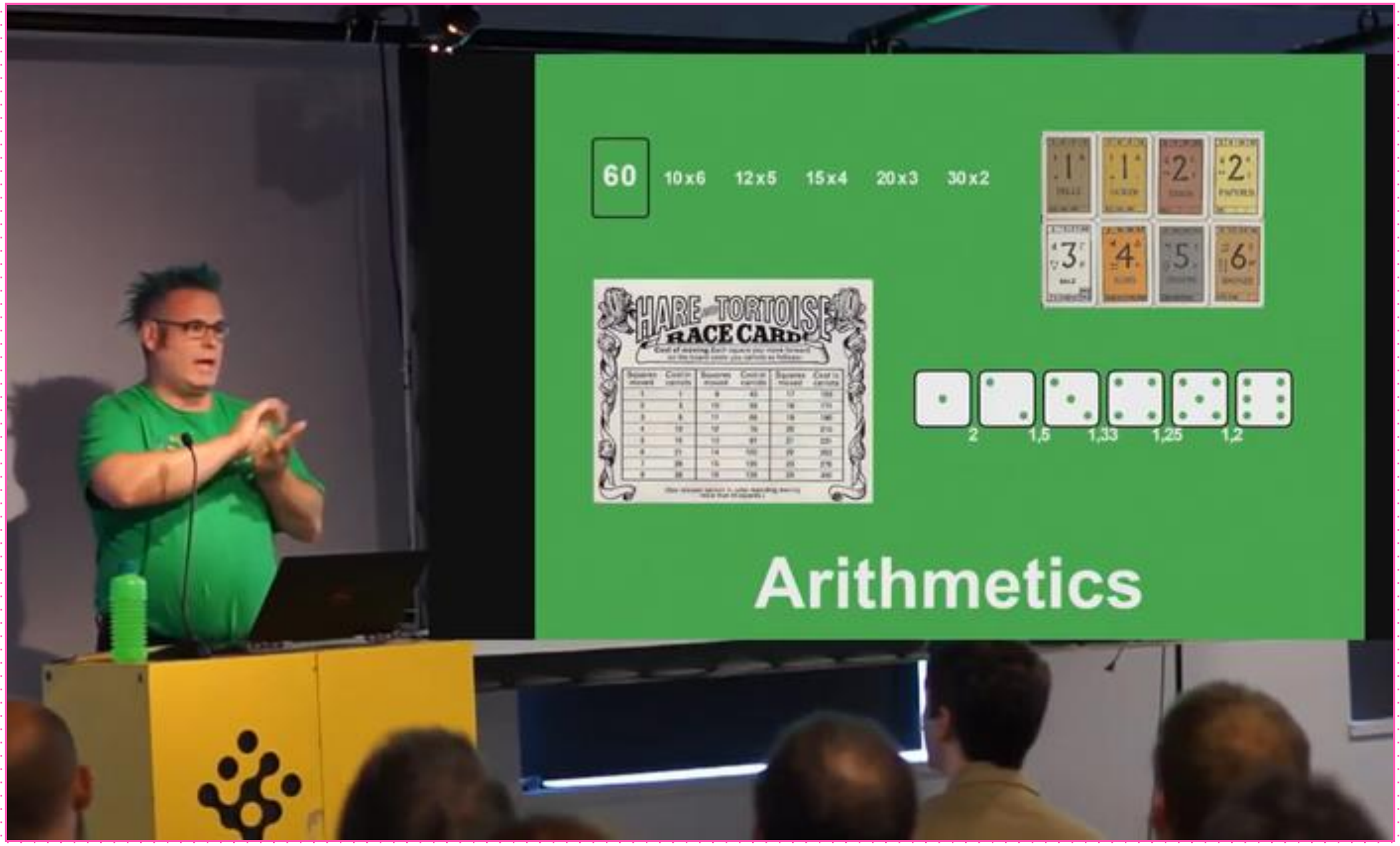
1,2,3,4,5,6?

- Never use a complex solution when the most basic will do
- Simplest series actually has great proportions
- The holy tetractys?
- Limitations of 1-6

1,2,3,4,5,6?





→ Friedemann Friese, *Creating Structures* (2018)

→ Reiner Knizia, *Dice Games Properly Explained* (1999)

LINEAR SETS

- Linear sets have *constant difference*
- The distance between each term is the same

LINEAR SETS

x	1	2	3	4	5	6	7	8	9	10
y = 1x + 0	1	2	3	4	5	6	7	8	9	10
# difference		*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*	*1*
% difference		*100%*	*50%*	*33%*	*25%*	*20%*	*17%*	*14%*	*13%*	*11%*
Cumulative	1	3	6	10	15	21	28	36	45	55
Current / Total	*100%*	*67%*	*50%*	*40%*	*33%*	*29%*	*25%*	*22%*	*20%*	*18%*
Diff / Total	*0%*	*33%*	*17%*	*10%*	*7%*	*5%*	*4%*	*3%*	*2%*	*2%*

LINEAR SETS

- Linear sets have *constant difference*
- The distance between each term is the same
- Which means the difference is *falling proportionally*

LINEAR SETS

- Fixed distance is regular and easy to understood (maybe too easy)
- Proportional falloff can be good for making something cheaper/easier over time
- Works great for small sets

3,7,11,15

50,100,150,200

10,20,30,40

9,18,27,36

EXPONENTIAL SETS

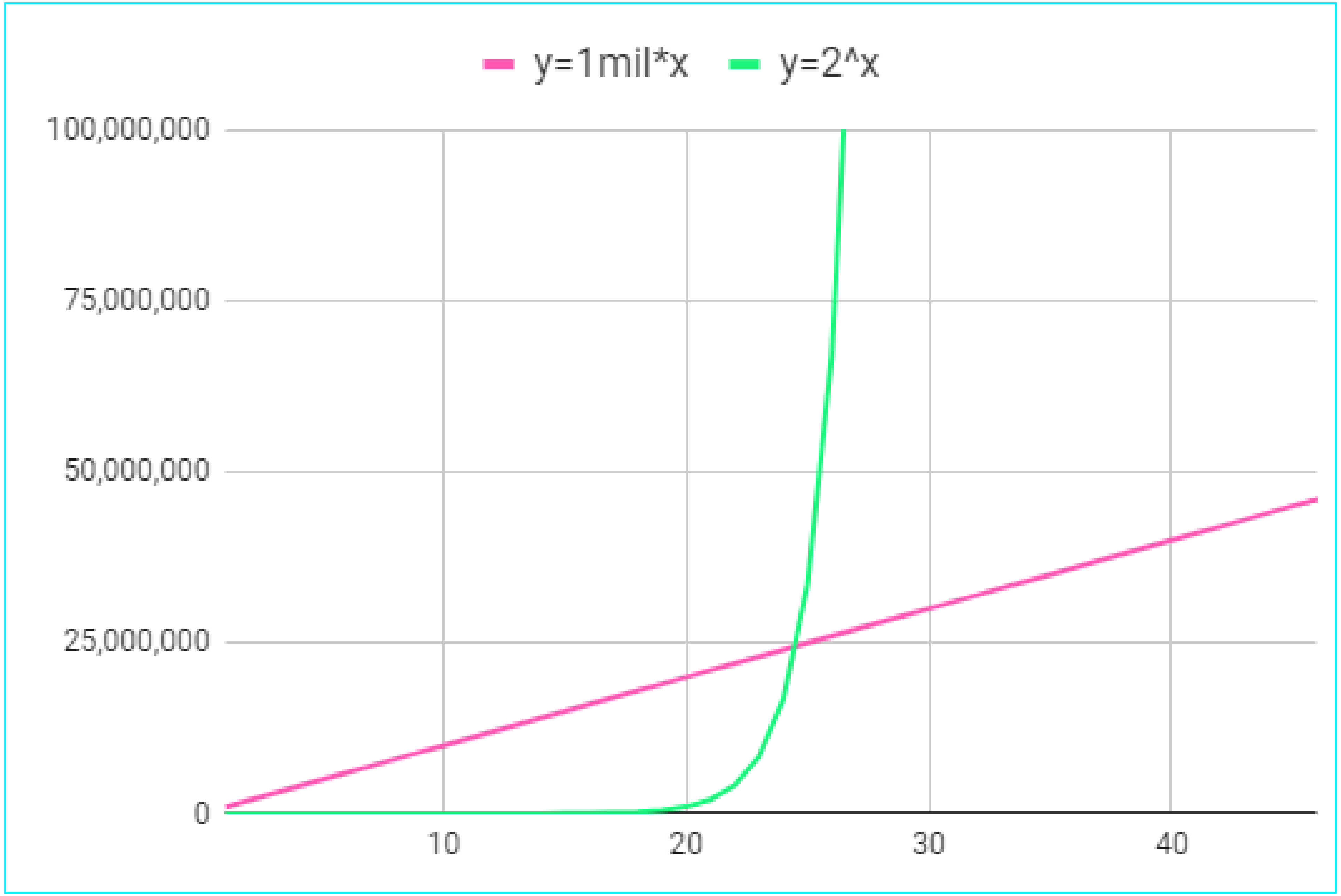
- The distance between each term is increasing
- But the proportional increase is the same

2,4,8,16,32,64

EXPONENTIAL SETS

x	1	2	3	4	5	6	7	8	9	10
y = 2^x	2	4	8	16	32	64	128	256	512	1,024
# difference		*2*	*4*	*8*	*16*	*32*	*64*	*128*	*256*	*512*
% difference		*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*	*100%*
Cumulative	2	6	14	30	62	126	254	510	1,022	2,046
Current / Total	*100%*	*67%*	*57%*	*53%*	*52%*	*51%*	*50%*	*50%*	*50%*	*50%*
Diff / Total	*0%*	*33%*	*29%*	*27%*	*26%*	*25%*	*25%*	*25%*	*25%*	*25%*

EXPONENTIAL SETS



EXPONENTIAL SETS

- Being proportionally constant is good for cost treadmills
- Or where the degree of change is more important than the nominal amounts
- Exponential progressions can grow very large very fast though

PROPORTIONAL AND CONSTANT DIFFERENCE

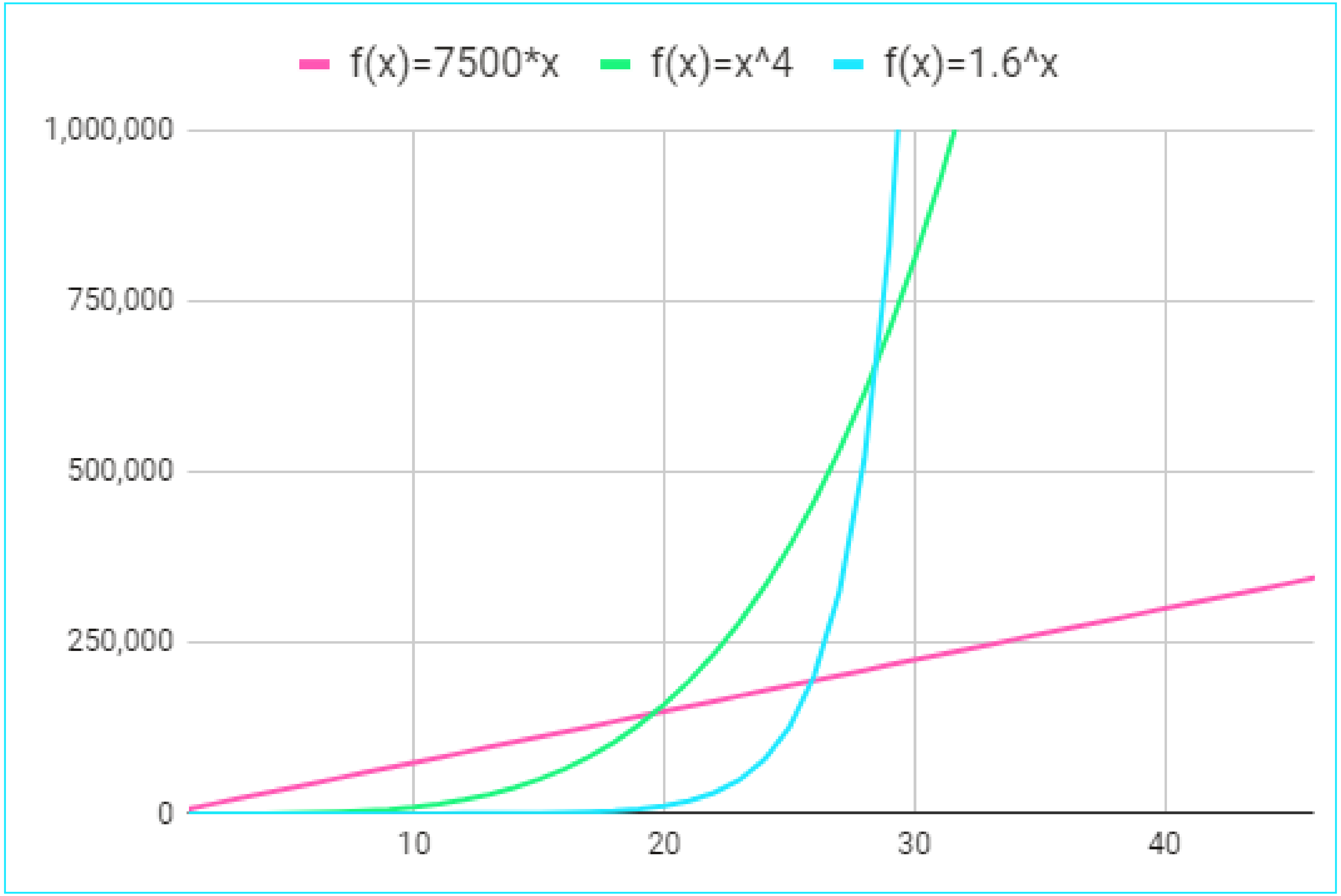
POLYNOMIAL SERIES

- Very versatile, splits the difference between linear and exponential
- The difference between terms rises nominally (like an exponential)
- But the proportional difference decreases (like a linear)

POLYNOMIAL SERIES

x	1	2	3	4	5	6	7	8	9	10
y = x^2	1	4	9	16	25	36	49	64	81	100
# difference		*3*	*5*	*7*	*9*	*11*	*13*	*15*	*17*	*19*
% difference		*300%*	*125%*	*78%*	*56%*	*44%*	*36%*	*31%*	*27%*	*23%*
Cumulative	1	5	14	30	55	91	140	204	285	385
Current / Total	*100%*	*80%*	*64%*	*53%*	*45%*	*40%*	*35%*	*31%*	*28%*	*26%*
Diff / Total	*0%*	*60%*	*36%*	*23%*	*16%*	*12%*	*9%*	*7%*	*6%*	*5%*

POLYNOMIAL SERIES



POLYNOMIAL SERIES

- Polynomial curves have a "just right" steepness for lots of uses
- Have them increasing steepness that linear sets don't, but don't go to the moon like exponentials
- They're also much easier to fine-tune by changing terms than exponentials

TRIANGULAR NUMBERS

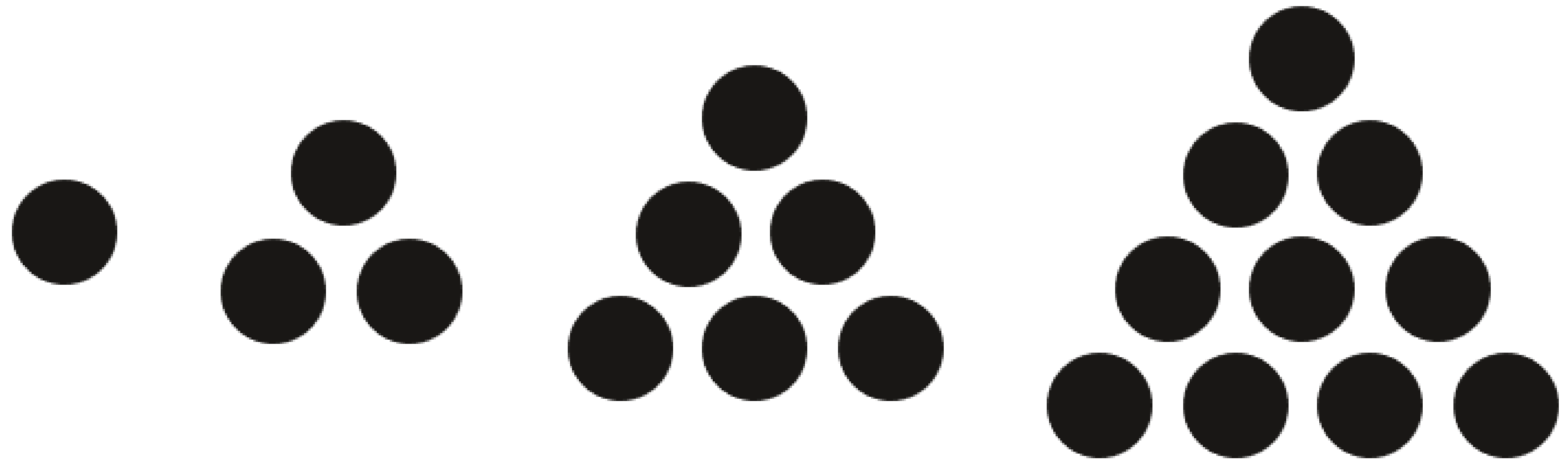
- Actually a polynomial
- But, much easier to calculate and makes intuitive sense
- Easy enough to mentally calculate
- The difference between terms is itself just the basic linear series
- So the distance to the next term is always 1 plus whatever the difference to the last one was

1,3,6,10,15,21

TRIANGULAR NUMBERS

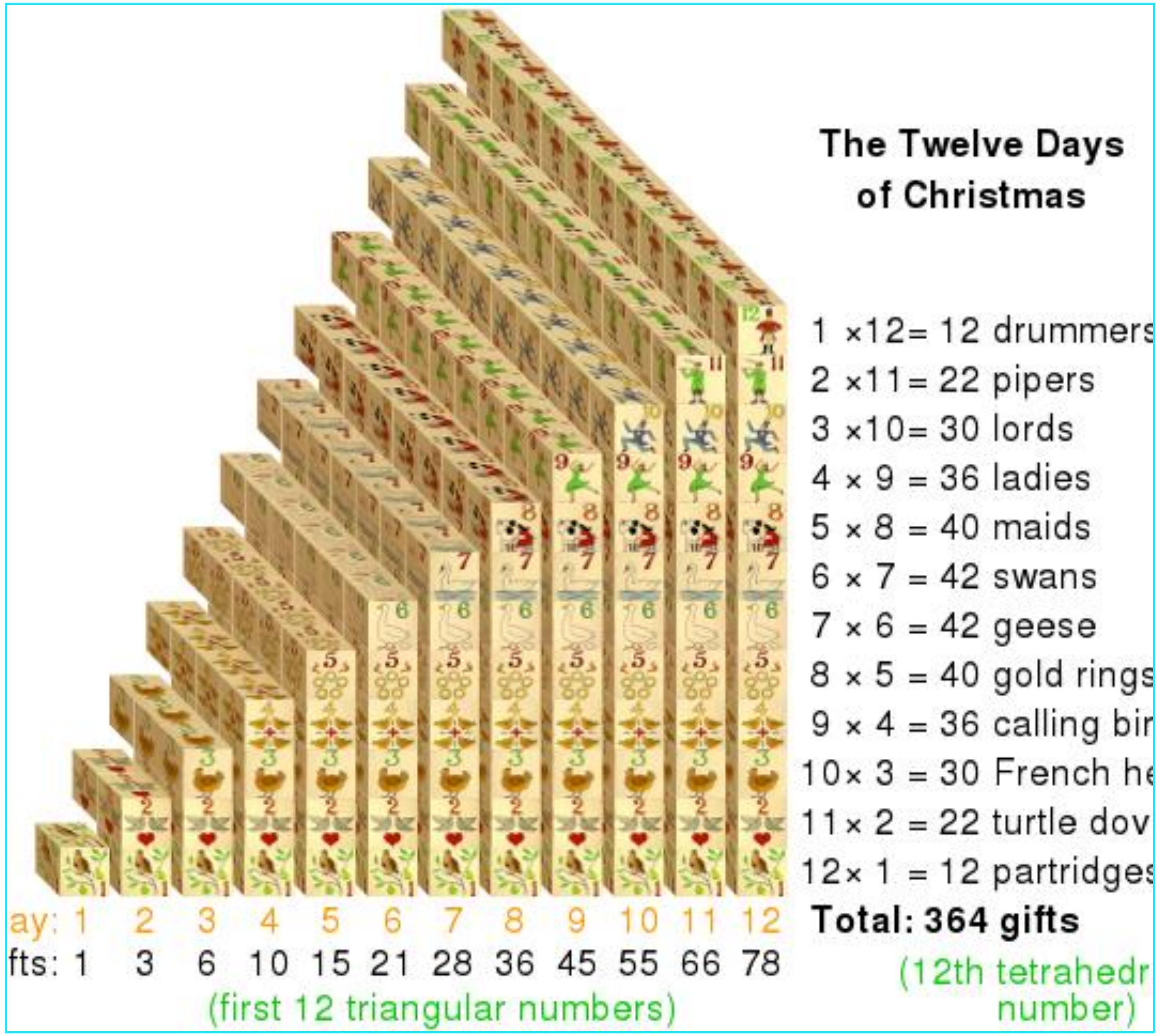
x	1	2	3	4	5	6	7	8	9	10
$f(x)$=C(x+1,2)	1	3	6	10	15	21	28	36	45	55
# difference		*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
% difference		*200%*	*100%*	*67%*	*50%*	*40%*	*33%*	*29%*	*25%*	*22%*
Cumulative	1	4	10	20	35	56	84	120	165	220
Current / Total	*100%*	*75%*	*60%*	*50%*	*43%*	*38%*	*33%*	*30%*	*27%*	*25%*
Diff / Total	*0%*	*50%*	*30%*	*20%*	*14%*	*11%*	*8%*	*7%*	*5%*	*5%*

TRIANGULAR NUMBERS



OTHER INTERESTING SETS

- Figurate & Polygonal numbers
  - Triangular numbers' wider family
  - All similar to triangulars, but with different steepness
- Fibonacci series
  - Iterative calculation
  - But actually a polynomial raising inputs to the golden mean
- Primes
  - Great formal qualities proportionally
  - All the numbers are sort of ugly though since none are easily divisible
  - No known way to produce them



MAKING YOUR OWN GOOD NUMBERS SHEET

And Here's One I Made Earlier

You're welcome to make your own from scratch, but I've gone ahead and set up a google sheet that's ready to go. You can find that here:

GOOD NUMBERS (Part 1) Spreadsheet

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T
25																				
26																7.860596884				
27																				
28																				
29																				
30																				
31																				
32				1	5	15	35	70	126	210	330	495	715	1001	1365	1820	2380	3060	3876	4845
33																				
34																				
35																				
36																			15	16
37			2																32,768	65,536
38			3																48,907	43,046,721
39			4																741,824	4,294,967,296
40			5																78,125	152,587,890,625
41			x																225	256
42			x																3,375	4,096
43			x																50,625	65,536
44			x																759,375	1,048,576
45																				
46																				
47	Constant	a, ar, ar^2,																	653739	188.21518
48	Constant	An = Am +																	29	31
49	Triangular																		120	136
50	Tetrahedr	(a pyramid																	680	816
51	Pentatope	(further powers are pasc																	3060	3876
52	Square Numbers				1	4	9	16	25	36	49	64	81	100	121	144	169	196	225	256
53	Pentagonal Number				1	5	12	22	35	51	70	92	117	145	176	210	247	287	330	376
54	Hexagonal Number				1	6	15	28	45	66	91	120	153	190	231	276	325	378	435	496
55	Septogonal Numbers				1	7	18	34	55	81	112	148	189	235	286	342	403	469	540	616
56	Pronic				2	6	12	20	30	42	56	72	90	110	132	156	182	210	240	272
57	Fibonacc	Binet's formula			1	1	2	3	5	8	13	21	34	55	89	144	233	377	610	987
58				0	5	5	15	40	100	245	610	1525	3815	9535	23840	59605	149010	372530	931325	2328305
59																				
60					1	5	3,834	#########	##########	##########	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!	#NUM!
61																				
62																				
63																				
64					50%	120%	220%	350%	510%	700%	920%	1170%	1450%	1760%	2100%	2470%	2870%	3300%	3760%	4250%
65																				

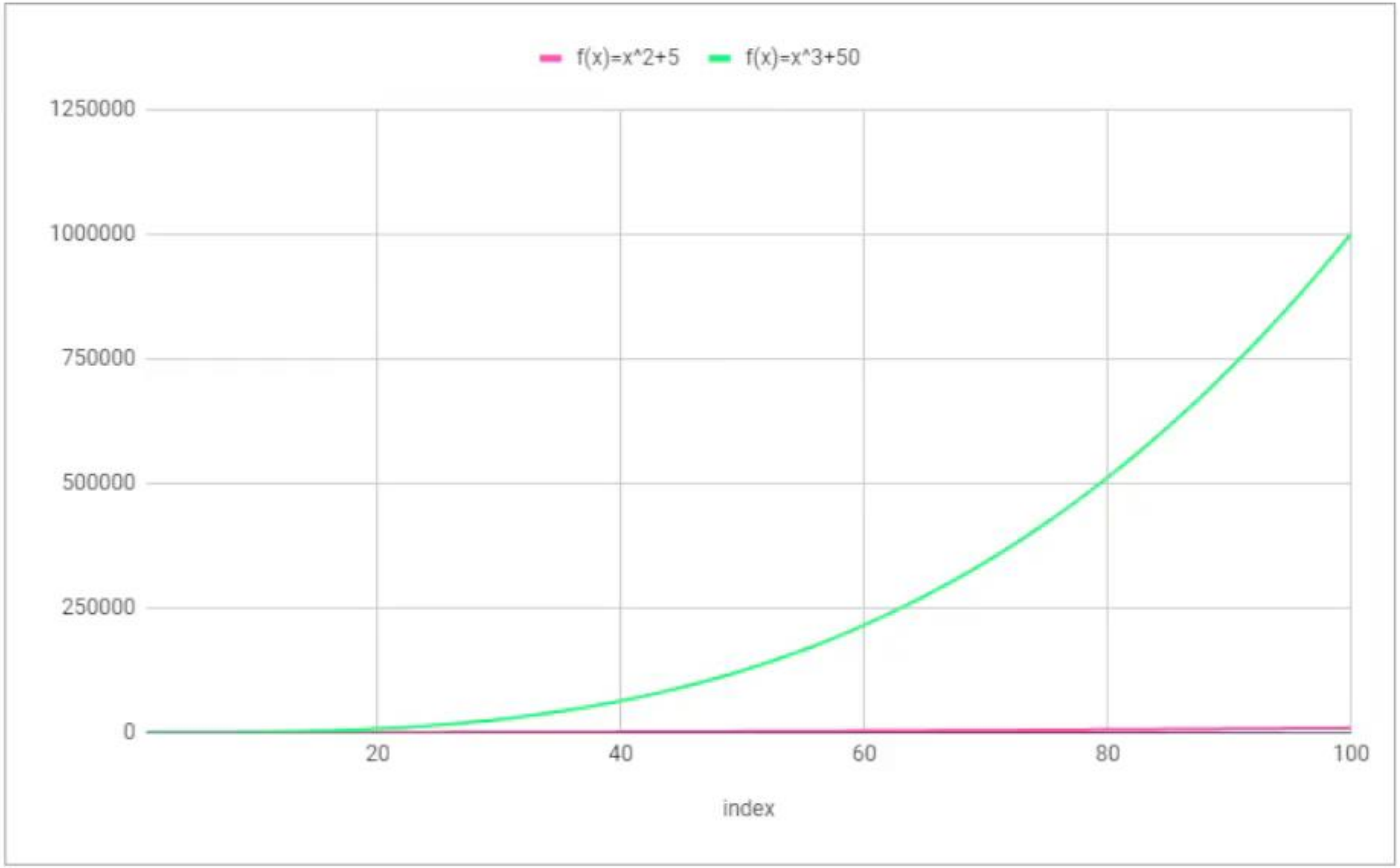
- Grab your favorite spreadsheet software
- Populate a spreadsheet tab with useful numbers
- Use as a starting point

	Polynomial	
main term:	2	3
offset:	0	6
index	f(x)=x^2+0	f(x)=x^3+6
1	1	7
2	4	14
3	9	33
4	16	70
5	25	131
6	36	222
7	49	349
8	64	518
9	81	735
10	100	1006

	A	B	C	D	E
1	**GOOD NUMBERS**				
2	**Spreadsheet Example from Part 1**				
3					
4		**Linear**		**Polynomial**	
5	main term:	1	5	2	3
6	offset:	0	0	0	6
7	index	f(x)=1x+0	f(x)=5x+0	f(x)=x^2+0	f(x)=x^3+6
8	1	1	?	=($A8^$D$5)+$D$6	7
9	2	2	10	4	14
10	3	3	15	9	33

GOOD NUMBERS

	Polynomial	
main term:	2	3
offset:	5	50
index	f(x)=x^2+5	f(x)=x^3+50
1	6	51
2	9	58
3	14	77
4	21	114
5	30	175
6	41	266
7	54	393
8	69	562
9	86	779
10	105	1050
11	126	1381
12	149	1778
13	174	2247
14	201	2794
15	230	3425
16	261	4146
17	294	4963
18	329	5882
19	366	6909
20	405	8050
21	446	9311
22	489	10698
23	534	12217
24	581	13874



PLAYING AROUND

- This enables you to “play around”
- **Play Around** is a technical term
- There is no absolute ‘best numbers’ to use in every case
- Instead you need to rely on your own instincts and taste
- Choosing numbers is an aesthetic choice you are making!
- So make the choice thoughtfully, by playing around

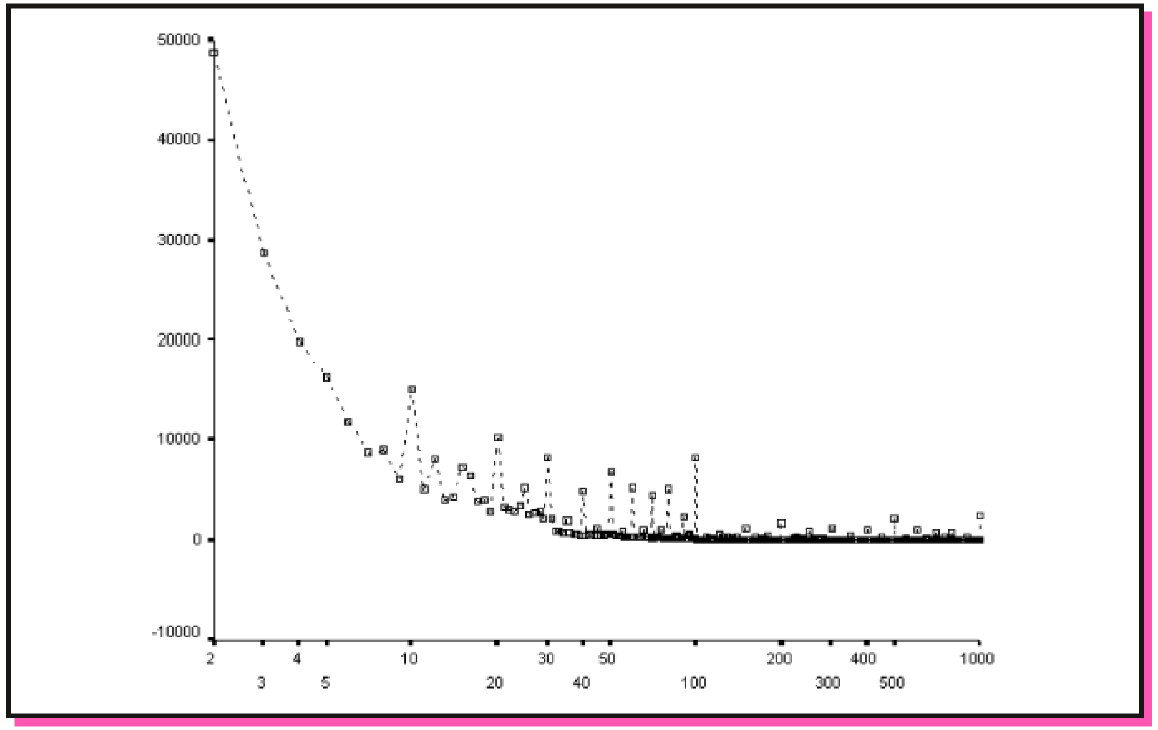
Idea: Aesthetic Qualities of Rounding

> *You*: Why am I looking at this pile of the roofing material?
> *Perception (Sight)*: Because it's nice and orderly. Well laid pallet. Easy on the eyes.
> *Conceptualization*: Rhythmic pattern — calms your mind. Mammals like this stuff.
>
> \- *Disco Elysium* (2019)

Back in Part 1, I made an assertion you might have felt is unfounded: that numbers themselves have aesthetic properties. This is actually quite a claim I think, and I don't begrudge in the least if at the time you read that and thought, "Sure thing grandpa, let's get you back to bed."

After all, you might feel numbers are mere data, dry vessels of fact, without emotional valence of any kind. Oh, if only that it were so. In fact, that we ascribe cultural connotations to numbers at all, like objectivity, precision, and scientificity, is maybe a clue that they are distinct from, say, the universal constants of physics.

The truth is, numbers are actually quite peculiar. You might think numbers are simple because you learned to count when you were very young, but how our minds perceive and work with numbers is extremely complex and poorly understood. Numbers are like words, though also obviously distinct from them in some way (and evolutionarily, numeracy almost certainly predates language, as number sense can be observed in certain animals). But in the same way that words can be carefully chosen for their own sake, so it is with numbers.



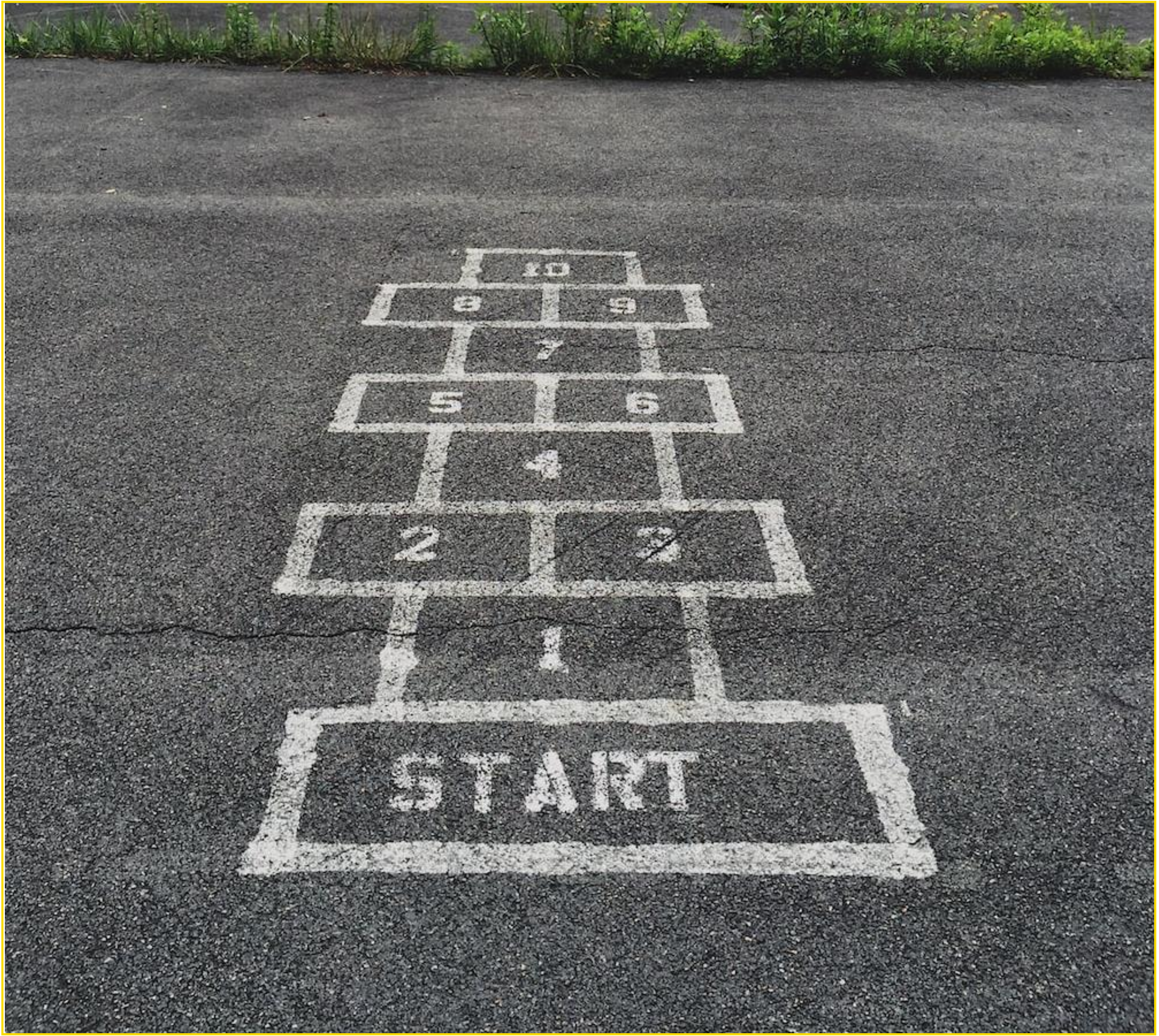
Distribution of numerals in text, from On Round Numbers: Pragmatic Aspects of Numerical Expressions by Jansen & Pollmann (2010)

Roundness and N-ness

2 (or 2√3)	3,4641 0161 5137 7545 8705 4892 6830 1174 4733 8856 1050 7620 7612 5611 1613 9589 0386 6034
9 x5)2√3 (	769 8003 5891 9501 0193 4553 1707 3359 4327 4196 8023 3502 6835 8346 9146 9768 6453 0356
9x9x9)2√3(	47 5185 4067 4043 2727 9910 6895 5145 6439 9641 7779 2191 5236 7799 1922 6528 9287 2244
9^3x 13)2√3(	3 6552 7235 9541 7902 1531 5915 0395 8187 6895 5213 7860 8864 3676 8609 4348 3791 3250
9^4x 17)2√3(	3105 7869 7215 9691 0326 2136 5719 9061 6991 1227 3151 5785 8613 0666 1611 3001 8773
9^5x 21)2√3(	279 3565 0014 1347 8706 5906 4641 4730 4173 8046 9013 6340 5272 0747 7499 4291 1741
9^6x 25)2√3(	26 0732 7334 6525 8012 6151 2699 8708 1722 8884 3774 6058 4492 0603 1233 2800 5096
9^7x 29)2√3(	2 4974 3997 5720 8621 8980 0067 0374 3460 0467 8522 4718 2422 6111 4102 8046 0258
9^8 x33)2√3(	2438 5777 5407 0875 5388 6201 8319 3805 8631 5411 2851 2761 8037 8144 7182 9453
9^9x 37)2√3(	241 6608 5851 1528 2065 5389 3707 3260 0404 9274 9922 1985 4039 7834 1612 7243
9^{10}x41)2√3(	24 2315 7659 8716 9204 4036 3325 6668 3509 4371 7471 8735 6638 1354 6448 9724
9^{11}x45)2√3(	2 4530 7318 6536 7746 6186 3941 6107 1663 9183 3126 7822 6227 5643 3097 3034
9^{12}x49)2√3(	2503 1359 0462 9361 8998 6116 4908 8945 2977 8890 4879 8594 6494 2152 7861
9^{13}x53)2√3(	257 1355 5414 4316 0022 9181 7778 9011 1521 8376 5910 0903 8528 7558 6719
9^{14}x57)2√3(	26 5656 6153 9276 3121 2761 4702 3036 2398 9422 9226 5785 3883 0878 3813
9^{15}x61)2√3(	2 7581 8343 8504 0979 8046 2728 6544 7462 1852 6531 7212 6905 8943 6571
9^{16}x65)2√3(	2876 0545 2561 9657 7232 1754 6118 3410 5868 3963 1367 4771 3838 5694
9^{17}x69)2√3(	301 0363 0300 3667 8776 3146 6179 8585 6491 8611 2784 0354 4926 7423
9^{18}x73)2√3(	31 6156 8479 0339 5487 9234 5763 1814 9311 9306 2073 2092 0243 4478
9^{19}x77)2√3(	3 3303 6795 0497 5282 2776 5138 1129 1341 6608 0131 8099 1598 5161
9^{20}x81)2√3(	3517 6725 9517 5715 6863 9116 0969 7439 3798 1029 0114 7260 7486
9^{21}x85)2√3(	372 4594 5125 3899 3079 7082 8808 5611 2284 5050 1306 2651 1381
9^{22}x89)2√3(	39 5244 1118 1749 6144 5383 3269 3229 6559 5292 4608 0306 3005
9^{23}x93)2√3(	4 2027 1516 7473 9733 4096 9128 9961 0984 2271 2413 5181 9125
9^{24}x97)2√3(	4477 1192 5057 3648 5762 9013 7418 5362 5808 9638 5534 8429
9^{25}x101)2√3(	477 7563 9967 6175 9206 8222 5885 1463 3337 1501 5838 1515
	3.5462 3317 2182 1216 8216 8891 2068 8337 2605 8456 6289 2593 5926 3028 6006 8370 3313 5867

YOUR DAYS ARE NUMBERED

- The numbers you use, for anything, are never neutral or natural
- Numbers have intrinsic and extrinsic qualities
- Be thoughtful in what you pick



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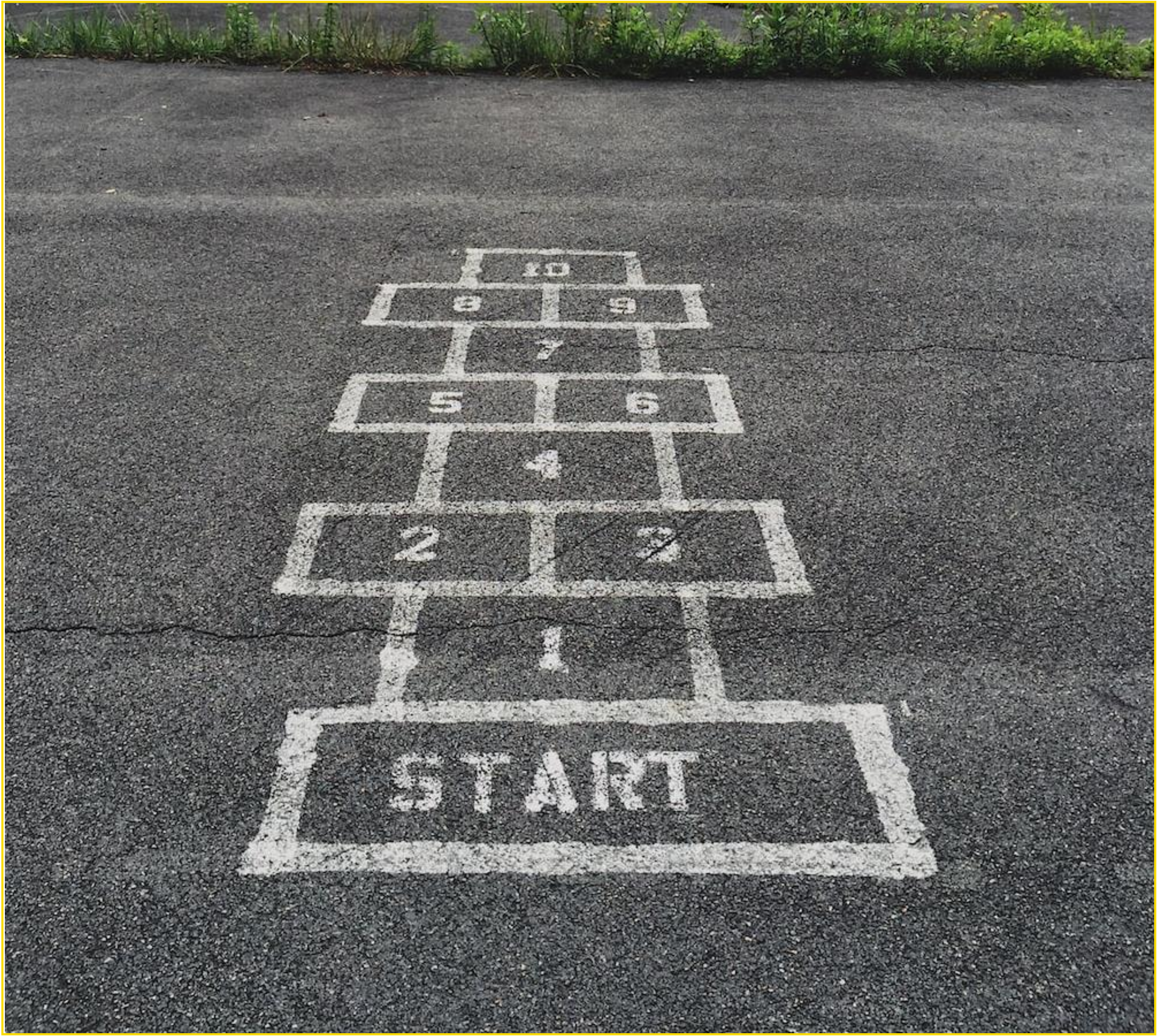
- The numbers you use, for anything, are never neutral or natural
- Numbers have intrinsic and extrinsic qualities
- Be thoughtful in what you pick
- If comedians can do it, then so can we!



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San Francisco, CA

"GOOD NUMBERS"
IN GAME DESIGN

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