Increasing the Economic Value from Digitalisation through Eye-tracking

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Abstract: The objective of this position paper is to demonstrate that eye-tracking is a cross-sectional technology for digitalisation because it provides a bridge between "machines" on the one hand, i.e. computers, networks, robots, and other man-made results of digitalisation like web pages, and humans on the other hand, who interact with them. Eye-tracking is utilised at the interface between the human and the technology side of digitalisation and it is exactly at that interface, where technological innovations translate into economic values through productivity gains, increased sales, higher realised prices, improved customer satisfaction, fewer litigation cases, longer lasting customer relationships and thereby increased lifetime customer value, more profitable management decisions and improved shareholder trust. Unfortunately, numerous frictions between "machines" and humans exist at these interfaces. Over the last decades, scientists have refined methods and invented tools to detect those frictions, reflected in visual perception: eye-tracking. While the causes of these frictions are countless, eye-tracking is a single scientific method for detecting very many of them. Eye-tracking – so to speak – is "digitalisation's best friend". Because of the numerous applications eye-tracking provides for reducing these frictions at the human-machine interface, users pursuing a digitalisation strategy should become aware of the financial benefits by using this scientific method in their applied research and development.

1 INTRODUCTION

Digitalisation means different things to different people. For IT-developers and quantitatively educated professionals, for instance, digitalisation is a blessing. It increases the demand for their human capital manifold. In contrast, for those who have invested their human capital in fields of work that now become obsolete, digitalisation is a curse.

For example, thousands of university students have invested their human capital in foreign languages and earn their living as professional translators. Germany has a particularly high demand for translations between various languages and German. Professional translators were convinced they were enjoying a high degree of job security because they always believed the German language to be so difficult, no computer could ever take over their jobs. Well, a start-up from Cologne – DeepL – simply disproved their claim.

The quality of this "translation machine", powered by artificial intelligence, is much higher for the languages it covers than Google Translate. Certainly, there are applications, where you cannot substitute human translations with DeepL. In law, each and every word matters, and a single ambiguity or imprecision can have very severe consequences. A qualified native speaker will always be required for proofreading automated translations for such applications. Therefore, it is by no means clear, whether the total demand for human translation services will increase or decrease as a result of such automated translations, because they radically reduce the costs of translations and thereby enlarge the market for proofreading in many ways. Outside the legal profession, problems with readability, which can be detected by eye-tracking, might impede the attention of readers, a friction that is especially costly

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in B2B marketing.

As this example shows, digitalisation affects the productivity of existing human capital, the need for human capital investments, and the optimal mix of labour and capital. And this is true for a very large array of already existing fields of work. This is the human side of digitalisation that comes to mind in most employees, who earn their living in these existing fields of work. It is the narrow focus of *existing fields of work* that Frey and Osborne[1] take in their working paper.

Yet the human side of digitalisation has many more dimensions than its impact on *existing fields of work* and the human capital employed there. Digitalisation creates many novel fields of work. It changes the productivity of employees, creates new products and services for consumers, customers or patients, it improves the quality and economic value of existing products and services, and it enlarges the type of knowledge that is teachable for certain types of content.

These are applications, where eye-tracking has been contributing to the long-run success of digitalisation and will continue to do so[2]. All applications will either affect us as employees, as customers, as entrepreneurs, as self-employed professionals or as learners and students:

I. Improving the productivity of employees
II. Improving the profitability of e-commerce
III. Creating new products and services
IV. Improving the quality and economic value of existing products and services
V. Creating new opportunities for entrepreneurship and the self-employed
VI. Enlarging and improving the type of knowledge that can be taught

While eye-tracking is a highly specialised academic field, as compared to other academic fields, figure 1 shows it has been growing steadily. The growth of the field is not only a result of its use in various academic fields. On www.eye-tracking-education.com we mention over 40 different academic disciplines, where eye-tracking is being used for research. Moreover, this growth is also due to eye-tracking's contribution to very many business functions that significantly benefit from using eye-tracking. We describe about a dozen different business functions in detail and there certainly will be more to come.

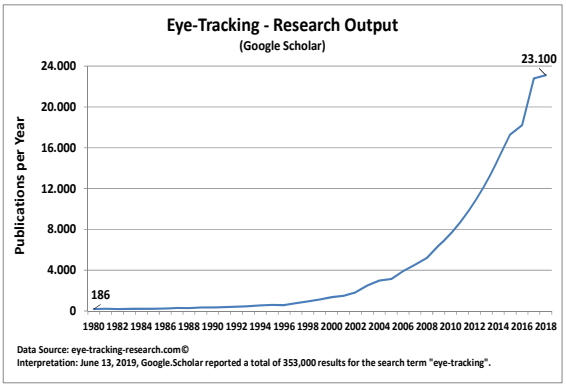

Figure 1: Research Output over time.

2 OBJECTIVES OF THE PAPER

The objective of this position paper is to demonstrate that eye-tracking is a cross-sectional technology for digitalisation because it provides a bridge between "machines" on the one hand, i.e. computers, networks, robots, and other man-made results of digitalisation like web pages, and humans on the other hand, who interact with them. Eye-tracking is utilised at the interface between the human and the technology side of digitalisation and it is exactly at that interface, where technological innovations translate into economic values through productivity gains, increased sales, higher realised prices, improved customer satisfaction, fewer litigation cases, longer lasting customer relationships and thereby increased lifetime customer value, more profitable management decisions and improved shareholder trust. Certainly, these benefits have a price-tag. Important caveats of lubricating the frictions of digitalisation through eye-tracking are the facts that the application of this scientific method is time consuming and requires highly qualified professionals. Yet the return on human capital investments for Eye-tracking for users, who are in the process of digitising parts of their businesses, is almost always much higher than one might expect from the cost-benefit relation of the very first eye-tracking project. Where do these additional returns of investment come from? Eye-tracking is a cross-sectional technology for digitalisation because with this single scientific method all these frictions that

[1] Frey, Carl Benedikt and Osborne, Michael A., 2013. *The Future of Employment: How Susceptible are Jobs to Computerization?*, Department of Engineering Science, University of Oxford, September 17, 2013

[2] At the same time, eye-tracking itself is part of digitalisation since it requires specialized software and hardware equipment.

arise and which are reflected in visual perception can be reduced. Eye-tracking – so to speak – is "digitalisation's best friend".

3 ADDED ECONOMIC VALUE THROUGH THE APPLICATION OF EYE-TRACKING

The following overview lists 22 applications, where eye-tracking can increase the economic value of digitalisation.

Improving the Productivity of Employees:

1. Optimised Human Computer Interaction (HCI) with eye-tracking
→ improved productivity of employees

2. Meeting the usability challenges in medical technology with improved HCI through eye-tracking
→ fewer litigation cases

3. Optimised Human Machine Interaction (HMI) with eye-tracking
→ improved productivity of employees

4. e-Health: eye-control during surgeries via eye-tracking
→ fewer infections, fewer litigation cases

5. Optimising the UX of data visualisations, dashboards in business intelligence, infographics and visualisations of law with eye-tracking
→ higher profits from improved business decisions

Improving the Profitability of e-Commerce:

6. Conversion Rate Optimisation (CRO) with eye-tracking
→ higher volume of sales

7. Measuring emotional reactions in virtual home staging with eye-tracking
→ higher volume of sales and/or premium prices

8. Measuring emotions and trust-building in e-commerce with eye-tracking
→ higher volume of sales and increased customer loyalty and life-time customer value

9. The death of banner ads: measuring the attention gain of content marketing with eye-tracking
→ decrease of wasted marketing budget

10. Readability and the quality of artificial intelligence translations (DeepL) with eye-tracking
→ higher volume of sales in international markets (exports and domestic migrants)

11. Measuring the readability of online newspapers with eye-tracking
→ higher volume of subscriptions and increased customer loyalty and life-time customer value

12. Measuring attention paid to digital signages and displays with eye-tracking
→ higher prices for digital signage and display ads

13. UX-design optimisation with eye-tracking
→ higher volume of sales and/or premium prices

Creating New Products and Services:

14. User interaction with virtual reality through eye-tracking
→ higher volume of sales and/or premium prices

15. User interaction with augmented reality through eye-tracking
→ higher volume of sales and/or premium prices

Improving the Quality and Economic Value of Existing Products and Services:

16. Ageing and the independent living movement: improving the usability of IT, AAL and assistive technologies with eye-tracking
→ higher volume of sales and/or premium prices because of user recommendations

17. Detecting distracted driving due to the use of smartphones or fatigue with eye-tracking
→ fewer accidents

Creating New Opportunities for Entrepreneurship and the Self-employed:

18. Self-Publishing with WordPress: measuring attention and readability of WordPress themes with eye-tracking
→ higher economic value of the website

19. Online Mystery Shopping with eye-tracking
→ higher volume of sales and/or premium prices because of improved competitive position

Enlarging and Improving the Type of Knowledge that Human Beings and Algorithms Can Be Taught:

20. e-Health: visual expertise extraction with eye-tracking
→ fewer malpractice suits

21. Using driving simulators for extracting the visual expertise in risk management with eye-tracking
→ fewer accidents

22. Eye-tracking for developing autonomous driving algorithms
→ Model behaviour of self-driving cars

In this position paper we can only discuss two of these applications in more detail: 1. Optimised Human Computer Interaction (HCI) with eye-tracking and 2. Meeting the usability challenges in medical technology with improved HCI through Eye-tracking.

3.1 Optimised Human Computer Interaction (HCI) with Eye-tracking

3.1.1 Lessons from the past: The IT Productivity Paradox

What is technically possible today and inspires the imagination of researchers and investors often does not lead to immediate economic success. The needs, expectations, habits and routines that shape the perception and decision-making of customers and employees have not been adequately taken into account when designing frictionless interfaces. Yet this problem is anything but new.

More than 20 years ago, the discovery of the so-called "IT productivity paradox" in economic research attracted a lot of attention beyond academic conferences. In a nutshell, the paradox means that there was no empirical evidence of an increase in productivity in the economy as a whole despite billions of Euros in IT investments. How was this possible? The improved productivity was precisely the argument that the IT companies had so convincingly presented. As a result, executives provided enormous investment budgets worldwide to realise these expected productivity gains, that however did not materialise.

Landauer [3] showed the connection between the lack of productivity increases and the inadequate usability of software employed within companies. So clearly frictions in digitalisation are anything but new. In the past, low ranking employees had to struggle with IT systems regardless of their complaints about lack of usability, and their resulting productivity was massively slowed down. Today, poor usability designs in e-commerce annoy many customers, who ultimately turn away resulting in low conversion rates. Yet IT-developers continue to blame users and refuse to acknowledge poor usability of e-commerce systems they designed. Once again, responsibilities are being turned upside down.

What Are the Economic and Financial Consequences for Companies, Customers and Employees?

Poorly designed human-computer interfaces:

- waste employees' working time, reduce their productivity,
- create a variety of operational risks and
- reduce sales.

3.1.2 How Can Eye-tracking Reduce Frictions at Human-Computer Interfaces and Improve Economic and Financial Performances?

Chapman [4] documents and analyses the gigantic business failures strictly technology-centred views can cause. If, however, a customer-centric view is adopted, this typically receives positive customer reviews and recommendations, thus enabling even small and medium-sized companies to grow rapidly despite low advertising budgets.

Adopting a customer-centric view is easier said than done though. What is obvious and logical for IT-developers might be counter-intuitive for non-IT-specialists. Developers can become aware of this by observing users in a structured, unbiased and objective way with eye-tracking.

The main advantage of using eye-tracking is the information gain compared to traditional UX studies, relying on the so-called "Think Aloud" method. Strandvall[5], was able to determine improvements in the information content of a usability study by recording eye movements with the help of a “Retrospective Think Aloud” (RTA).

Additional papers recommending eye-tracking for UX studies are Bojko and Adamczyk [6] as well as Email and Ahmad[7] by pointing out the distortions in the acquisition of information when using the Think Aloud methodology, especially in traditional, strongly hierarchised societies.

One needs objective, quantitative data showing usability problems when arguing with IT staff about the need for improving their design. And indeed, it is

[3] Landauer, Thomas K., 1996. *The Trouble with Computers: Usefulness, Usability, and Productivity*, MIT Press, 1996.

[4] Chapman, Merrill R., 2006. *In Search of Stupidity*: Over Twenty Years of High Tech Marketing Disasters, 2nd Ed., Apress, 2006.

[5] Strandvall, Tommy, 2009. *Retrospective Think Aloud and Eye Tracking - Comparing the value of different cues when using the retrospective think aloud method in web usability testing*, September 2009 Whitepaper by Tobii Technology.

[6] Bojko, Agnieszka and Adamczyk, Kristin A., 2010. *More than Just Eye Candy - Top Ten Misconceptions about Eye Tracking*, User Experience, Volume 9, Issue 3, 3rd Quarter 2010

[7] Email, Ashok Sivaji and Ahmad, Wan Fatimah Wa, 2014. *Benefits of Complementing Eye-Tracking Analysis with Think Aloud Protocol in a Multilingual Country with High Power Distance (Hofstede’s)*, in: Horsley, Mike, Eliot, Matt, Knight, Bruce Allen, and Reilly, Ronan, (eds.), 2014. Current Trends in Eye Tracking Research, pp. 267-278, Springer International Publishing, 2014.

eye-tracking that can deliver such data.

3.2 Meeting the Usability Challenges in Medical Technology with Improved HCI through Eye-tracking

Poor usability of medical devices, which could result in incorrect operating situations, can have extremely serious health consequences for the patient. In the worst-case scenario, patients can die because of maloperation. It is hard to think of other cases, where user-friendliness is as important as with medical devices. These risks in the operating theatre lead to more and more government regulations and a higher number of malpractice suits, where hospitals and medical technology companies are being sued for millions of Euros.

Yet superior usability in medical technology is not just an "annoying cost factor", but an important sales-relevant marketing instrument. Easy to learn operating skills is an important sales argument, because it can be effectively demonstrated in customer education or product training videos, instead of hiding superior usability in voluminous manuals or operating instructions that are difficult to understand and which nobody has the time to read.

Also, effortless usability saves time, an important sales argument in view of the shortage of personnel and the work overload of nursing staff. Moreover, high usability improves training time, thus reducing the probability of claims against the medical technology provider for damages arising from user errors.

Furthermore, improved usability enlarges markets. In the case of medical technology, good usability effectively supports exports to countries with low training standards for nursing staff. And in OECD countries, health insurance providers pressure hospitals to discharge patients from hospitals as quickly as possible. For those medical devices that can be taken home by patients, there is an economic incentive to also use such devices for home care applications. Of course, this requires particularly easy and fool proof operating of these medical devices.

3.2.1 Why Is Eye-tracking so Useful for Usability Studies Especially for Medical Devices?

Over the last two decades, medical devices have developed more and more into medical computers where increased emphasis is being placed on visual control elements. Touch screens are also used here as well as eye-controlled devices (for example communication devices for patients of Cerebral Palsy, ALS, Autism, Spinal Cord Injury, Rett Syndrome, Aphasia, etc. or control of an endoscopic manipulator as discussed in Yang Cao et al. [8]). However, users' expectations of effortless and intuitive operability, which they are accustomed to their smartphones, has increased, which means that the findings of usability research in the field of Human Computer Interaction (HCI) can also be applied to such medical devices. Eye-tracking has become one of the standard techniques for the optimisation of usability in the field of HCI. And this applied research method can generate objective, quantitative data reflecting accurately the usability of technology.

An important advantage of usability studies that employ eye-tracking compared to the classical method of usability studies - the so-called "Think Aloud" method (TA) - is that problems of the TA method, which can lead to a systematic falsification of the actually documented operating problems, are objectively avoided with eye-tracking. What are these problems?

With the TA method, it is always assumed that the test persons are not afraid to name any difficulties in operating the device openly and completely. Such answers, however, require a high degree of self-confidence when using complicated and technically demanding equipment. Technical understanding and the necessary self-confidence are normally connected with education. In the case of usability studies for medical devices, test persons will be nursing staff from the hospital sector. Especially in hospitals there is a very strong inequality in education, the base for their strong hierarchisation. A further complicating factor is that a large proportion of nursing staff comes from societies where authoritarian leadership is the common rule rather the exception. As already mentioned, the study by Email and Ahmad[9] drew

[8] Cao, Y, Miura, S, Kobayashi, Y, Kawamura, K, Sugano, S & Fujie, MG 2016, *Pupil Variation Applied to the Eye Tracking Control of an Endoscopic Manipulator*, IEEE Robotics and Automation Letters, vol. 1, no. 1, 7393466, pp. 531-538. January 2016.

[9] Email, Ashok Sivaji and Ahmad, Wan Fatimah Wa, 2014. *Benefits of Complementing Eye-Tracking Analysis with Think Aloud Protocol in a Multilingual Country with High Power Distance (Hofstede's)*, in: Horsley, Mike, Eliot, Matt, Knight, Bruce Allen, and Reilly, Ronan, (eds.), 2014. Current Trends in Eye Tracking Research, pp. 267-278, Springer International Publishing, 2014.

attention to this problem. They write on page 268: "Due to the power distance that is already present in the Malaysian culture, the user during the Think Aloud (TA) process sees the moderator as a supervisor and hence has a tendency to be afraid in disagreeing in the effectiveness, efficiency and satisfaction of degree of usability of a website under test. This is one reason why Think Aloud (TA) technique alone may not be suitable and reliable in usability studies in Malaysia." Aga Bojko [10] explains in Chapter 6 of her book the advantages of RTA (or retrospective verbal protocol), the main benefit being that it has no impact on eye movements during the task.

3.2.2 Eye-tracking for Medical Devices under Realistic Working Conditions

With mobile eye-trackers, usability studies can now also be carried out for medical devices that have to be tested under realistic conditions, such as those prevailing in the hospital environment. Stressful situations increasing the cognitive workload significantly are typical for real working conditions. Eye-tracking allows the cognitive workload of test persons to be measured objectively and over time and leads to corresponding quantitative measurement data that can later objectively prove the representativeness of the study to third parties.

An example of a usability study for medical devices using eye-tracking is the work of Spaeth, et al.[11], who carried out research on the user-friendliness of four different anaesthesia and ventilation devices at the University of Freiburg. The eye-tracking analysis of their work has revealed that operating problems limit work performance. According to the users' assessments of user-friendliness Dräger's Perseus ventilator received the best rating. All in all, this usability study, supported by eye-tracking, shows that the user-friendliness of various ventilators differs considerably and that operating problems limit the efficiency in performing certain tasks. Eliminating these problems will increase work performance and thus patient safety.

4 CONCLUSIONS

Now, what is the main contribution of our position paper? Applied eye-tracking research consumes substantial financial resources because of the staff training time required to come up with valid results. Entrepreneurs, of course, care about the return on their research investments, so they might prematurely reach the conclusion, eye-tracking is just too expensive. Yet their cost-benefit calculation is flawed.

They implicitly assume that the human capital investments for the training of their staff members, who will be involved in conducting eye-tracking studies, will yield financial gains for only one application – the application they view as most pressing, thus overlooking other possibilities.

Likewise, the attention of academic researchers is also quite selective. They necessarily focus on a single research question. Because of this selective attention, it is widely overlooked that eye-tracking by now has become a cross-sectional technology for digitalisation. It is the objective of our position paper to give a comprehensive overview of the vast array of business applications, where eye-tracking can reduce potential frictions of digitalisation projects. Through our applied research we were able to identify 22 different applications so far, where decision-oriented eye-tracking research can yield economic rewards for users pursuing a digitalisation strategy with at least a dozen financially rewarding applications.

A narrow focus on the benefits from just one or two eye-tracking projects will grossly underestimate the potential financial rewards for entrepreneurs. This in turn will cause underinvestment in eye-tracking related human capital, thus perpetuating frictions at the human machine interface.

Ever since Kenneth J. Arrow's article "The Economic Implications of Learning by Doing" [12], learning has been identified as the main source of economic growth, and the application of all these scientific methods requires human capital investments so that learning can take place.

Because of the numerous applications eye-tracking provides for reducing the frictions at the human-machine interface, users pursuing a digitalisation strategy should become aware of the

[10] Bojko, Aga,, 2013. *Eye Tracking the User Experience: A Practical Guide to Research,* Rosenfeld Media, 2013

[11] Spaeth, J., Schweizer, T., Schmutz, A., Buerkle, H. and Schumann, S., 2017. *Comparative usability of modern anaesthesia ventilators: a human factors study*, British Journal of Anaesthesia, 3. October 2017.

[12] Arrow, K.J., 1961. *The Economic Implications of Learning by Doing,* Technical Report No. 101, December 7., 1961, prepared under Contract Nonr-225(50), (NR-47-004) for Office of Naval Research, Institute for Mathematical Studies in the Social Sciences, Applied Mathematics and Statistics Laboratories, Stanford CA 1961.

financial benefits from the use of this scientific method in their applied research and business models.

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