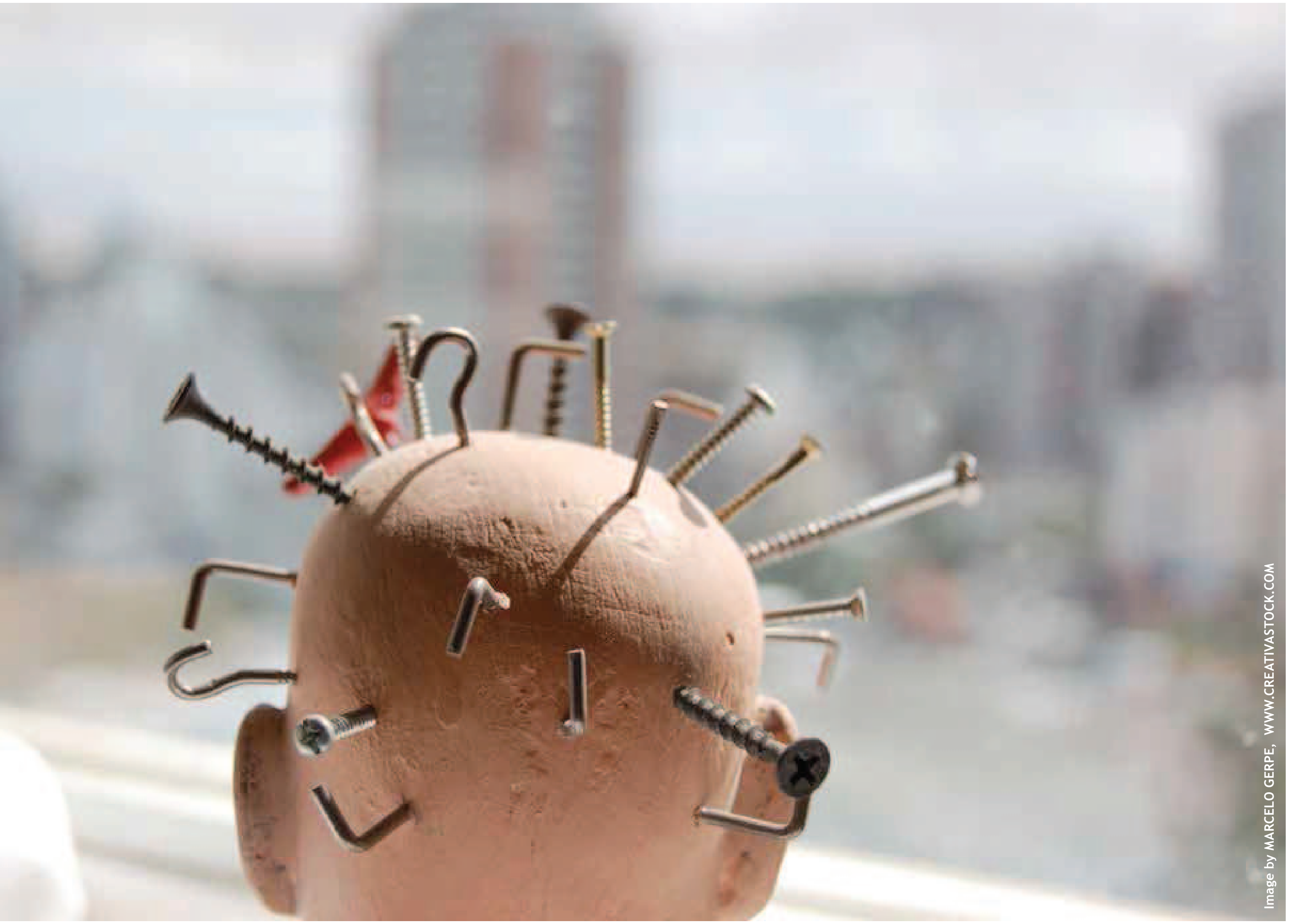

AUGMENTED EDUCATION

HOW AR TECHNOLOGIES EXTEND OUR MINDS

ROBIN DE LANGE

In the field of education, just as in many other fields, researchers and developers are experimenting with potential applications of Augmented Reality technologies. Many of these experiments draw on of the possibilities to explore virtual information spatially. An interesting example is the 4D Anatomy project by daqri (2012), where you can explore the physiology of a human being by moving the display device along a piece of paper with markers. On the screen you see a 3D model of the human body. With sliders and buttons you can set the transparency of the skin, or switch on the layer showing the nervous system for example.

Another interesting project in development is the Sesame Street app Big Bird's Words (Qualcomm, 2013), which uses the latest text recognition algorithms. The (young) users of this upcoming app are asked to look for certain words in their home and aim their device at it. When the device recognizes the word, it gives points to the user. This way the user is asked to involve their environment in the process of learning words.

These examples show some of the new forms of interaction and presenting information, with which developers are trying to create new, interesting, and memorable learning experiences.

In this article I will argue that the developments in AR technologies will make digital information sources much more transparently available to us. In certain cases, this information may even be seen as part of our cognitive process. Because of this change of perspective regarding external information sources, AR technologies could not only lead to new learning methods, but could, and in my opinion should, also trigger debates about the very goals of education itself. To back-up this claim, I will first introduce the concept of the Extended Mind.

EXTENDED MIND AND THE PARITY PRINCIPLE

Andy Clark and David Chalmers start their renowned paper 'The Extended Mind' with a thought experiment. In this experiment the reader is asked to consider three cases and to think about how much cognition is present in each case:

(a) A person sits in front of a computer screen which displays geometrical shapes and is asked to fit the shapes in the displayed 'sockets', by rotating the shapes in his mind.
(b) The same situation as in (a), but now the person can choose either to mentally rotate the shape or physically rotate it by pressing a button, the latter having some speed advantage.
(c) The same situation in a possible future, where the person can choose between using his neural implant that does the rotation operation as fast as the computer does in (b), or using 'old-fashioned' mental rotation.

Now, these kinds of cases are actually not as abstract as they might seem: they describe a very well-known real-life situation, namely playing the video game Tetris. In their paper about cognitive performances while playing Tetris, Kirsh and Maglio found that the physical rotation in (b) is actually much faster than the mental rotation. Furthermore, players were not only physically rotating the shapes to fit the slot, but were also trying to *determine whether the shape fits* in the slot, thereby simplifying the task. (Kirsh and Maglio, 1994)

It is this example of the human capacity to manipulate the environment to solve problems, which Clark and Chalmers employ to introduce the Parity Principle:

"if a part of the world functions as a process which, were it done in the head*, we would have no hesitation in recognizing as part of the cognitive process, then that part of the world is (so we claim) part of the cognitive process*." (Clark and Chalmers, 1998)

According to the Parity Principle, the human mind is not bound by the borders of skin and skull. To make this claim plausible, Clark and Chalmers present a thought experiment involving the fictional characters Otto and Inga, who are remembering how to get to the museum. Otto has Alzheimer's disease and uses a notebook to serve the function of his memory, while Inga's biological memory is functioning properly. Inga is thought to have a belief about the location of the museum, before she recalls this from her internal memory. In the same manner, Clark and Chalmers argue, Otto can be said to have a belief about the location of the museum before he actually consults his notebook. Thereby, under the right circumstances, the notebook can be seen as an extension of Otto's memory. By showing how beliefs are not bound by the borders of the body, Clark and Chalmers show that true mental events can extend in the environment as well.

All the examples of cognitive extension that Clark[1] gives in his books and papers are not the typical futuristic technologies that come to mind when thinking about humans merging with technology. Although the possibilities of Brain-Machine Interfaces and neural implants such as in case (c) offer very exciting new ways of communicating with technology, this direct interaction with brains is by no means necessary to become part of the cognitive process (nor are they sufficient for cognitive extension: communicating with technology through a Brain Machine Interface usually still takes too much cognitive effort.) Our brains incorporate the world and some of the technologies therein in their cognitive processes in such an intimate way, that Clark considers us to be "natural born cyborgs" (Clark, 2003).

In fact, the technologies which Clark considers as cognitive extensions of our cyborg minds are hardly identified as technology anymore. One example he mentions is the use of pen and paper when doing long multiplications. To calculate the product of two numbers, we use an algorithm that divides the process of multiplying arbitrary large numbers into very simple steps. By writing down figures in certain locations, we use the pen to manipulate the external memory source, the paper. The writing utensils play a crucial role in this cognitive process and are therefore, according to the Parity Principle, actually part of this process.

Another example shows that it has become common to talk about the information that is in some of our technologies as if part of our own knowledge. When somebody asks us on the street whether we know what time it is, and we are wearing our watch, we often answer "yes". Subsequently we raise our arm, look at our watch and see what time it is. Now, according to Clark this is not simply loosely formulated informal language. You actually do know what time it is, 'you' is only "the hybrid biotechnological system that now includes the wristwatch as a proper part" (Clark, 2003). (This proven transparency of the wrist watch is what makes the development of smart watches interesting.)

Now, wrist watches have been around for many decades, writing utensils even for centuries. During this time these technologies have become ubiquitous. They have become socially accepted and actually shaped culture itself. An interesting question is whether more modern external information sources could obtain the same status as these age-old technologies and play a similar, active role in cognitive processes. Could digital information sources, for example parts of the Web, actually become parts of our minds?

Could digital information sources actually become parts of our minds?

To begin to answer this question and decide whether a part of the world should (temporarily) be seen as part of the cognitive process, we can refer to the three criteria suggested by Clark:

1. The information retrieved from the external source should be directly endorsed and trusted;
2. The technological aid should always be available when needed;
3. The external resource should be directly available without difficulty. More precisely: the *information access costs*, a measure of the combination of time and physical and cognitive effort, should be as low as with an equivalent function of the brain (Smart et al, 2008).

From this, it is quite clear that the Web with which we interact on a daily basis cannot be seen as part of our cognition. From our critical stance we do not immediately believe most information we encounter on the Web something which is, due to the open character of the Web, probably a wise attitude. Furthermore, the information access costs when retrieving information from the Web is way too high. The user has to put physical and cognitive effort into navigating the browser to the right page, then wait for the downloading of the page and scan through the text to find the information he needs. In the widespread current way of interacting, the information access costs of retrieving information from the Web are way too high to be considered as part of the cognitive process.

LOWERING INFORMATION ACCESS COSTS

However, technology is ever-evolving and many of the present advancements will make information available to us in more reliable, quicker and more intuitive ways. Processors in smartphones are becoming faster, telecommunication service providers keep improving their networks to decrease download times, batteries are getting better, user interfaces are becoming more intuitive, etc. The technological developments that are associated with Augmented Reality especially have the potential to lower the information access costs for digital sources considerably. Let us consider the following scenario to get a better idea:

For a few years now you have your own AR glasses. Despite of what many critics expected, it has become socially quite acceptable to be wearing a Head-Up Display at all times. An application running in the background does speech and text recognition and keeps track of words you (the biological 'you') don't know the meaning of. You've been using this application for a few months now and it's starting to have quite a good sense of when to present you with the meaning of a word you encounter. Of course, the application knows when you're busy driving for example and doesn't bother you then. Now, when a friend (who is not really into new technology and rather asks a friend to help him) asks you whether you know the meaning of a certain word that is not in your biological memory, and a short, clear description of the word pops up immediately in the corner of your field of view, would you say that you know the meaning of this word?

The main goal of education should be to train the technologically extended cognitive system.

I can imagine that you — after you get more and more used to the device and have experienced this situation a few times already — might say 'yes', similar to the situation with the wrist watch.[2] More so, in a very real sense, I think you might start to feel like you really do know it.

But what is it with AR technologies, that they could lower information access cost so significantly? Of course Head-Up Displays (HUDs) play a great part in this, by eliminating the physical effort of getting your smartphone from your pocket and having to hold it in within your view. When it does indeed become ordinary to wear HUDs, information can be presented to the user at all times, at the exact moment when it is needed. Another important aspect of AR is the use of information from different sensors and smart algorithms doing image and speech recognition. By combining these, possibilities are created to present information in context-sensitive ways responding both to the environment and the user. Furthermore, digital information can be placed over the world, which is of course the main idea of AR[3]. By doing so, you can interact with digital information in similar ways to how you interact with the physical world, creating a very natural, intuitive interface.

These are the characteristics of AR that create the potential of making digital information much more transparently available to us. I suggest that under certain conditions, well designed, personalized information sources are able to compete with mental resources in terms of costs of information access. According to the Parity Principle, these digital information sources could then be seen as proper parts of our hybrid minds.

EXTENDED COGNITION AND EDUCATION

In the previous I have introduced the concept of extended cognition and explored the possibilities of digital technology for cognitive extension. Adopting this philosophical perspective can have huge consequences for a field like education. One could argue from this perspective that the main goal of education should be to train the technologically extended cognitive system.

By accepting digital external information sources as a proper part of memory, it could be decided to store certain information that we want to remember in an easily accessible, personalized cloud of knowledge. Instead of trying to store all information in biological memory by endless repetition,

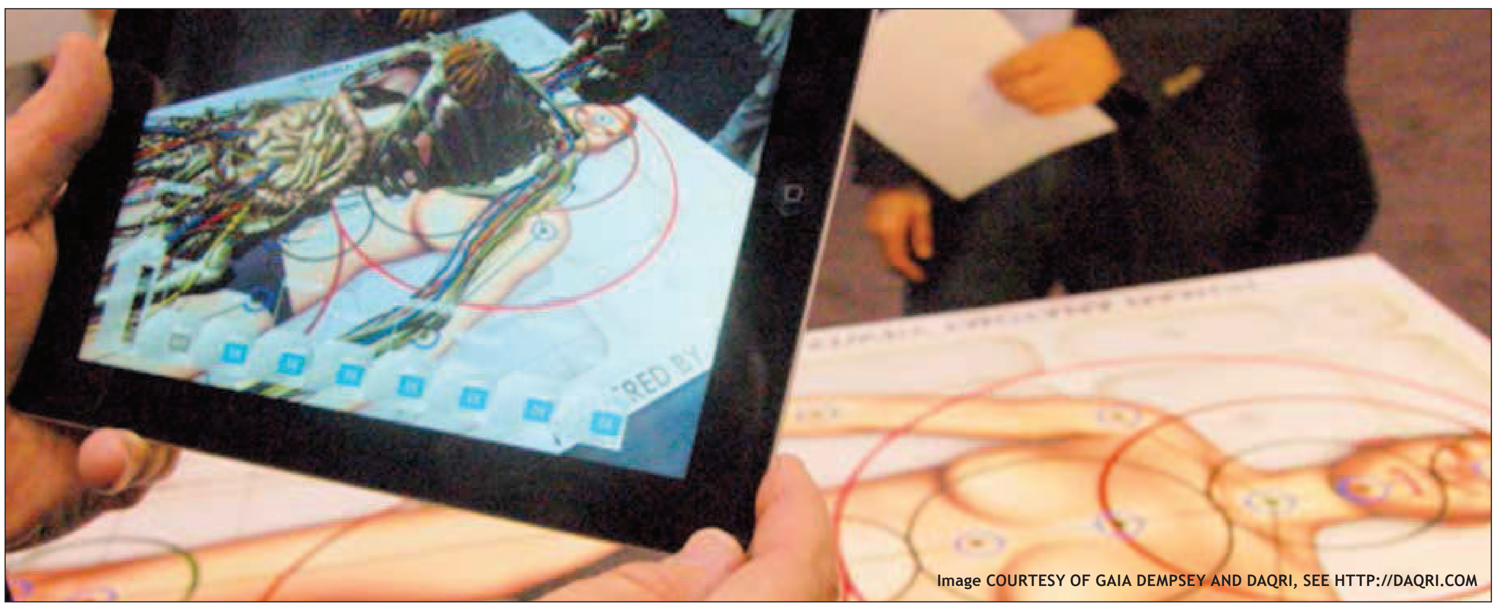

Image COURTESY OF GAIA DEMPSEY AND DAQRI, SEE HTTP://DAQRI.COM this task of storing information could be off-loaded to an external source which is constantly available to us at low information access costs.

The general view on the use of technology in education is quite different from the view expressed in this article though. For the most part of their education, students still only get to use some basic technologies: a pen, a piece of paper and maybe a dictionary[4] or an outdated (graphical) calculator[5].

This critical attitude towards the use of technology is very understandable. Digital technology is developing very rapidly, careful decisions have to be made about how to use it in education. To come to these decisions, a lot of research on the use of technology in the learning process is needed. Furthermore, there should be an active discussion on the goals of education and what technologies students can use to reach these goals. An extended view of the mind, in which external resources have an active role in the cognitive process, can offer a valuable perspective in this discussion. ■

REFERENCES

- Blomberg, O. (2009). Do socio-technical systems cognise? 2nd Symposium on Computing and Philosophy .
- Clark, A. (2003). Natural-Born Cyborgs. Minds, Technologies, and the future of human intelligence. Oxford: Oxford Univ. Press.
- Clark, A. (2008). Supersizing the Mind. Embodiment, Action and Cognitive Extension. Oxford: Oxford Univ. Press.
- Clark, A., & Chalmers, D. (1998). The Extended Mind. Analysis , 10-23.
- daqri. (2012). 4D ANATOMY. Retrieved from http://site.daqri.com/labs/4d-anatomy
- de Lange, R. (2011). Het Semantic Web en netwerktechnologische cognitieve uitbreidingen. Retrieved from http://www.robindelange.com/wikisofie
- Dennett, D. (1996). Kinds of Minds: Toward an Understanding of Consciousness. New York USA: Basic Books.
- Dror, I. E., & Harnad, S. (2008). Offloading Cognition onto Cognitive Technology. In I. E. Dror, & S. Harnad, Cognition Distributed: How Cognitive Technology Extends Our Minds (pp. 1-23).
- ESRC/EPSRC Technology Enhanced Learning Programme. (2012). System Upgrade - Realising the Vision for UK Education. London: tel.ac.uk.
- Kirsh, D., & Maglio, P. (1994). On distinguishing epistemic from pragmatic action. Cognitive science , 513-549.
- Qualcomm. (2013). Big Birds words. Retrieved from http://www.qualcomm.com/media/videos/big-birds-words-demo-reel-video
- Rorty, R. (1999). Education as Socialization and as Individualization. In R. Rorty, Philosophy and Social Hope (pp. 114-126). London: Penguin Books.
- Smart, P. (2010 (In Press)). Cognition and the Web. Network-Enabled Cognition: The Contribution of Social and Technological Networks to Human Cognition .
- Smart, P., Engelbrecht, P., Braines, D., Hendler, J., & Shadbolt, N. (2008). The Extended Mind and Network-Enabled Cognition. Retrieved June 24, 2011, from University of Southampton - School of Electronics and Computer Science: http://eprints.ecs.soton.ac.uk/16649/1/Network-Enabled_Cognitionv17.pdf
- Wheeler, M. (2011, November). Thinking Beyond the Brain: Educating and Building, from the Standpoint of Extended Cognition. Computational Culture .

ENDNOTES

1. The initial paper 'The Extended Mind' was written by Andy Clark and David Chalmers. Because Clark has written many other papers and books on this subject, I will refer to Clark further on.
2. If the word would be jargon of a field you are not familiar with for example, you would probably not understand the meaning directly and need to look up more information, thereby increasing the costs of information access.
3. This characteristic of AR of overlay ing the physical world with virtual objects is not really present in this scenario. For this reason, one might argue that the example does not really show AR. However, it does use certain AR technologies intensively to provide context-sensitive information to the user who interacts with the world.
4. The information access costs of looking up a word in the dictionary go through the roof.
5. Moore's law seems to be failing here. The hardware in these devices stays roughly the same, even remains the same price!

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Robin de Lange has a bachelor's degree in Physics and Philosophy and has followed courses on Artificial Intelligence. He is now a student at the Media Technology MSc program at Leiden University and is particularly interested in technologically extended cognition. For his graduation research project he is developing an Augmented Reality application that supports the graphical solving of mathematical equations; thereby showing educational challenges and possibilities.

Besides his studies, Robin has taken part in several entrepreneurial projects. Most notably, he was the co-owner of a company that specialized in homework guidance and tutoring. He is a freelance video producer and science communicator. At the moment, he is looking for funding to do a PhD within his field of interest.

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