

## CONVERSATIONS AROUND ARTIFICIAL INTELLIGENCE FROM THE CATALAN PERSPECTIVE<sup>1</sup>

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### Abstract

Artificial intelligence moves millions of euros and occupies an important part of governments' political and strategic agendas. In this article we reflect on this varied concept through interviews with three people who hold important positions in the field of artificial intelligence and who also have in common the fact that they were born and trained in Catalonia. We talked with them about the origins of this technological revolution, its impact on social organization and the labour market, its ethical implications, the future trends which are emerging and also on what role we Catalans play in this. With regards to the Catalan question we wanted to know if our universities are capable of generating the necessary talent, how to strategically boost the fabric of business in this area, what role the Administration should play and what should happen for artificial intelligence to communicate in Catalan. Throughout these conversations, the interviewees have conveyed to us the urgency and need to work on the definition of country-specific strategies in order not to be left behind socially and structurally in what seems to be a revolution without limits.

Keywords: artificial intelligence; deep learning; unsupervised learning; neural networks; language and technology; technology and ethics.

## CONVERSES AL VOLTANT DE LA INTEL·LIGÈNCIA ARTIFICIAL EN CLAU CATALANA

### Resum

*La intel·ligència artificial mou milions d'euros i ocupa una part important de les agendes polítiques i estratègiques dels governs. En aquest article reflexionem sobre aquest concepte difús i ho fem a través de tres entrevistes a tres persones que ocupen llocs rellevants en aquest àmbit, i que a més tenen en comú que són nascudes i formades a Catalunya. Amb elles hem parlat distesament dels orígens d'aquesta revolució tecnològica, del seu impacte sobre l'organització social i el mercat laboral, de les seves implicacions ètiques, de les tendències futures que es dibuixen i també sobre quin paper juguem els catalans en aquesta revolució. En la qüestió catalana hem volgut saber si les nostres universitats són capaces de generar el talent necessari, com impulsar estratègicament el teixit empresarial en aquesta àrea, quin paper ha de tenir l'Administració i què hauria de passar perquè la intel·ligència artificial també parli en català. En aquestes converses, els nostres interlocutors ens han transmès la urgència i la necessitat de treballar en la definició d'estratègies concretes de país per tal de no quedar socialment i estructuralment enrere en el que sembla una revolució sense límits.*

*Paraules clau: intel·ligència artificial; aprenentatge profund; aprenentatge no supervisat; xarxes neuronals; llengua i tecnologia; tecnologia i ètica.*

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## **Summary**

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## Introduction

Artificial intelligence (AI) is difficult for the general public to understand. It is a great unknown but everyone speaks about it. The tendency is either to be carried away by what we see in science fiction movies, where machines are able to do everything people do and will soon replace them, or at the other extreme, to underestimate the capabilities of machines and consider them to be “stupid”. As always, *in media, virtus*. In these pages we wish to reflect on this indeterminate concept, which moves millions of euros and occupies an important part of the political and strategic agendas of governments. We will do this through interviews with three people who hold important positions in the field of artificial intelligence and who also have in common the fact that they were born and trained in Catalonia. We talked with them about the origins of this technological revolution, its impact on social organization and the labour market, its ethical implications, about future trends which are emerging and also on what role we Catalans play in all this. With regards to the Catalan question we wanted to know if our universities are capable of generating the necessary talent, how to strategically boost the fabric of business in this area, what role the Administration should play and what should happen for artificial intelligence to communicate in Catalan. Throughout these conversations, the interviewees have conveyed to us the urgency and need to work on the definition of country-specific strategies in order not to be left behind socially and structurally in what seems to be a revolution without limits.

This article contains selected excerpts from conversations we had separately with Cristian Canton of Facebook Research, Elisenda Bou-Balust of Vilynx, and Oriol Vinyals of Google DeepMind. We have put together their answers without tweaking them much as we want to hear their expert voices, and we’ve organized them into blocks. In the first block we review the concept and history of artificial intelligence, in the second we reflect on its impact on our society and in the third we analyse components specific to Catalonia. They agree on many things, but each of them has given us their perspective as a privileged observer in this “exciting adventure”, as one of them has described it.

## Three Catalans at the Forefront of AI

Our interviewees are three Catalans with drive, who hold positions of responsibility in the international AI ecosystem. Two men and a woman. Two of them live and work abroad, while the third lives and works in Catalonia.

Cristian Canton, PhD in Engineering from the Universitat Politècnica de Catalunya (UPC), was born in Terrassa but currently lives in Seattle and works at Facebook Research, where he leads a team of researchers in the field of computer vision and more specifically in the identification of fake news and cybercrime. Cristian is passionate about his work. He is happy to go to bed every day thinking that he has helped to make this world a better place. In the evenings and on weekends he is a musicologist, concert pianist and composer.

Elisenda Bou-Balust, PhD in Engineering from the Universitat Politècnica de Catalunya in collaboration with MIT (Massachusetts Institute of Technology), is co-founder and chief technical officer of Vilynx, where she leads a team with the goal of building the first artificial brain capable of learning autonomously. Elisenda is a very inquisitive person who is passionate about working in teams capable of pushing the boundaries of technology and science. Apart from this, she has a strong interest in plants. She is fascinated by their ability to reproduce. She has a map of the trees and plants of Barcelona and when it is time for seeds or cuttings, she specifically goes to look for them to plant: “It’s fascinating; it’s as if your hobby is reading, and books grow in the street and you only have to go out and pick them up at the right time.”

Oriol Vinyals, Ph.D. in Electrical Engineering and Computer Sciences from the University of California, Berkeley, originally from Sabadell, lives in London and works at Google DeepMind where he leads the Deep Learning team. He led the AlphaStar team that created the first artificial agent to beat a professional playing StarCraft, a well-known real-time strategy video game. Oriol is dedicated to the development of new ideas concerning machine learning, neural networks and reinforcement learning. A great fan of climbing, he misses being close to nature and especially the mountains of *el Vallés*.

## What is Artificial Intelligence?

To be clear what we are talking about when we use this term, we asked our interviewees to give us their definition of the concept of “artificial intelligence”, avoiding technicalities. We explored with them how this technology came about and what have been the main milestones during its advance, which has accelerated in recent years. We spoke about machine learning and we were told that it can be classified into three main types: supervised learning, unsupervised learning, and reinforcement learning. They also gave us some clues as to where AI will go in the coming years.

**[Elisenda Bou-Balust]** *The term “artificial intelligence” was first introduced by John McCarthy<sup>2</sup> in 1955 and he defines it as “human behaviour that machines can exhibit,” such as predicting what the weather will be like tomorrow, recognizing speech, identifying images, driving vehicles, and so on. A few years later, a cognitive psychologist, Frank Rosenblatt,<sup>3</sup> invented the perceptron, the first algorithm inspired by the neural connections of the human brain. The perceptron was a very basic artificial neural network, capable of learning from examples. Learning from examples is called supervised learning. These supervised learning systems have become more and more complex, with increasingly deep networks, but they still depend on human coding to learn. For example, for a system to learn to recognize images of cats, we must tell it many times “this is a cat”. This is done through data sets specifically labelled for the task we want the machine to solve.*

*An alternative system to supervised learning is reinforcement learning, introduced by Richard Sutton,<sup>4</sup> and which is like educating with a system of rewards and punishments. This consists of allowing the machine to explore solutions, but it needs the supervision of a human who positively reinforces the correct solutions and negatively reinforces incorrect ones.*

*Later, unsupervised or autonomous learning systems appeared. For example, we give the machine pictures of cats and dogs, and without telling it which is which, we ask it to classify them into two groups based on their similarities and differences. The machine won't know what a cat is or what a dog is, but it will be able to separate the set of images into two groups. The machine can learn a specific task without human intervention.*

*So-called deep learning uses neural networks which, unlike the original perceptron, have many layers of depth. It is difficult to say exactly when it started, but in any case, around 2010 there was a real explosion in all areas, thanks to a widespread increase in computing power. Right now, access to computing power is not the problem; the real problem for medium or small businesses, or research centres, is access to sufficient amounts of the labelled data that supervised learning requires. There has been a lot of talk about big data, but what companies are discovering is that what really matters is quality data. Data has to be filtered, organized and labelled, with all the costs this implies.*

*In the last year and a half, there has been a great increase in research into algorithms that avoid relying on large amounts of previously labelled data, either by managing to learn with fewer examples, such as so-called one-shot learning, or through unsupervised or autonomous systems, which save on the cost of manually labelling data.*

**[Cristian Canton]** *I think using the word intelligence with regards to artificial intelligence is a misuse of the term. AI isn't really intelligence, it's a black box that emulates human behaviour but which doesn't do things the way a human would. To begin with, the machine needs to see many examples in order to learn, while a human learns having seen very few examples; in fact, often we are capable of learning with just one example. Machines still don't think.*

*The first important milestone in getting to where we are was to get multi-layered neural networks to work, and from there neural architectures have become increasingly complex. The second, and very important,*

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<sup>2</sup> [https://ca.wikipedia.org/wiki/John\\_McCarthy](https://ca.wikipedia.org/wiki/John_McCarthy)

<sup>3</sup> [https://en.wikipedia.org/wiki/Frank\\_Rosenblatt](https://en.wikipedia.org/wiki/Frank_Rosenblatt)

<sup>4</sup> [https://en.wikipedia.org/wiki/Richard\\_S.\\_Sutton](https://en.wikipedia.org/wiki/Richard_S._Sutton)

*milestone was for large companies such as Google, Microsoft or Facebook to see the potential of this technology and invest in it. A key factor for the AI explosion has been access to large amounts of labelled data, as it is from this data that systems learn. However, there is an even greater amount of data that is not labelled. This is the data which is used for unsupervised learning.*

*Fortunately research is advancing in the direction of this unsupervised learning and we will increasingly need fewer labels to achieve the same results. Without doubt, unsupervised learning will be the second big wave of AI. For example, much progress has been made in language processing using unsupervised systems. We now need to work more on understanding videos, through multi-modal learning, which uses several types of data at once, for example, image and text. Today, advances in research arrive in the hands of the consumer very quickly in the form of products, especially through mobile phones, for example, translators, image recognition, and so on.*

*Another aspect that will be very important is the AI that preserves data privacy. Much research is being done on how to ensure that the models that are generated do not contain personal information or are not biased towards certain profiles, just because certain profiles appear more often in training data.*

*Another line in which we are already working hard is “adversarial” AI, which aims for an AI which is robust against malicious attacks. It consists of abusing systems, as someone with bad intentions would do, in order to intentionally confuse them. Given that AI is everywhere, even in sensitive areas, it is critical that systems are robust and cannot be manipulated.*

*We could say that we have only just started with AI. This is truly an exciting adventure and I consider myself lucky to be able to follow it so closely.*

**[Oriol Vinyals]** *Artificial intelligence can be seen as a human study, a study of all those skills that define us as humans, such as speech, creativity, memory or reasoning. We want to learn, understand these skills and know how they work. If we understand them, we will know how to make machines that can mimic these behaviours. Obviously, this imitation by machines does not necessarily occur by replicating exactly the same human mechanisms. For example, it is possible to find a mathematical function that translates a sentence from Catalan into English. This mathematical function is currently encoded in neural networks. And those deep neural networks are precisely one of the paradigms that artificial intelligence has most recently revolutionized.*

*Most commercial smart systems, for example, movie recommendations on Netflix or products on Amazon, voice recognition for personal assistants, machine translators and so on, all these systems are based on supervised learning which is done through a large numbers of examples. We at DeepMind work primarily with reinforcement learning. Reinforcement learning, which is also used in robotics, has great potential for the future but it is still in a very early phase. The same goes for unsupervised learning, which in the opinion of many people may revolutionize the world of AI in the near future, but which still has a long way to go.*

*In AI research, developers of artificial systems look for inspiration in neuroscience although influence in the opposite direction also occurs. In the case of DeepMind, neuroscience has been a mainstay since its founding and we still have a team of 50 neuroscientists trying to understand how the brain works, from the tiny neuron to how those neurons communicate with each other. Recently, this neuroscience team has shown that a common mechanism in artificial learning systems, that of recurrent memory, is also typical of the neural processes of an animal or a human, for example, when they must orient themselves in a space in order to find a way out. Conversely, discoveries in neuroscience also serve to improve artificial systems. For example, we know that when we sleep, what is known as “reproductive memory” starts to act, producing a compendium of the day’s experiences. So, inspired by this brain function, we have implemented the same concept in a machine that plays ATARI.*

*It’s a lot of fun watching old movies about the future, such as 2001: A Space Odyssey, with those giant computer screens. If we compare them with our thin screens, we see that they didn’t get this right! But there are aspects that were correctly predicted, such as HAL<sup>5</sup> playing chess with humans. At DeepMind we*

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<sup>5</sup> HAL is the name of the intelligent computer in the film 2001: A Space Odyssey (1968).

*have a machine that plays Go,<sup>6</sup> called AlphaGo, which beats the grand masters. Speech recognition was also predicted, and we are perhaps even more advanced in the synthesis of artificial voices than expected. However, where we differ greatly from the movies is in the content of the dialogue, and especially in that our machines do not have their own emotions, personality or goals. In this regard we are a long way from HAL because, in fact, our dialogues are pre-programmed; they are, as it were, pre-cooked recipes. It is currently impossible to have a long and sensitive conversation with a machine. Groundbreaking advances would need to be made for HAL to be possible. We still have work to do!*

## **Ethical and Social Impact of AI**

Just as the Industrial Revolution transformed European society in the early 19<sup>th</sup> century, AI will have a major impact on the labour market, the consequences of which we are only just beginning to see. This will mean rethinking aspects such as social policies or our education system. As our interviewees point out, AI should not be seen as a “competitor” or a danger, but as a complement to human capabilities.

**[Cristian Canton]** *The world is changing and we are currently at the beginning of this process. In the short term, people can see the immediate benefits of AI: Amazon packages arrive very quickly, Google creates an album for me, Facebook puts me in touch with a friend from my youth and so on. In the medium and long term, there will be jobs which are more mechanical or monotonous that will disappear, but new ones will emerge, some that we can already envisage, such as “data curator” and many others that we cannot even imagine. On the other hand, there will be many hybrid scenarios, in which AI will not replace humans, but will complement them: for example, support for medical diagnosis. I think the real impact on the job market has not yet begun. Young people need to be educated about AI, so that they begin to understand technological tools earlier. They need to become familiar with digital technologies. The same goes for the general public.*

*Regarding ethical aspects of AI, we must fight for it to be inclusive. Intelligent systems need to represent the whole world, north and south, men and women, children and adults, and different ethnicities. Currently systems do not work the same for everyone. The technology is neutral but its uses are not necessarily so. For example, facial recognition may have negative uses. Ethical dilemmas will appear that we cannot even imagine at the moment, because the ethical concepts themselves are also evolving. Technologies, which we are now developing with all good intentions, may have harmful uses in the future.*

*That’s why it’s important for AI to have its critics. They force us to reflect. These critics need to come from within corporations as well as from the outside. It is essential to talk to experts outside the world of AI, to encourage debate, and not let specific interests dictate the steps to be taken.*

**[Elisenda Bou-Balust]** *It is true that AI will replace humans in some jobs, but we must fight so that automating simple tasks serves to improve everyone’s working conditions and not to harm them. AI should be seen as an aid not as a threat. Rather than replacing humans, it will help them. If I could choose, I would rather be operated on with a hospital’s Da Vinci robot than without it. As happened with the Industrial Revolution, some jobs will disappear and new ones will be created. But we will need more training in technology. There is a risk that a technological gap will be created and this should be avoided. For example, there are very few women who pursue scientific and technical careers, which are known by the acronym STEM.<sup>7</sup> I am often called upon to go and talk about this in high schools. Girls have the impression that doing STEM subjects means being a “geek”. We need to do away with these stereotypes and make technology more diverse.*

## **Professional Careers**

Our three interviewees trained in Catalan universities, continued their training in the United States and have ended up occupying prominent positions in commercial AI. In the case of Oriol and Cristian, in two large multinationals, and in the case of Elisenda in a start-up founded by herself in Catalonia. We asked them what the main turning points of their successful careers were.

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<sup>6</sup> A Chinese board game of greater complexity than chess.

<sup>7</sup> Science, Technology, Engineering, Mathematics

**[Cristian Canton]** *I believe that my career has been built on personal decisions and successful professional choices. I remember it was during an internship in Poland that I discovered computer vision, and I became interested in it. Afterwards there were other professional periods in England and the United States.*

*While at Microsoft Research I was given the opportunity to participate in a Hackathon to rescue missing children, which was organized by Facebook. It dealt with the application of facial recognition techniques to a database with pictures of these children and a prostitution services website. This marked a turning point in my career. Suddenly I discovered that I could make a positive contribution to the world with the tools I knew. Since then I've worked at Facebook. Part of my job consists of applying AI to prevent abuse and misuse in social networks (fake news, terrorism, hate speech, child pornography, etc.). When I go to bed, I feel like my team and I have helped make the world a better place.*

**[Oriol Vinyals]** *I may have been influenced by my father and a good teacher I had at school in Sabadell, but I have always liked mathematics. When I was at UPC I went to a talk on AI that made me decide to go to the United States to do my PhD. Once there, opportunities arose. Internships at large companies (I did four at Microsoft and one at Google) put me in touch with industrial research, which can be very varied and also gives you the opportunity to publish.*

*While doing an internship at Microsoft I met students of Geoffrey Hinton and became interested in deep learning, long before it became fashionable. I am particularly proud of a specific piece of work I did in 2014 on machine translation related to the probability that a sequence, for example, in Catalan, is the translation of a sequence in English. This probability model of bilingual sequences has been extrapolated to many areas: for example, in speech recognition, to a voice sequence and a text sequence; in dialogue, to a question and its answer, and so on.*

*One advantage of being in a company like Google is the impact of your research. There are teams of engineers who turn the things we researchers do into products. Google publishes a lot and there is a lot of contact with academia. I have a lot of contact with it myself and I try, for example, to be part of thesis boards as much as I can.*

**[Elisenda Bou-Balust]** *I went to do my PhD in Boston, at MIT (Massachusetts Institute of Technology), and when I finished it I had two options: the most obvious was to go to work for some big multinational in California, and the other was to go back to Catalonia and try to set up something here. That was a defining moment. If you stay there, it's easy to stay forever. I wanted to come back.*

*The great difficulty you encounter if you want to found a technology company in Catalonia is access to investment funds. European investment funds demand very fast returns, a maximum of two years; for example those that provide e-commerce. But the technological challenges posed by AI make it impossible for you to set such short-term profitability goals.*

*In the United States, on the other hand, there are investment funds specifically dedicated to cutting-edge technology. At that time, I met Juan Carlos, CEO and co-founder of Vilynx with me. He wanted to live in the United States and look for American investment funds and I wanted to set up a technical team in Barcelona. It was the perfect combination. Our vision for the future when founding Vilynx was to bet on unsupervised autonomous systems.*

## **AI in Catalonia**

Obviously, one of our goals when we set out to do these interviews was to hear opinions on the situation in Catalonia, from the privileged position that the interviewees have in the world of cutting-edge AI. There is a consensus among them that the training in Catalan universities is very good, but that problems start later. We found their opinions and recommendations to be of great interest, especially considering that the Generalitat is beginning to deploy an AI strategy in Catalonia.<sup>8</sup> We are also very interested in the health of the Catalan language in a future dominated by AI. Their answers are optimistic.

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<sup>8</sup> <https://web.gencat.cat/ca/actualitat/detall/Estrategia-dIntelligencia-Artificial-de-Catalunya>

**[Cristian Canton]** *I had to leave Catalonia and look for work abroad because at that time there weren't the right conditions for developing my career. Now, if by staying in Catalonia, I had been able to achieve a quarter of what I achieved abroad, I certainly would have stayed. My goal is to come back someday and if possible, reinvest everything I've learned. I maintain a strong relationship with the UPC where I trained. It's my alma mater, and so it's very important to me.*

*I think that at the national level, well defined, ambitious, long-term strategies are needed that take into account all aspects, technical, ethical and social. A comprehensive transformation is needed. It is worth mentioning that there are many very good people everywhere; Catalans scattered around the world who are pioneers in their fields, and who could help with many things. The Catalan administration should take advantage of this network of experts, who are eager to help build a better country, and who would not do it for the money. There are very valid people with a lot of desire to do things but it's difficult to find a way to articulate it; to know how to contribute.*

*We need to take advantage of initiatives such as DLBS,<sup>9</sup> which every year brings together leading AI researchers who have a relationship with Barcelona, to create a network of Catalans who are in key positions in AI inside and outside the country. Many things can be done: creating synergies, enhancing tutoring relationships between established researchers and students, and so on. For example, I dedicate a few hours a week to guiding students who are doing their thesis at the UPC. Plus all of this can easily be done remotely. You don't need to be a great power to be a leader; Israel is a good example of a small country that knows how to make the most of talent and which stands out in many areas of the AI sector and in AI research. So what are we missing? We have talent, but people leave because there are no opportunities. We should ask ourselves as students, researchers, developers and politicians, "What could I do that I'm not doing to strengthen AI in my field?" I think that asking this question could be a trigger to start synergies, collaborations, internships in companies and tutorials; in short a more active participation by all parties involved.*

*With regard to the issue of language, and from a purely economic point of view, it is true that Catalan is a small market. But that's not an absolutely determining factor. I think companies don't only move with that in mind. Big corporations need to be asked what their strategy is. It would be useful to obtain official statements on these topics from these corporations, in order to understand their strategy for smaller languages and to appreciate their willingness to collaborate with the administrations or research centres of the language community in question. In fact, Facebook has a Catalan translator.*

**[Elisenda Bou-Balust]** *Here in Catalonia the ecosystem is very good. We have the UPC, the Universitat Pompeu Fabra (UPF), the Centre de Formació Interdisciplinària Superior (CFIS) and so forth. The CFIS<sup>10</sup> is a marvel. We also have something very special which is telecommunication engineering which does not exist in other countries, and which provides very complete training in signal processing, language, video, and so on.*

*What worries me is the lack of public investment. AI is a very expensive technology and public investment is insufficient. And it's not all about investment; synergies are also important. We should learn from Canada, from President Trudeau's strategy. He has created three centres of reference in the world, around his three most important figures: Sutton, Hinton and Bengio. He has been able to align start-ups, public and private investment, research and even immigration policies to facilitate the arrival of talent. And it has been a resounding success. This must be our challenge. Be ambitious, set clear goals and achieve them. We must bet on cutting-edge and differential technology, and not be content with producing apps or e-commerce. If we look at the Canadian example, we see that there are three key factors that need to be analysed to guide the strategy well: what talent we have, what relevant scientific personalities we have and which technological lines might have a more positive impact on our labour market.*

*On the question of Catalan, the problem is the same for any language that is not one of the "giants" such as English, Spanish or Chinese, which is that there is not enough labelled data to train supervised learning*

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<sup>9</sup> Deep Learning Barcelona Symposium <https://sites.google.com/view/dlbcn2019>

<sup>10</sup> Centre de Formació Interdisciplinària Superior of the Universitat Politècnica de Catalunya. <https://cfis.upc.edu/ca/>



*systems. We've been using Spanish language data to develop products for the Catalan language. Obviously this is not ideal, as the results are necessarily inferior.*

*That said, the advantage we discussed earlier concerning autonomous, or unsupervised, learning systems is that they don't need this type of data and can partially overcome this limitation of lack of data that relatively small languages have. Much of the current research in AI is done on unsupervised learning systems and they are already starting to reach the industry. I predict that in the next two years we will see that many AI applications are adopting this type of learning.*

**[Oriol Vinyals]** *Training in Catalonia is good. I finished my degree very well prepared professionally. Perhaps even too well! In American universities there is less content but instead they greatly enhance the research profile of students. There is less density of subjects in America but there are many opportunities to participate in research projects from the first year.*

*Regarding Catalan, I am very optimistic for several reasons. Part of that is the good work that Catalan research groups are doing, despite the low investment in research. The other part is due to advances in unsupervised learning. Machine translation, for example, was learned up to now based on sentences previously translated by humans. We can now learn using only a monolingual text. In order to create applications in Catalan, we will always need text or voices in the Catalan language, but with new advances we will need less of it and it won't need to be labelled manually. In general, in AI there is a pressing need to work with few resources. So far everything that has been done is in English and for Americans. But the world is diverse in languages, people, and nationalities, and AI has to be able to reflect that diversity.*

## Conclusions and Final Messages

Artificial intelligence is a technology that is changing the world as we know it. A confluence of factors, driven by dizzying advances in computing power, is making the science fiction of the last century a reality. But we are still far from creating HAL, the conscious machine with its own personality. The reality is more prosaic, but no less impressive. In these conversations, we have explored the concept of artificial intelligence and reviewed the technological advances of recent years.

Our interviewees have told us that AI so far learns from our data, that a lot of it is needed and that it needs to be filtered and labelled, with all the costs it implies. But we have also been told that a lot of research is being done on machines that learn without human supervision. These are autonomous or unsupervised learning systems and reinforcement learning systems. The next generation of smart systems will need less data in order to learn. And this is good news for Catalan.

The Catalan university ecosystem is highly thought of by our interviewees, who studied here and maintain links with Catalan universities. However, all of them had to leave to finish their training and only Elisenda returned and established herself as an entrepreneur in Catalonia, and that because she found a way to channel American investment into her Catalan company.

They are just a sample of the great talent that the country generates and which we need to take advantage of if we want Catalonia to be competitive in this strategic area.

To end each of the interviews, we gave them the opportunity to summarize in a few phrases what they consider to be most important about this technological revolution.

**[Cristian Canton]** *We are facing a revolution that will change the way we understand the world. We cannot understand this future world without AI. We need to accept it, take advantage of the opportunity it affords and adopt it responsibly.*

**[Oriol Vinyals]** *“Keep calm and carry on.” AI needs to be better understood and I hope articles like this help. We should not be afraid of superintelligence. Instead we need to address the real problems of AI, such as that it should be inclusive and that it should avoid racial or gender biases.*

**[Elisenda Bou-Balust]** *To the extent that AI replicates human behaviour, as humans we must be very careful about our behaviour. If we are racist, AI will be racist. If we discriminate, AI will discriminate. As AI will increasingly replicate human behaviour, let's make sure that this behaviour is what we would like it to be.*