CRAIG: [00:09](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=9.66) This is Craig Smith with a new podcast about artificial intelligence. I'm a former New York Times correspondent now focused on AI and I've been talking to people who are making a difference in the space. I'm bringing the most interesting of those conversations to you. This week. I talked to Julian Togelius, perhaps the most prolific researcher at the intersection of video games and artificial intelligence. Julian, Swedish by birth, is currently an associate professor at New York University where he works on AI for games and games for AI. Some of his most significant work is in training deep neural networks to play video games and generalize what they have learned, a critical step toward artificial general intelligence. For those of you who don't understand the importance of video games to artificial intelligence research, Julian will enlighten you. For those of you who do his recent work will surprise you.

CRAIG: [01:14](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=74.59) I wanted to ask you about the role of computer games in AI research. It's something that the world at large is not necessarily aware of, and there are a lot of people who look down on video games without realizing their value.

JULIAN: [01:30](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=90.49) Yeah, I don't understand why people look down on video games. If you look at this from the beginning of AI, people thought of using computers to play chess, and chess was considered something close to pure thinking. It seemed like such a perfect AI problem. This kept being an important problem until 1997 when IBM's Deep Blue computer beat Garry Kasparov and for the first time a computer was the world champion of chess, which was sort of an important cultural moment. Twenty years later, back in 2016, we saw the same thing repeated again with Go and Go is a board game which holds a similar cultural significance in many east Asian countries as chess does in Europe and North America. My own sort of personal history here is that I studied philosophy because I was very, very bad at mathematics and didn't want to have anything to do with it - true story

CRAIG: [02:20](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=140.81) That's surprising.

JULIAN: [02:21](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=141.71) Yeah. No, no. I still. I still don't know much math. And I thought that that was how I would understand the mind, Understanding the mind by reading and writing about it was going to take too much time, so I went into computer science so I could study artificial intelligence because I wanted to build minds. And then for my PhD the plan was to use evolutionary computation, which is, attempts to build algorithms to evolve neural networks that could control robots. And I started with that, but I was too impatient to do that. Robots are really slow and they breakdown all the time and you need to change tires and fill up oil and all kinds of these that I'm just not interested in. Then what do we want these robots to do? Well, we want them to navigate the environments and pick things up and so on, Well, that's what we do in video games all the time. And in video games, you can do these things like thousands of times faster and it's much more dependable - if something goes wrong, you just restart the game - and also video games, especially good video games that have had commercial success and are considered well designed, these have been built by hundreds of people and in effect tested by millions of people, so they're much more well tested than the best robot benchmarks. So video games are in many ways ideal. Another reason why video games are so good is that they were designed to challenge our minds. So if games are designed to challenge our minds, that must mean that they are very good benchmarks for artificial intelligence as well. Video games are in many ways a godsend for artificial intelligence researchers because it's like you have a whole industry working really hard to give us the perfect benchmarks for our methods

CRAIG: [04:04](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=244.77) Yeah, and particularly now that they're online, you're collecting tremendous amounts of data.

JULIAN: [04:10](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=250.571) You can learn about humans as well, doing things such as classifying players, predicting what players will do, and you can find out that you can predict a lot about humans from how they play games. Humans are a pretty predictable.

CRAIG: [04:25](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=265) Can you walk us through a little bit the history of AI researchers developing systems to play games from the arcade games to today?

JULIAN: [04:36](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=276.49) The Atari 2600 console was the world's first commercially successful home video game console with swappable games. It was released in 1976 or 77 and it's an astonishingly simple machine. Most of the games were encoded in two kilobytes, or four kilobytes of read only memory, which is nothing - it's like one page of text. And the internal memory, the writable memory, was 128 bytes, not kilobytes or megabytes or gigabytes: bytes. That's half a tweet, which is like almost nothing. It had no video memory and a very slow processor,

JULIAN: [05:15](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=315.66) So the games you could make in this machine was very, very simple. There were also a number of limitations that are less obvious to people, but very important for its role as AI benchmark. One is that it had no system clock. It means that you cannot make a real random number generator. So they were all deterministic. The same sequence of inputs would always lead to the same sequence outputs. Many modern games rely on the pseudorandom number generators which rely on you having a system clock among many other things as an input to create randomness. So these are super, super simple games. The ALE framework - ALE stands for the Arcade Learning Environment, built around an emulator of the Atari 2600 console - it started becoming popular in 2012, 2013. By that time there was already a community since at least 2005 that had been working on using various video games as AI benchmarks and on using video games to improve game design and game development in various ways, Google's DeepMind unit started using ALE as their main testbed and put out a very sort of significant paper about how we could use deep reinforcement learning algorithms and deep neural networks to play these games straight from the pixels and that sort of started the current craze.

JULIAN: [06:38](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=398.56) But even before then, there's been a lot of research and using other video games as well. For my PhD, back in 2004, 2007 I did a lot with car racing games - those that I built myself and other existing car racing games, learning how to drive - using evolutionary algorithms to learn how to drive. Or other people have been working with first person shooters such as Unreal Tournament, Doom and so on. Neural nets have been in widespread use in AI research since the mid-80s. What happened around 2013 or so was that there was a realization that very deep neural nets with enough data, enough computation power and a few algorithmic tweaks could be made to work well, and, in particular, that very deep neural nets could work straight on visual data, such as pixel inputs, pixels from playing a video game or from images if you're sort of building an image recognition AI.

CRAIG: [07:36](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=456.87) And DeepMind’s use of ALE ...

JULIAN: [07:40](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=460.65) They use deep reinforcement learning to play Breakout or a number of other games. They managed to show super human performance in about half of Atari games and the since then there's been literally hundreds of papers trying to come up with better performance on especially those games that you did not, did not have super human performance back then. And now people have been able to train neural nets to play all of these games to at least human performance level.

CRAIG: [08:07](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=487.381) Has your research then moved beyond ALE into more immersive environments?

JULIAN: [08:12](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=492.8) Interestingly, I've never used ALE much myself. One reason is that we have our own environment that we call the General Video Game AI Environment, which can represent very similar types of games. But we built an emulator ourselves, which works with our own video game description language and we use that for a lot of experiments. Part of the reason we did this is that the games in the ALE environment are fixed. There's a certain set of games and you can't change them. Or you could write a new Atari game, but that's horrendously difficult. So we wanted to make it very easy to make new games or to change existing games for either a human or an algorithm. Part of the reason for this is that if what you're after is testing your AI algorithms, it's very important that you don't overfit to a particular set of levels for a particular game.

CRAIG: [09:07](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=547.231) You talk in some of your writing about the need to have sort of an infinite number of games so that when you're training you're not overfitting to one specific set of constraints.

JULIAN: [09:19](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=559.351) So. So one very important thing to note is that these deep neural networks trained to play Atari games, they only learned to play one game at the time. There are very few examples of networks being trained to play more than one game and as far as I can tell, no examples of networks being able to learn something in one game that is then used in learning to play another game or no significant examples of that. In effect what you're doing is you are training to play a particular game. And as we have recently discovered, not just a particular game but a particular set of levels for a particular game. We have what in machine learning terms is called overfitting - it's when you are not learning to solve a task, you just learn to solve a very specific instance of that task. And you're not generalizing. Now, any kind of real intelligence can do more than one thing. As human beings, we can do a myriad of different things and we have all this sort of general knowledge about the world that teaches us how to quickly pick up a new skill. So currently we are seeing almost none of that with deep learning. What is really important now is that we go beyond particular games, and particular scenarios and levels of particular games, because we've done that almost a death and it's not bringing us much closer to actual general intelligence.

JULIAN: [10:40](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=640.9) If you want to reach general intelligence, you need to train networks that can learn to do one task and then use the knowledge they learned here to learn a wider and wider variety of tasks. And these networks don't because they don't know anything. So that's an issue with the current artificial intelligence research and much of it really.

CRAIG: [10:59](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=659.291) Yeah. I mean, one thing, if you just alter the color of the pixels or change the dimness, it breaks down, it's very specific.

JULIAN: [11:07](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=667.721) Yes, and we've seen this in so many ways. If you alter the screen ratio or something. So one thing we did recently was that in this general video game AI environment we have, we train networks to play particular games and then we did small changes, not even to the game rules, how they were presented, but we changed the levels a bit and we saw these trained networks breaking down completely. So we said, what if we don't train on a particular level but on a level generator that generates new levels and every time it plays it plays a new level.

CRAIG: [11:39](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=699.521) By level you mean the complexity of the task?

JULIAN: [11:41](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=701.85) No, no, no. The particular instance of the problem, so a game level, the geometry of the level, so where there are walls where the monsters are, where the treasures are - If you're playing such a game. Or if you're playing breakout, where the different bricks are and maybe where your paddle is placed. I mean you change the problem instance. This brought us forward. If you train it so that it never encounters the same problem instance twice, so if it has to solve a maze, it's always a new maze, if it has to learn to collect things, the things are always placed in different places. Then suddenly, it has to learn an actual skill instead of sequence of actions that will solve the problem. The more we do this, the more we realize that the current dominant way of training these neural nets are not training it to think at all, it's just training it to, shall we say rote learn, like in this situation, I do that, under that situation, I do that. Whereas we want it to learn some more general strategies and by giving it new levels all the time, new environments all the time, every time it plays, you can learn somewhat more general skills.

CRAIG: [12:48](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=768.91) And that's the importance of the game generator.

JULIAN: [12:51](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=771.43) That's one of the important things about generating games. So we talked about how games, in particular video games, are perfect artificial intelligence benchmarks, but if you flip it around then this is at least as fascinating. So generating new game environments, new game levels, is super important for testing AI algorithms to develop new AI algorithms, but also for human players. Developing a new hit game are going to cost hundreds of millions of dollars to develop. So, just around the corner here, we have Rockstar Entertainment, they just released Red Dead Redemption 2, which is a very impressive game. You're essentially playing a Western, but it's also extremely expensive to do this sort of thing. And it's still limited - the world you're in is limited to a number of square kilometers. It's not like an actual huge world because everything has to be more or less hand made. Now, could you use AI methods to create that world either as you develop the game or as you play the game? So that's the other half of my research which is deeply intertwined - using games for testing AI, the other part is using AI to help improve game design and development and so on and generating game levels to support a part of that.

CRAIG: [14:04](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=844.3) So on the one hand it's important to have continually changing game environments so that AI is generalizing. On the other hand, in order to create continually changing game environments, you can create an AI system that does that.

JULIAN: [14:22](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=862.01) These things go hand in hand. And also like in more traditional game development, it's very important to have game testing. Now if you have AI systems, or AI agents that can play the games, then these can help you test the games as well.

CRAIG: [14:36](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=876.55) How general have neural nets gotten in playing? Is there transfer learning between games?

JULIAN: [14:44](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=884.24) No. So I feel quite strongly about this because there was so much bullshit going around, where people say these insane things, such as AI can play all Atari games and they can't. Almost all of the deep neural network learning we see results in a network that plays one game, this small set of levels for that game. And we're trying to change that. But it's hard because neural nets are not very good at generalizing and learning generalizable skills. Now one important thing to remember is that training deep neural nets is not the only thing to do. It is sort of the only thing to do if all the input you have is the pixels on the screen. So you have to look at the image and you don't have what's called a forward model. A forward model means that you have a simulator of the game that can run very, very fast so that you can essentially ask questions. If I did this, what would happen. If I do that, what would happen? If you have these things - for many games, the reason why we can play chess and Go so very, very well with computers, is that we have very, very good forward models. We can simulate taking actions in chess and Go extremely much faster than real time, like millions of times faster.

JULIAN: [15:56](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=956.58) And then you can use search algorithms. So Deep Blue, that won over Garry Kasparov in chess didn't use any machine learning and neural networks at all. AlphaGo which uses deep neural nets, but that's not the most important part. The most important part is tree search - using simulations in very clever ways to see what would happen if you are taking various moves. And this can be used in many other games as well. So we have one set thing of our general video game environment where it gives you the ability to simulate moves forward and there we have a lot of search algorithms. There's a class of algorithms called Monte Carlo tree search, which is very powerful for this, and there we see agents that can play not one game but can play half of all games we throw at it essentially. So we see some kind of real generality there, which is very important. We don't see that kind of generality when training deepening neural lots that don't have a forward model to play games. Obviously, why don't we just always had a forward model? Well, many complicated games are just too complex to simulate that fast. A lot of challenge in making real generalizable artificial intelligence for the real world is in learning models of the world so that you can easily plan ahead. And the reason why you and me can go out into the streets and cross the street, even in Manhattan, is that we have all these models of what people are going to do, how are they going to walk, how the cars are going to drive - these things. All these little models we have is what allows us to make lots of little simulations that will allow us to sort of live and act in the real world. This is where we need to go with game-playing AI.

CRAIG: [17:44](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1064.121) Where are you now in your research - I mean I know you have various interests and various projects - but in this specific domain of trying to generalize?

JULIAN: [17:55](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1075.111) Yeah, so one project we have is trying to generalize deep reinforcement learning, and we're working on new ways of generating game levels that challenge the learning algorithm in interesting ways. Sort of searching for the levels that give the right kind of challenge to the learning algorithm to force it to learn more generally. Think of what it does as automatic curriculum construction and we're working on essentially that in creating new video game versions for learning algorithms. That's one part. Another part we are dealing with is that these deep neural networks are extremely big. They're reasonably bigger than they should be because they're so big and in relation to the relatively few number of games they can actually play. That sort of urges them to overfit. It makes it easier for them to learn specific cases than general strategies because they're so big. That's at least a strong hypothesis we have. But we've trained absolutely tiny neural networks - orders of magnitude smaller than the commonly used deep neural networks to play the Atari games. The way we did it was that we replaced the visual processing with other algorithms that basically identified common scenes and instead of giving you all the pixels then, it gave you a vector of how close you were to different common scenes. So it's a very much lower dimensional input and that allowed us to create these tiny neural networks. And one hypothesis we have is that they will overfit much less and we're trying to test this and see how we can go further with separating the visual processing from learning how to play. In terms of generalization, that's what we're doing right now. In terms of game generation, we are doing a ton of things.

CRAIG: [19:34](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1174.82) The content generation, can you describe that a little bit and how you go from that to generating complete games?

JULIAN: [19:41](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1181.901) So generating game content, what's called procedural content generation, has been in games since the early eighties, at least. One of my favorite examples is Elite, this game from 1984 where you traveled around and it has 4,096 different star systems and these stars have planets with space stations around them and they have various spaceships around, traders or police or pirates or whatever. You solve missions and so on. But this game fit in memory on a Commodore 64. It was called 64 because it had 64 kilobytes of memory. So basically the total size of memory was about 30 printed pages. You cannot physically fit this game world inside this computer memory. How did they do it? Well they do it by generating each star system as you go there. This is very significant because they sort of made another kind of game possible and these days and we have games such as No Man's Sky, which even though we have literally a million times more memory now that we had then, we will never be able to fit a game world of the size and detail as we want into memory. So we use the same trick and all games to some extent to use some procedural tricks where some aspects of the game such as the vegetation is generated as you see it - the majority of complex games these days use some level of procedural generation. So I've been working for a long time with how can you take this further, how can you generate richer and bigger and more meaningful game worlds and maybe more personalized game worlds. One of our core tools is evolutionary computation, using Darwinian evolution as an algorithm. And when we do that, let's say that you want to generate levels. You start with a hundred levels and they are all random, they are all very bad and you test them in some way. For example, letting artificial intelligence play them and then you keep the half that was a little bit less bad and then you throw away the worst half. Then you let the best halves have sex with each other, so you mix them around essentially and then you mutate a little bit and then you test all those levels again and see which ones are best and you do this again and again, just like animals or plants would do in real life. And sometimes these little mutations will lead to improvements. And you keep the improvements so this evolutionary search can generate much better levels than you had before. This is a concept that's being tried again and again that we know we can create, for example, Super Mario Bros levels that have the right challenge and that have the right amount of variation and that have the right problems of this and these types, for example, and you have an unlimited source of new Super Mario Bros levels to give you just to right experience.

CRAIG: [22:19](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1339.01) It's happening in real time? The generation is happening in real time?

JULIAN: [22:22](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1342.431) In some cases, yeah. We can certainly do Super Mario Bros levels in real time. Recently, this is also being complemented by what we call procedural content generation by machine learning. So you take lots of existing game content. You try to learn some general patterns from it and use that to produce new levels. So that's been done with Super Mario Bros levels as well. We do a lot of research of various versions Super Mario Bros because it's so easy to work with. Nintendo, by the way, doesn't support this research at all. The only thing I ever got from Nintendo was a cease and desist letter. It's sad, but some other game companies are much easier to work with. I have at various points had nice collaborations with Blizzard and Ubisoft, for example. But anyway, we keep doing lots of research on Mario because it's so easy to work with. Procedural content generation via machine learning is this new exciting idea of using machine learning to create new content. The problem is for most games you just don't have that much content. One thing we've done recently is trying to combine learning from existing levels with evolutionary methods to search for new interesting content in that space. There's a method we call latent variable evolution, which is really powerful for this. Yet another aspect of this is how can you make levels that are good, not just in general but for a particular person. So, say that you have been playing Super Mario Bros for a bit and the game sees what you're doing and wants to give you new, interesting challenges it thinks that you would like based on what you seem to like already and based on what you seem to be good at and what you seem to be bad at. So that's something we call the experience-driven procedural content generation. This requires that we learn from you, we create a model of your behavior and your preferences and then we use that as a target to search for new game content that fits your experience as well. This is something that I think will definitely change game development pretty significantly at some point.

CRAIG: [24:20](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1460.2) The idea of generalization across game environments, do you feel like that's 10 years away and then that will give you a set of deep neural nets that you apply in other domains? Or is this still in its infancy?

JULIAN: [24:34](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1474.55) I think we will probably eventually get to the point where we can have a game playing agent that if you gave it a new game that the human could learn to play quickly, this agent would also learn to play it quickly. And when we get there, this will be as good a claim to artificial general intelligence as any other. Probably the best one. I do believe honestly that video games are the best way to reach as general intelligence as we can get. However, if you want my most controversial opinion, it is that we will never get artificial general intelligence, not because computers are unable to implement intelligence, but because general intelligence doesn't exist. I mean that's also why I think all the fear for superintelligence is all bullshit. I think we are not general intelligence. We are animals evolved for fulfilling specific ecological niches and then we as a society built this complex culture and this built environment like New York City that is basically built for us to be able to feel smart.

JULIAN: [25:40](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1540.52) There are so many problems that we are not good at dealing with. Computers are already super intelligent in so many ways, but we choose to not count that as intelligence even though you or I are very, very bad at prime number factorization or database search or something like that compared to a computer. We choose to point at things that we think that we humans are good at and say that that's intelligence. But it's a very biased sample. So the games we create for ourselves to play is a good window into what we consider intelligence because they are designed to challenge our minds. And if we create a system that can play or learn to play any game that we give it, then we will have essentially created as general intelligence as we can get.

CRAIG: [26:27](https://www.temi.com/editor/t/udL8weUfgcjMOmax8m-V-j_FKamkVU6oyIa8NpGiMPnVKS3omrrIyN1vOKasrvNkr0zMFAZgQeSDvzfGCzNaZSuWEBY?loadFrom=DocumentDeeplink&ts=1587.84) That's it for this week's podcast. For those of you who want to go into greater depth about the things we talked about today, you can find a transcript of this show in the program notes along with a link to our Eye on AI newsletter. We welcome you to subscribe. Let us know whether you find the podcast interesting or useful and whether you have any suggestions about how we can improve. The singularity may not be near, but AI is about to change your world. Pay Attention.