

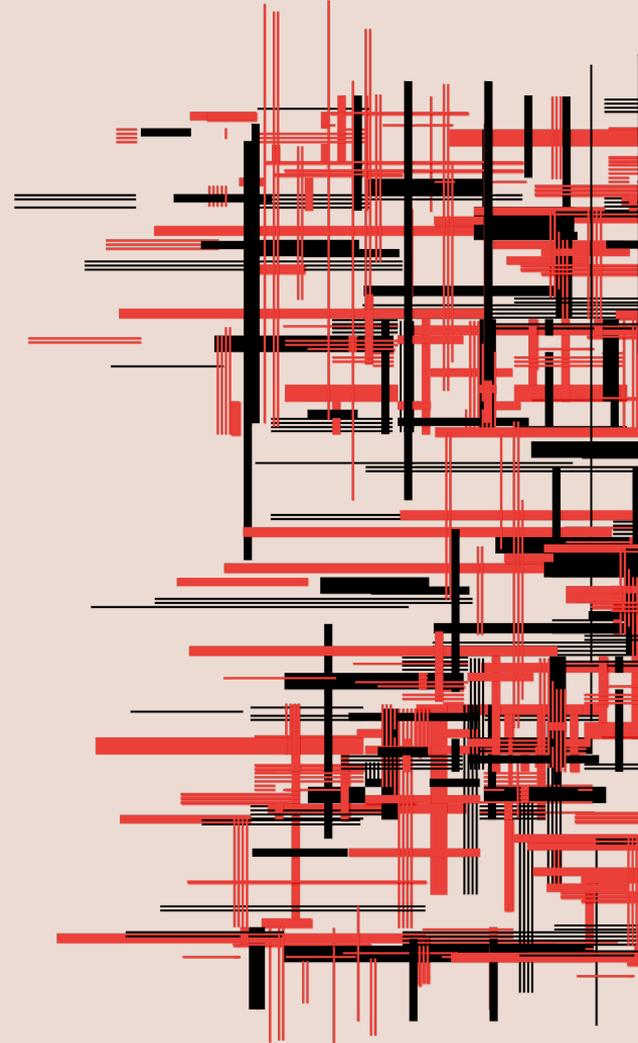


July 19-23, 2021

# Creating Game AI by Using Mostly English

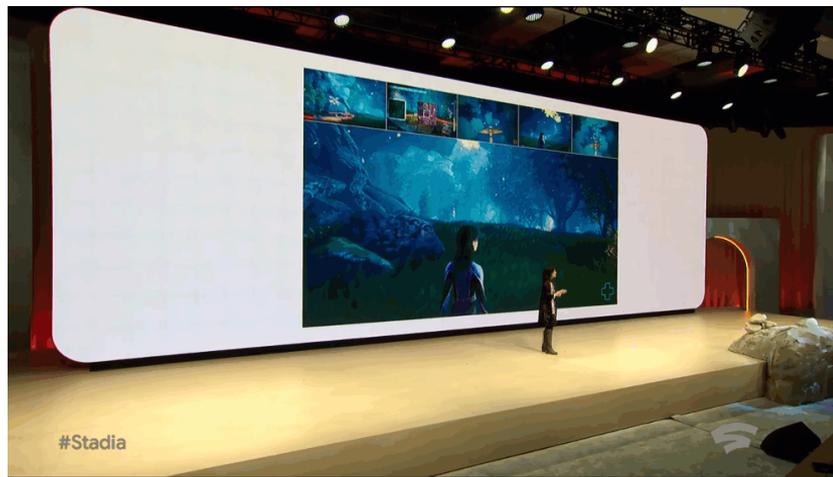
With Semantic ML

Anna Kipnis | @doubleanna



Demos Anna worked on at Google 

Stream Connect from many  
players inside one game



Real-time Style Transfer in a  
game engine



## Games Anna Worked on at Double Fine



Psychonauts



Brütal Legend



Costume Quest



Once Upon a Monster



The Cave



Dear Leader

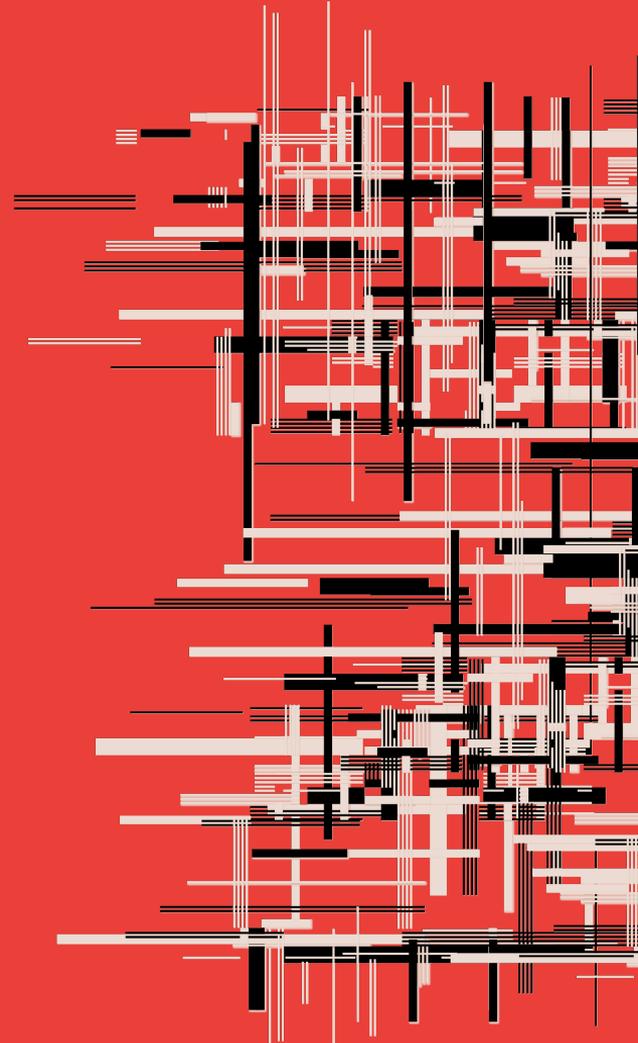


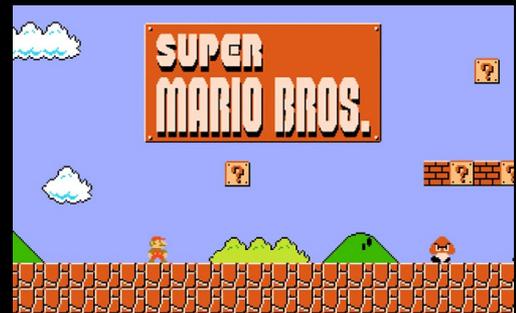
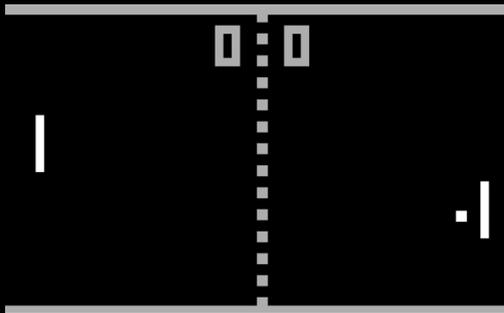
Broken Age



Headlander

# Statement of Problem





## Character Response Authoring in Games

### Anticipate what the Player might try to do

- It is difficult to account for the vast number of emergent interactions the game makes possible for the player

### Come up with a good answer

### Make sure it's hooked up correctly

Welcome to TEXT ADVENTURE!  
\*\*\*\*\*

You are standing in a field overlooking a scary castle. You can go EAST, WEST or NORTH down to the castle.

> HELP

I don't know how to 'help'.

> go to castle

I don't know where that is.

> GO NORTH

You go to the castle.

The castle portcullis is drawn. The walls are coated with thick adventitious roots and twining petioles.

> WHAT THE HELL DOES THAT MEAN

I don't understand that.

> NEITHER DO I, STUPID GAME

A trapdoor opens underneath you. You fall into a pit.

> WHOOPEE DO LA LA

I don't understand that.

It is dark. You may be eaten by a grue.

> FIGHT GRUE

You don't see any grue.

> LOOK FOR GRUE

I don't know what a 'Grue' is.

You have been eaten by a grue. GAME OVER. Would you like to play again?

> NO

# Character Response Authoring in Games

## Anticipate what the Player might try to do

- It is difficult to account for the vast number of emergent interactions the game makes possible for the player
- If you fail to anticipate something, the player will be disappointed.

## Come up with a good answer

- In modern games, content creation is a lot of work

## Make sure it's hooked up correctly



Content Authoring Is a Lot of Work

# Character Response Authoring in Games

## Anticipate what the Player might try to do

- If you fail to anticipate something, the player will be disappointed.
- It is difficult to account for the vast number of emergent interactions the game makes possible for the player

## Come up with a good answer

- All the content and engine features have to flawlessly come together to make a good answer work
- In modern games, content creation is a lot of work

## Make sure it's hooked up correctly

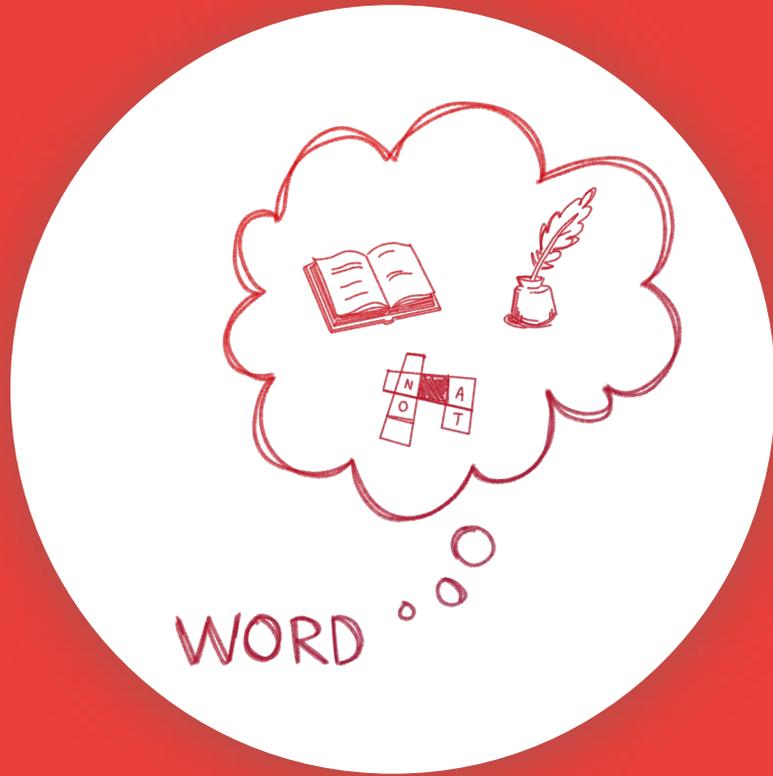
- Player action to game response must be explicit
- Requires programming background
- Translating from preferred language to code and back

# What is Semantic ML?

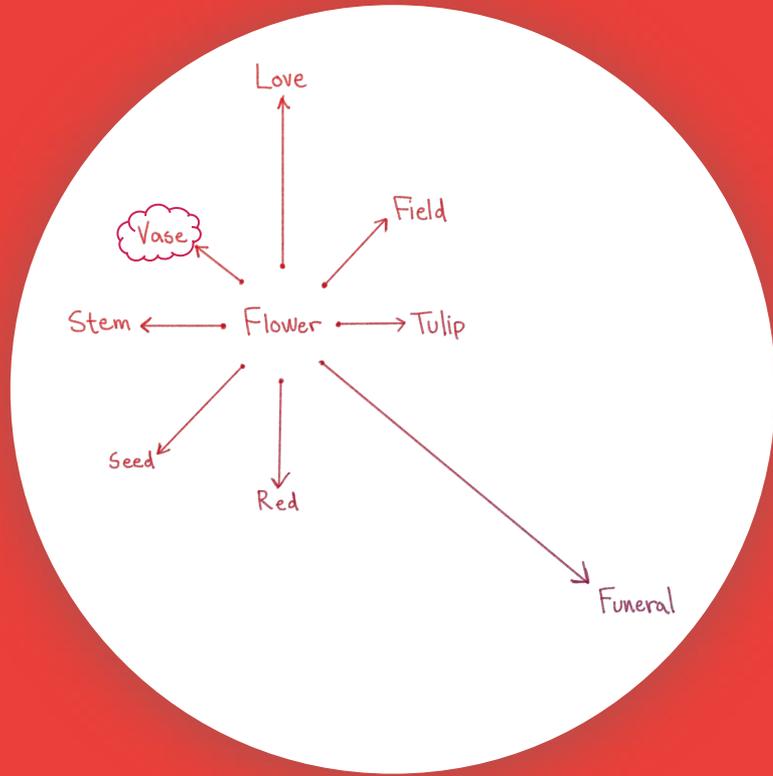


**Semantic:** relating to meaning in  
language or logic.

/sə'man(t)ik/  
adjective



WORD



What if you could  
smuggle context  
into a game?



**outside**  
*move to*  
*look at*

**stick**  
*look at*  
*pick up*  
*move to*

**fern**  
*look at*  
*pick up*  
*move to*

**lamp**  
*turn on*  
*look at*  
*move to*

**book**  
*pick up*  
*move to*  
*look at*

**mug**  
*pick up*  
*move to*  
*look at*

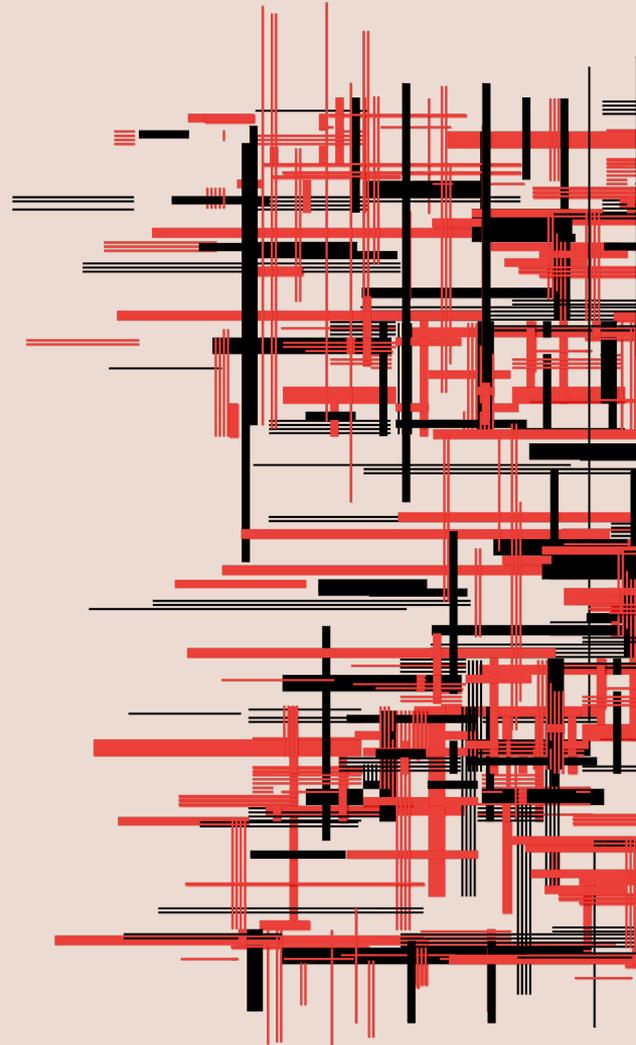
**table**  
*move to*  
*look at*

**couch**  
*move to*  
*look at*

**you**  
*move to*  
*look at*

Game objects and actions can be made of words

Demo





...

Type in here...







Listening... 



How does Fox work?

## Misconceptions about Using Machine Learning

### Myth: Requires training the model!

This is something you hear about a lot in connection with ML, but it is not necessarily true.

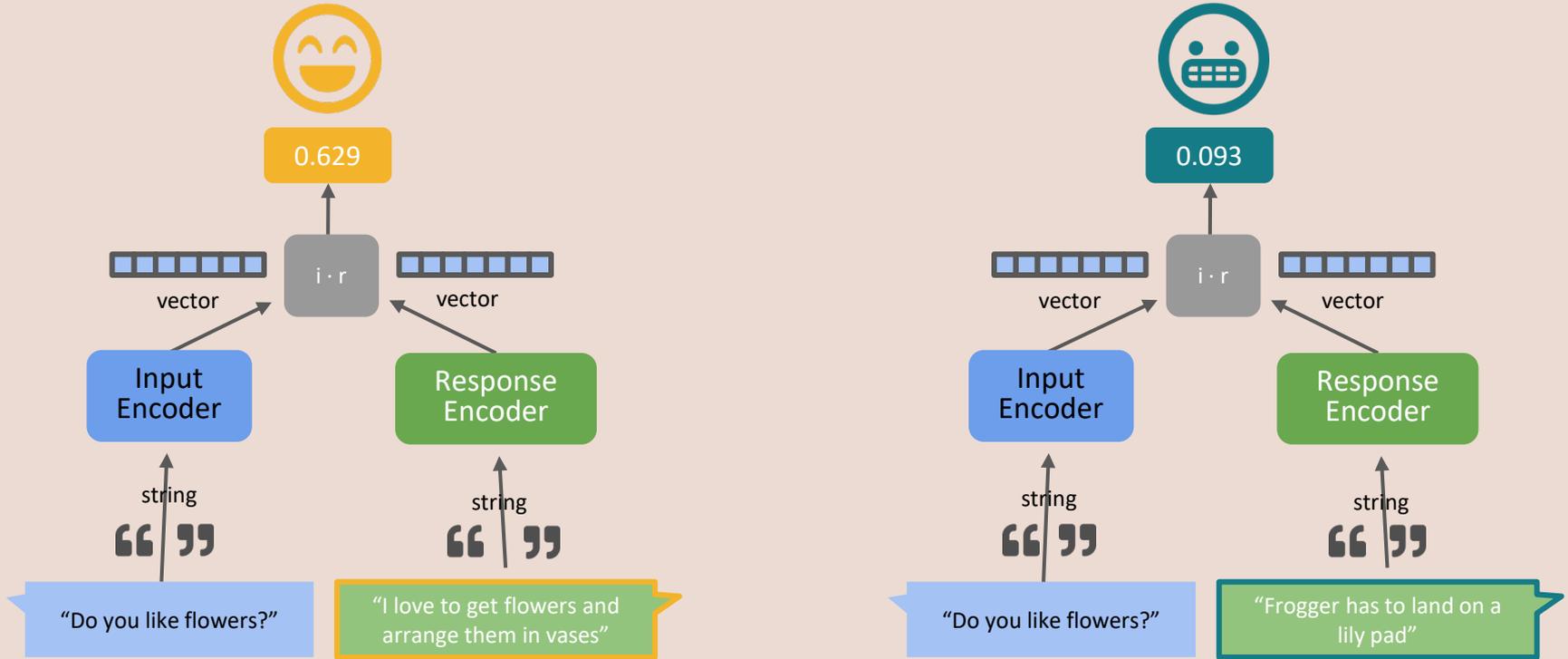
### Myth: Requires massive amounts of data!

This is important for being able to train or fine-tune an ML model. It turns out that it is not needed with this approach.

### Myth: Developers have no control over output!

There are clever ways to have control over, and also to be able to make a decision about whether to use the ML model's output, at runtime.

# How the Dual Encoder model works



Semantic ML model has two modes

### Input/Response

“Given this input, which of these phrases is the best response?”

### Semantic Similarity

“Given this input, which of these phrases is the most similar?”

To use this model, you:

Provide the input:

flower

Provide all the possible candidates:

#### Candidates

love

red

green

seed

stem

tulip

field

funeral

vase

Tell it which mode to use:

Input / Response

or

Semantic Similarity

Model ranks the responses!

1) vase	0.475
2) tulip	0.412
3) stem	0.405
4) field	0.362
5) red	0.345
6) seed	0.343
7) green	0.329
8) love	0.321
9) funeral	0.287

Grammar: | [Verb] [Noun]  
| [Verb]

Verb is an action the Fox can do

Pick up



Drop



Throw

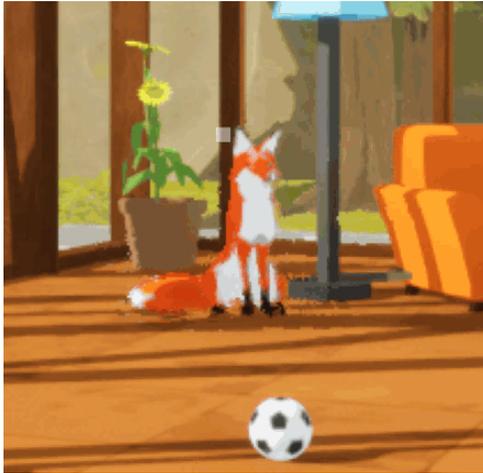


Noun is an object or point of interest in the room

Lamp



Ball



You



## Generating the Expression Space

I [Verb] [Noun]

I pick up lamp  
I pick up ball  
I pick up you  
I drop lamp  
I drop ball  
I drop you  
I throw lamp  
I throw ball  
I throw you

## Using the model for the Fox:

Provide input:

say hi to everyone

Provide all possible candidates:

### Candidates

I move to you  
I look at you  
I move to here  
I move to outside  
I look at here  
I look at outside  
I conjure broom  
I coniure aoblet

Tell it which mode to use:

Input / Response

or

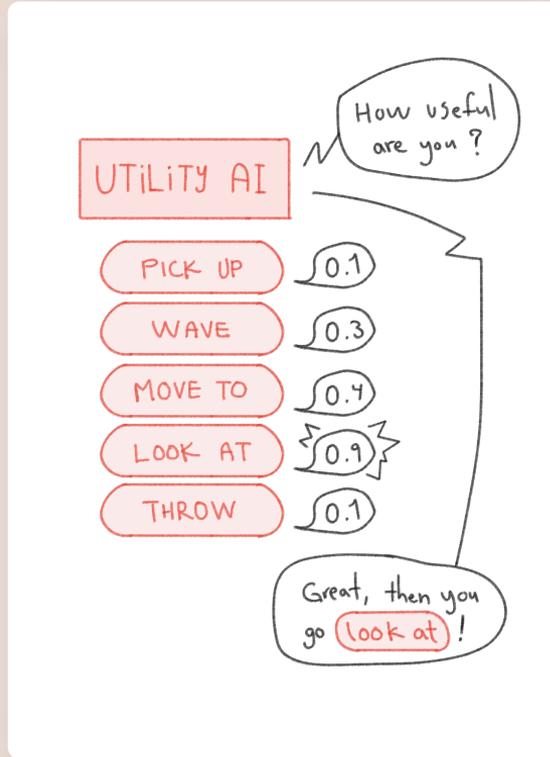
Semantic Similarity

Model ranks the responses!

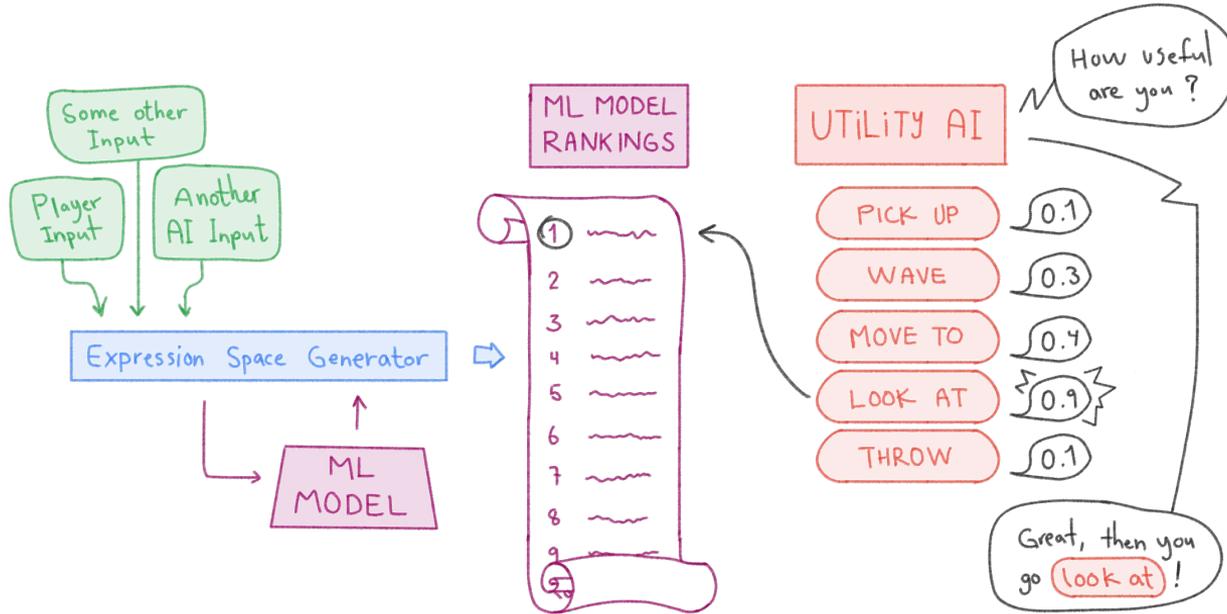
- 1) I wave
- 2) I nod
- 3) I shake head
- 4) I give ball to you
- 5) I open the door
- 6) I look at you
- 7) I drop mug near you
- 8) I drop ball near you

# AI Architecture

## Utility AI: Traditional game AI architecture for characters



# AI Architecture



Fox AI:  
Utility AI  
+  
Semantic ML

# Drawbacks of Using the Semantic ML Model on its Own

## Conflates Antonyms

For example:

- “yes” and “no”
- “relief” and “worry”

Will tend to score similarly

## Conflates Figurative & Literal Meanings

For example:

- “*I stand behind you*” (“I support you” vs “I am located near your back”)
- “*I hit the books*” (“I punch the books” vs “I begin to study”)

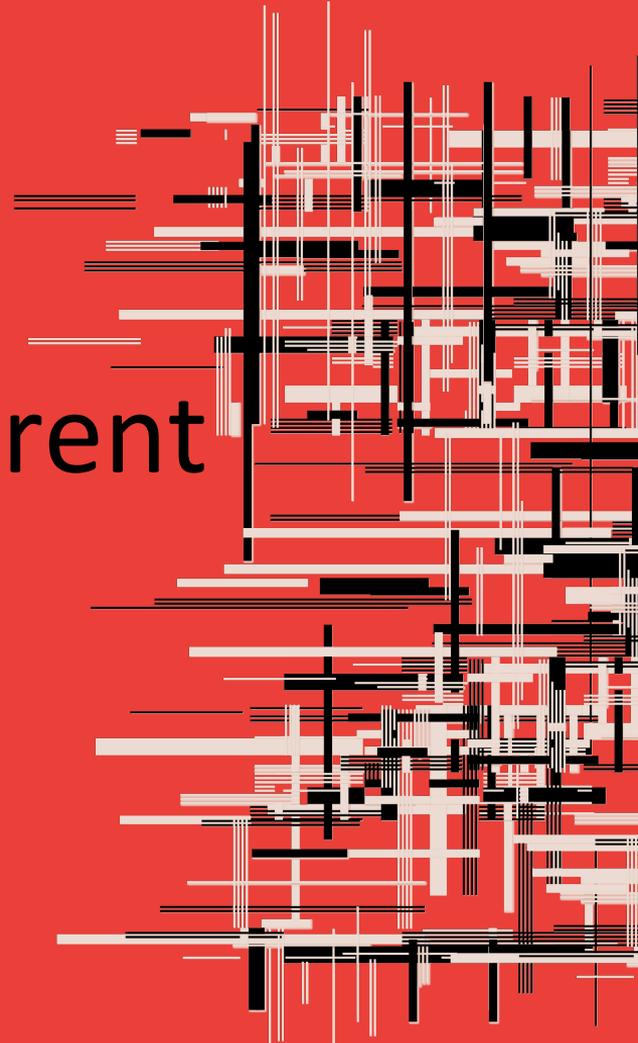
## Contains Human Biases

Model is trained on signal from human conversation, so you get the human wisdom, but unfortunately, also the human bias

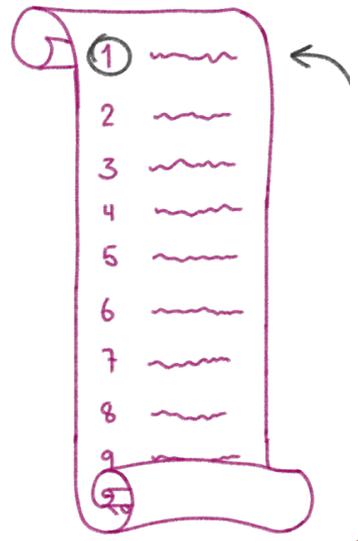
## Deterministic Output

Sometimes you just want the character to exhibit different behavior!

What if you wanted different reactions?



ML MODEL RANKINGS





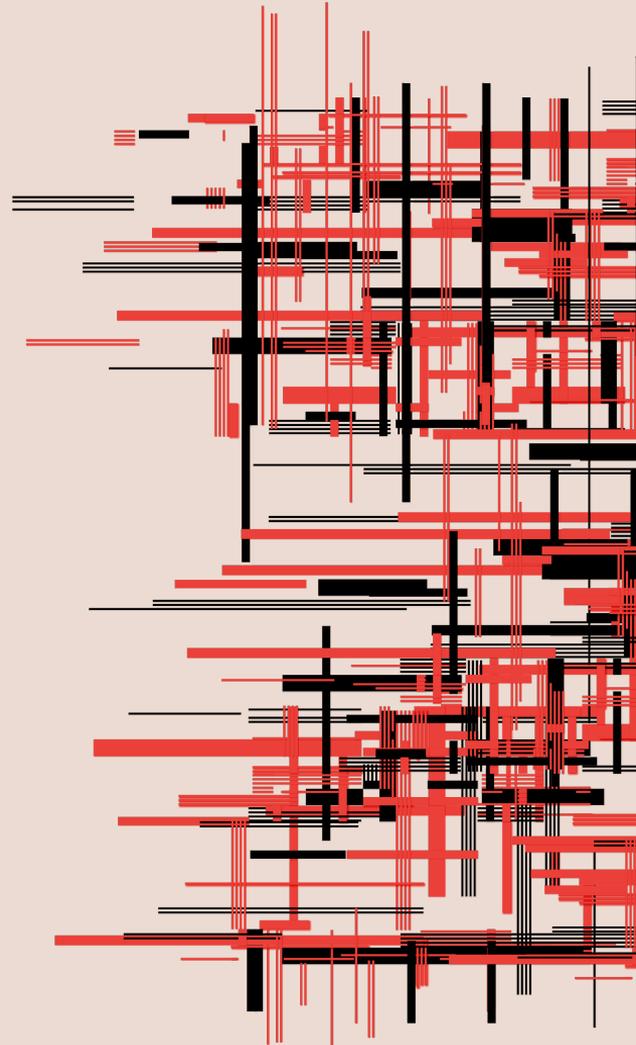
Different Fox  
personalities through  
rule sets!

## Applying rules to behavior

IF THE INPUT IS	THEN BIAS THE RESPONSE	TO BE
hi	i get very sad	Very Likely ▼
do you want to play?	no	Very Likely ▼
can i have some coffee?	i offer coffee	Very Unlikely ▼
i throw stick to you	i pick up the stick and drop it near the lamp	Kind of Likely ▼

A tool to alter the model's outcome, to further customize NPC behavior

Demo





...

...

|Type in here... ↩

## Semantic ML model has two modes



### Input/Response

“Given this input, which of these phrases is the best response?”

### Semantic Similarity

“Given this input, which of these phrases is the most similar?”



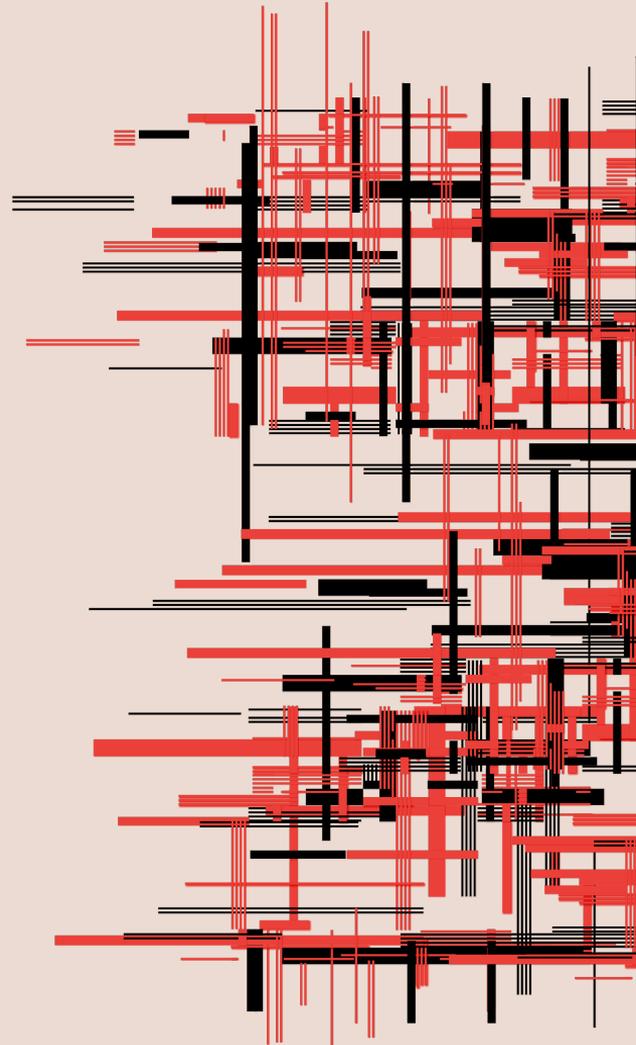
Authoring ambient  
behaviors in  
natural language!

Using ML and natural language to script the NPC's ambient behaviors

<i>fx</i>	A
1	<b>Patrol Room</b>
2	go to the lamp
3	look at the couch
4	go here
5	get excited
6	go play with the fern
7	find some money
8	look outside

Game just needs an  
asset with text in it

Demo





	Patrol Room	
1		
2	go to lamp	
3	look at sofa	
4	come here	
5	talk to me	
6		
7		
8		
9		
10		
11		
12		
13		
14		
15		
16		
17		
18		
19		
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32		
33		



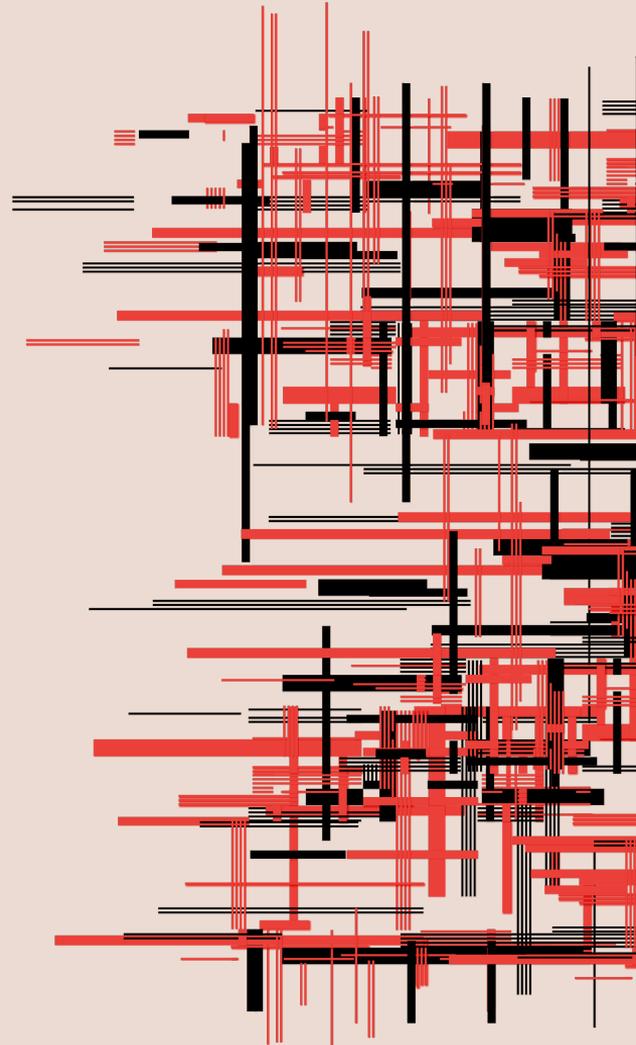
# Further Applications



# Semantic ML for Content Choreography, Music, Sound FX, Dialog, and more!



Demo





Type in here...



# Highly Versatile

## Engine-Agnostic

Models just need an ML environment to run. For example, the game can make REST (HTTP) calls to get/post the input and output.

## Modular

Does not require any changes to existing engine or systems to work.

## Flexible

Features can be used as much or as little as you want.

Use for AI, for dialog, for picking music, etc

## Pre-Trained, Free

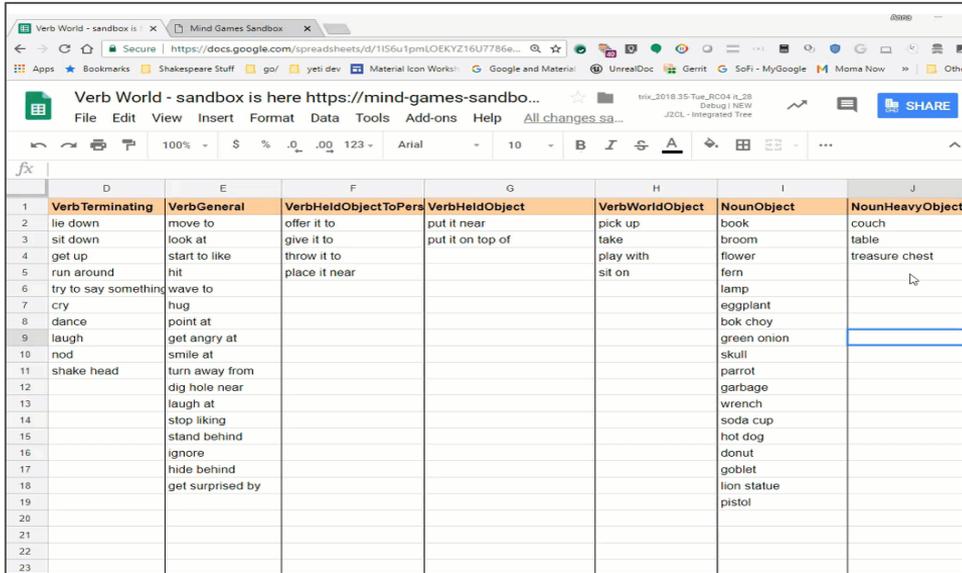
The models are pre-trained and publicly available here: [research.google.com/semanticsolutions/](https://research.google.com/semanticsolutions/) (in For Developers)

# Evolution of the Demo



# Prototyping Process

## First Prototype: Spreadsheet + Sandbox



The screenshot shows a Google Sheet with the following data:

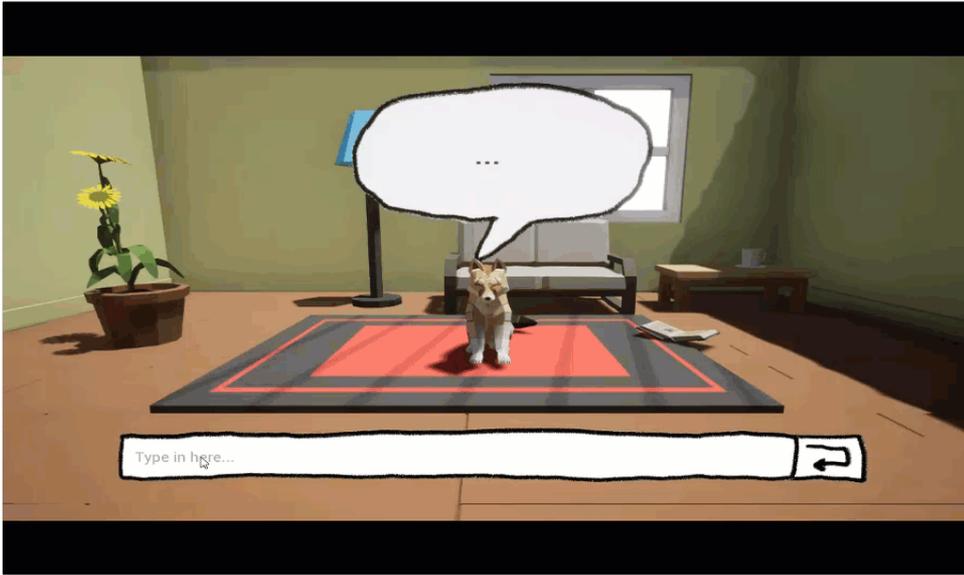
	D	E	F	G	H	I	J
1	<b>Verb Terminating</b>	<b>VerbGeneral</b>	<b>VerbHeldObjectToPers</b>	<b>VerbHeldObject</b>	<b>VerbWorldObject</b>	<b>NounObject</b>	<b>NounHeavyObject</b>
2	lie down	move to	offer it to	put it near	pick up	book	couch
3	sit down	look at	give it to	put it on top of	take	broom	table
4	get up	start to like	throw it to		play with	flower	treasure chest
5	run around	hit	place it near		sit on	fern	
6	try to say something	wave to				lamp	
7	cry	hug				eggplant	
8	dance	point at				bok choy	
9	laugh	get angry at				green onion	
10	nod	smile at				skull	
11	shake head	turn away from				parrot	
12		dig hole near				garbage	
13		laugh at				wrench	
14		stop liking				soda cup	
15		stand behind				hot dog	
16		ignore				donut	
17		hide behind				goblet	
18		get surprised by				lion statue	
19						pistol	
20							
21							
22							
23							

No need to build anything when starting out:

- Represent everything as text
- Take advantage of Sheets' scripting
- Try it with the sandbox
- Imagine how it plays out in the game

## Prototyping Process

### Next Step: Simple in-game prototype



Recreate the spreadsheet prototype in the game engine:

- Port the spreadsheet prototype (data + scripts)
- Get the ML model into the game
- Get it running just using text

## Prototyping Process

Next Step: Text expressed as content



Transform text into actions to perform on objects:

- Set up metadata to connect text to action
- Author modular actions
- Label actions and objects of interest in natural language

## Prototyping Process

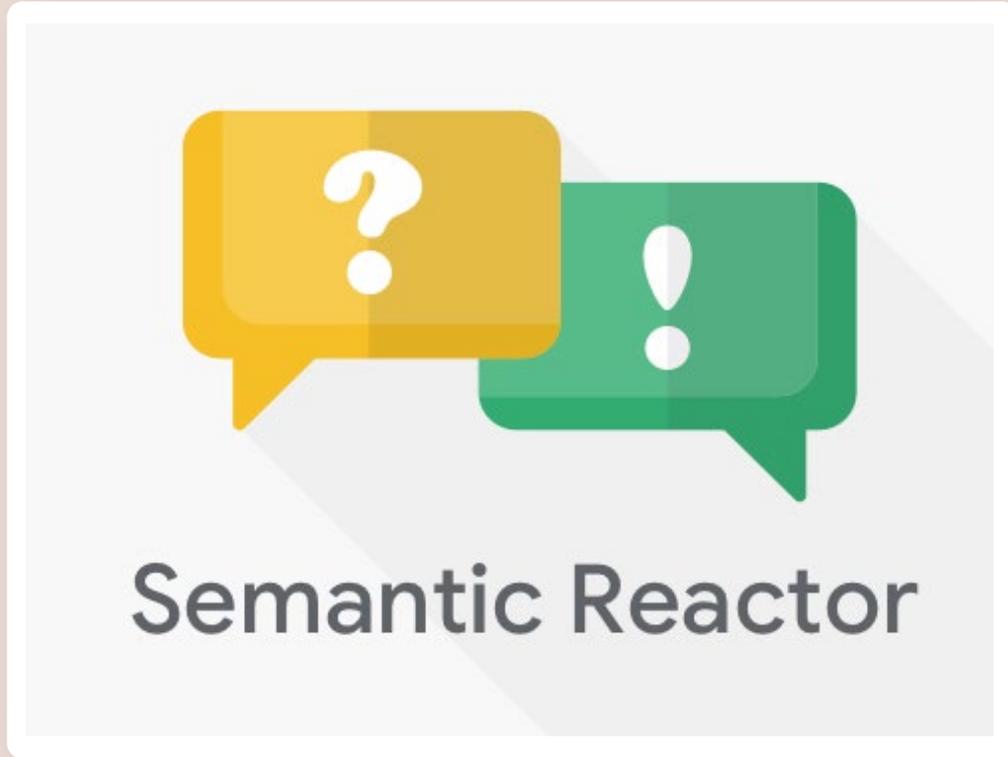
More actions implemented,  
environment is grey-boxed



Help from artists ❤️!



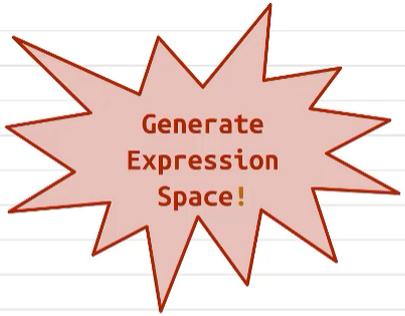
## Tool to Experiment with Semantic ML (Free)



Google Sheets Add-On sandbox for Semantic ML:

- Experiment with an idea in text, before trying it in the game
- Validate a result you're seeing in your game
- <https://research.google.com/semanticexperiences> (in Semantic Reactor)

	A	B	C	D	E	F	G	H	I
1			<b>Sentence Grammar (add the word columns on the right)</b>	<b>VerbTerminating</b>	<b>VerbGeneral</b>	<b>VerbHeldObject</b>	<b>NounObject</b>	<b>NounPerson</b>	
2			I [VerbTerminating]	try to say something	move to	give	book	you	
3			I [VerbGeneral] [NounObject]	cry	look at	offer	floppy disk		
4			I [VerbHeldObject] [NounObject] to [NounPerson]	laugh	pick up	throw	fern		
5			yes	nod	take		small mug		
6			no	shake head	play with		stick		
7				wave					
8				feel confused					
9				cheer					
10				feel empathetic					
11				feel shocked					
12				feel worried					
13				get excited					
14				get angry					
15				read					
16									
17									
18									



	A	B	C	D	E	F	G	H	I
1	I try to say something		<b>Sentence Grammar (add the word columns on the right)</b>	<b>VerbTerminating</b>	<b>VerbGeneral</b>	<b>VerbHeldObject</b>	<b>NounObject</b>	<b>NounPerson</b>	
2	I cry		I [VerbTerminating]	try to say something	move to	give	book	you	
3	I laugh		I [VerbGeneral] [NounObject]	cry	look at	offer	floppy disk		
4	I nod		I [VerbHeldObject] [NounObject] to [NounPerson]	laugh	pick up	throw	fern		
5	I shake head		yes	nod	take		small mug		
6	I wave		no	shake head	play with		stick		
7	I feel confused			wave					
8	I cheer			feel confused					
9	I feel empathetic			cheer					
10	I feel shocked			feel empathetic					
11	I feel worried			feel shocked					
12	I get excited			feel worried					
13	I get angry			get excited					
14	I read			get angry					
15	I move to book			read					
16	I move to floppy disk								
17	I move to fern								
18	I move to small mug								



**Semantic Reactor: <https://research.google.com/semanticeperiences>**

	A	B	C	D	E	F	G	H
1	I try to say something		<b>Sentence Grammar (add the word columns on the right)</b>	<b>VerbTerminating</b>	<b>VerbGeneral</b>	<b>VerbHeldObject</b>	<b>NounObject</b>	<b>NounPerson</b>
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4	I nod		I [VerbHeldObject] [NounObject] to [NounPerson]	laugh	pick up	throw	fern	
5	I shake head		yes	nod	take		small mug	
6	I wave		no	shake head	play with		stick	
7	I feel confused			wave				
8	I cheer			feel confused				
9	I feel empathetic			cheer				
10	I feel shocked			feel empathetic				
11	I feel worried			feel shocked				
12	I get excited			feel worried				
13	I get angry			get excited				
14	I read			get angry				
15	I move to book			read				
16	I move to floppy disk							
17	I move to fern							
18	I move to small mug							
19	I move to stick							
20	I look at book							
21	I look at floppy disk							
22	I look at fern							



**Semantic Reactor** ✕

**GDC Demo**

Embedding finished.

Model

Local  
 Basic Online  
 Multilingual Online

Rank method

Input / Response  
 Semantic Similarity  
 ...with Reranker

1) no	0.206
2) I play with stick	0.206
3) yes	0.204
4) I offer stick to you	0.199
5) I move to stick	0.198

Semantic Reactor: <https://research.google.com/semanticexperiences>

	A	B	C	D	E	F	G	H
1	I try to say something		<b>Sentence Grammar (add the word columns on the right)</b>	<b>VerbTerminating</b>	<b>VerbGeneral</b>	<b>VerbHeldObject</b>	<b>NounObject</b>	<b>NounPerson</b>
2	I cry		I [VerbTerminating]	try to say something	move to	give	book	you
3	I laugh		I [VerbGeneral] [NounObject]	cry	look at	offer	floppy disk	
4	I nod		I [VerbHeldObject] [NounObject] to [NounPerson]	laugh	pick up	throw	fern	
5	I shake head		yes	nod	take		small mug	
6	I wave		no	shake head	play with		stick	
7	I feel confused			wave				
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10	I feel shocked			feel empathetic				
11	I feel worried			feel shocked				
12	I get excited			feel worried				
13	I get angry			get excited				
14	I read			get angry				
15	I move to book			read				
16	I move to floppy disk							
17	I move to fern							
18	I move to small mug							
19	I move to stick							
20	I look at book							
21	I look at floppy disk							
22	I look at fern							



### GDC Demo

Embedding finished.

Reload Clear cache Hide config

Model

- Local
- Basic Online
- Multilingual Online

Rank method

- Input / Response
- Semantic Similarity
- ...with Reranker

do something amazing React

- 1) I cheer 0.095
- 2) I get excited 0.092
- 3) I throw stick to you 0.082
- 4) I look at stick 0.080
- 5) I laugh 0.080

	A	B	C	D	E	F	G	H
1	I try to say something		<b>Sentence Grammar (add the word columns on the right)</b>	<b>VerbTerminating</b>	<b>VerbGeneral</b>	<b>VerbHeldObject</b>	<b>NounObject</b>	<b>NounPerson</b>
2	I cry		I [VerbTerminating]	try to say something	move to	give	book	you
3	I laugh		I [VerbGeneral] [NounObject]	cry	look at	offer	floppy disk	
4	I nod		I [VerbHeldObject] [NounObject] to [NounPerson]	laugh	pick up	throw	fern	
5	I shake head		yes	nod	take		small mug	
6	I wave		no	shake head	play with		stick	
7	I feel confused			wave				
8	I cheer			feel confused				
9	I feel empathetic			cheer				
10	I feel shocked			feel empathetic				
11	I feel worried			feel shocked				
12	I get excited			feel worried				
13	I get angry			get excited				
14	I read			get angry				
15	I create fireworks!!!			read				
16	I move to book			create fireworks!!!				
17	I move to floppy disk							
18	I move to fern							
19	I move to small mug							
20	I move to stick							
21	I look at book							
22	I look at floppy disk							



**Semantic Reactor** ✕

**GDC Demo**

Embedding finished.

Model

Local  
 Basic Online  
 Multilingual Online

Rank method

Input / Response  
 Semantic Similarity  
 ...with Reranker

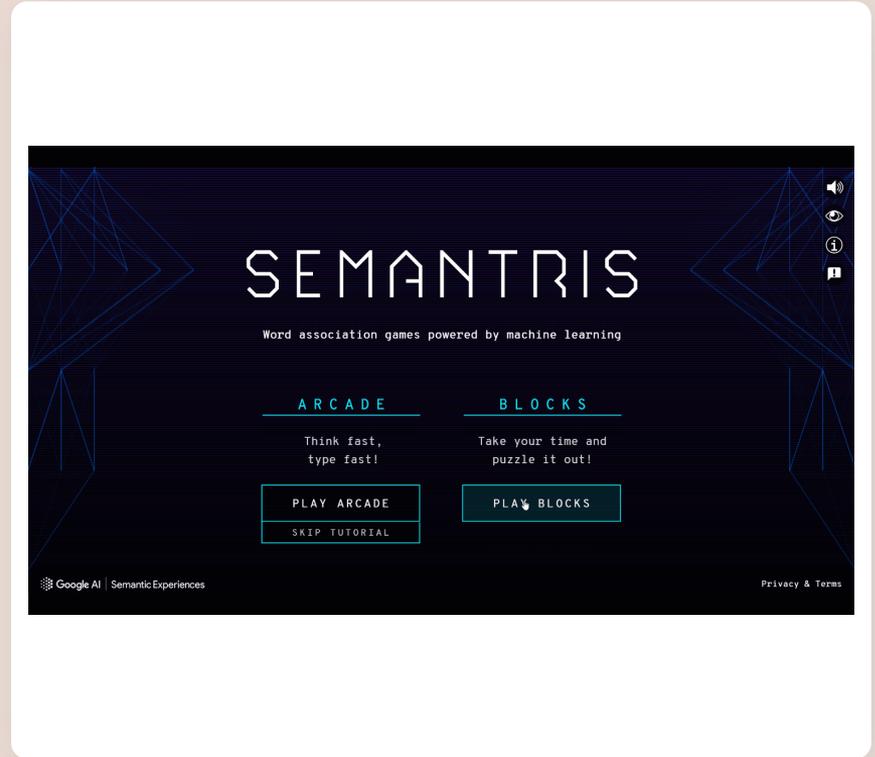
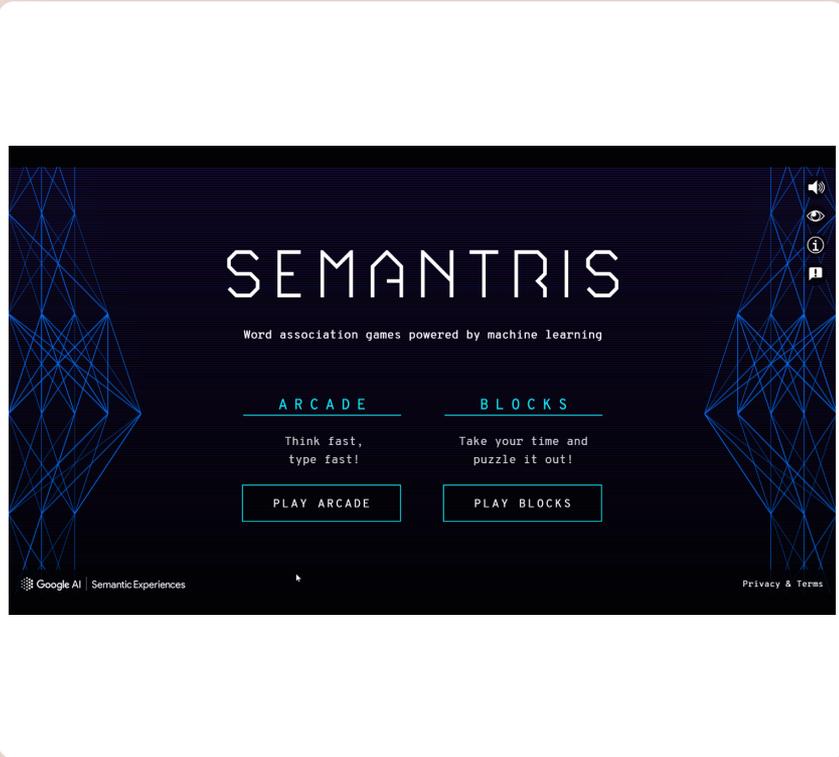
1) I create fireworks!!!	0.100
2) I cheer	0.095
3) I get excited	0.092
4) I throw stick to you	0.082
5) I look at stick	0.080

Semantic Reactor: <https://research.google.com/semanticeperiences>

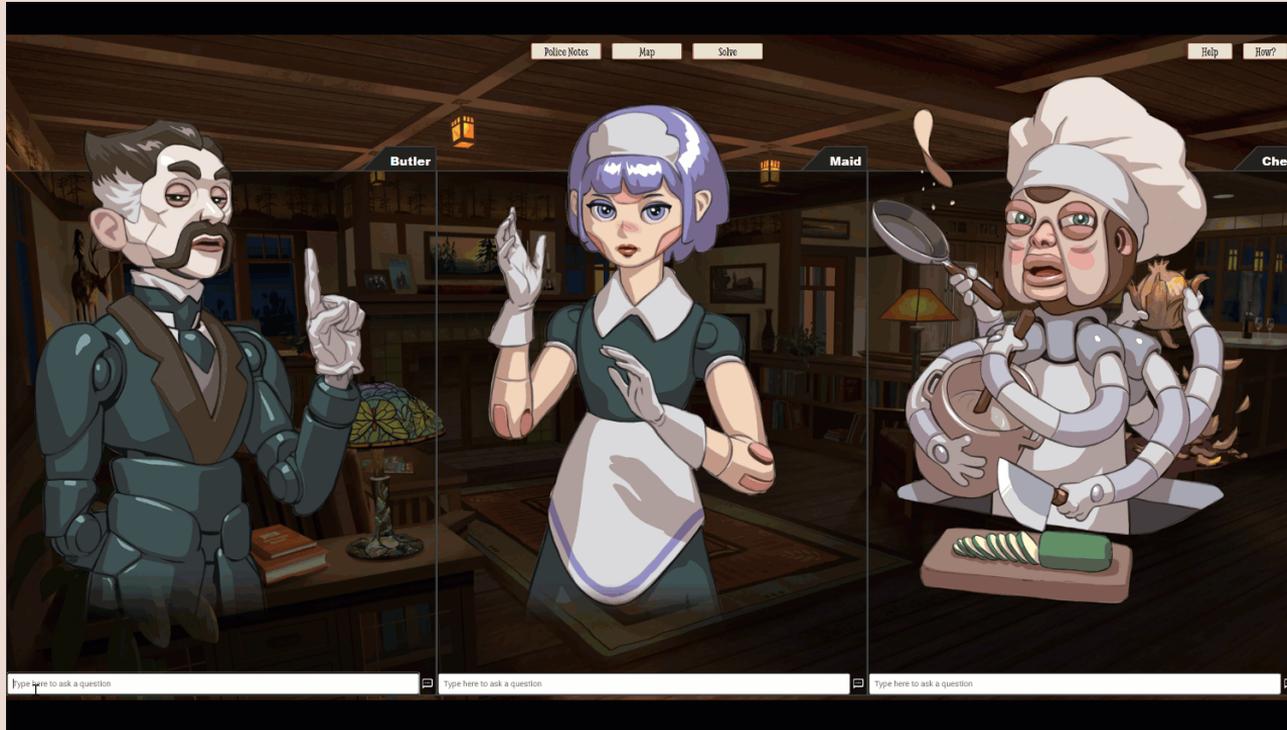
More to Explore



# Play Semantris - research.google.com/semantris



# Play Mystery of the Three Bots - [google.github.io/MysteryOfThreeBots](https://google.github.io/MysteryOfThreeBots)



OFF • ON ▶

DOT MATRIX WITH STEREO SOUND



Making With ML on YouTube:  
Building smarter games with machine learning ([youtu.be/30y9zk5COqw](https://youtu.be/30y9zk5COqw))

# From Spreadsheet to Code with TensorFlow.js

Underneath the hood, Semantic Reactor is powered by the open-source TensorFlow.js models found [here](#).

Let's take a look at how to use those models in JavaScript, so that you can convert your spreadsheet prototype into a working app.

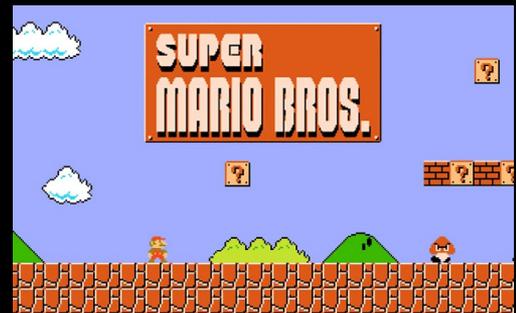
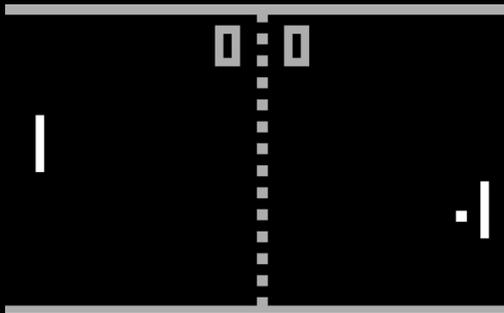
1 - Create a new Node project and install the module:

```
npm init  
npm install @tensorflow/tfjs @tensorflow-models/universal-sentence-encoder
```

2 - Create a new file (`use_demo.js`) and require the library:

```
require('@tensorflow/tfjs');  
const encoder = require('@tensorflow-models/universal-sentence-encoder');
```

DaleOnAI.com/semantic-ml Example of working code!



Thanks!

@doubleanna

Talk Summary: [stadia.dev/blog/creating-game-ai-using-mostly-english/](https://stadia.dev/blog/creating-game-ai-using-mostly-english/)

Semantic Reactor & Semantic ML Models:  
[research.google.com/semanticeperiences/](https://research.google.com/semanticeperiences/)

Example Code: [DaleOnAI.com/semantic-ml](https://DaleOnAI.com/semantic-ml)

Mystery of the Three Bots + Source:  
[google.github.io/MysteryOfThreeBots](https://google.github.io/MysteryOfThreeBots)