A-me: Augmented Memories

Jordi Puig[1], Andrew Perkis[1], Aud Sissel Hoel[1], Alvaro Cassinelli[2]
Norwegian University of Science and Technology (NTNU) [1]
Department of Information Physics and Computing, The University of Tokyo [2]

Abstract

A-me is a fictitious memory-evoking apparatus at the intersection of science, art and technology. The system enables users to experience other people's memories as well as store their own by interacting with a volumetric representation (MR) of a human brain. The user retrieves or stores memories (audio traces) by pointing and clicking at precise voxels locations. Triggered by their exploratory action, a story is slowly revealed and recomposed in the form of whispering voices revealing intimate stories. A-me it's a *public* receptacle for *private* memories, thus exploring the possibility of a collective physical brain.

The installation introduces an original optical see-through AR setup for neuronavigation capable of overlaying a volume rendered MR scan onto a physical dummy head. Implementing such a system also forced us to address technical questions on quality assessment of AR systems for brain visualization.

CR Categories: H.5.2 [Information Interfaces And Presentation]: User Interfaces—Graphical user interfaces (GUI); I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques

Keywords: augmented reality, visualization, collective experience, memory retrieval.

1 Introduction

Questions such as: "What is the basis of human behavior, though or memory? How do we define actions and decision processes? Can memories be disembodied from the individual that experienced them? Can memories be recorded and shared?" have traditionally been addressed by philosophers and psychologists using introspection and verbal report. While neurologists are looking at the connectivity of neurons, cognitive neuroscientists are seeking answers through behavioral experimentation, neuroimaging and computational modeling. In the young field of cognitive and behavioral neuroscience, psychological functions are partially classified by the *localization* of their underlying circuitry in specific areas in the brain. The emergence of powerful radiological measurement techniques (e.g., fMRI, PET, SPECT) combined with experimental techniques from cognitive psychology allows neuroscientists to address questions of the human mind such as cognition, emotion or memory by looking for their *neural correlates* in the physiological brain.

SIGGRAPH Asia 2013, November 19 – 22, 2013, Hong Kong.

Figure 1: A-me being used by the author.

Discussions on brain/mind matters and functionality take place across several specialized scientific disciplines, yet many fundamental questions remain of public interest and are at the core of everyday human experience. A-me offers the opportunity of a free, personal reflection on some aspects of these discussions; for one, the work exposes the ambiguity between the possibility of accurately locating places in the brain, and the uncertainty of defining a *place* in the world (or the brain) for a mnemonic experience. The installation also forces us to reflect on the ownership of a memory item: Whom do memories belong to? Are memories private events? Can we manipulate them?

2 Motivation

What *is* memory? *Where* is it? Do memories remain the same forever? Are they modified depending on our current emotional state or our will? What is the *substance* of a memory?

Since these questions are tied to the nature of human experience itself, it's not surprising they were explored extensively in philosophy, art and literature well before these could be considered in scientific terms. The problem of localizing 'a memory' is ill posed because the relation between a place and a memory can be considered in multiple ways. Before the advent of computational theories of the mind, a 'memory' had not other physical correlate in the world than, perhaps, the place where the memory was formed. Writing provided effective methods of externalizing certain important aspects of human memory [Donald 1990]. It was possible to think about a place for a particular memory: the writing itself, and the support for the writing. But in an obvious sense ink and paper is not the memory itself: without a reader, the set of written symbols remain meaningless. Adding other modalities to the recording (sound, image, etc) may not change the problem a bit - although some philosophers have mused over the possibility that a *complete* recording of physical reality may also bring about phenomenological experiences, as it happens in the novel "*La invencion de Morel"* [Casares 1974]. Leaving aside this intriguing possibility, it seems clear that for a memory to come to life, the symbols, sounds or images need to be interpreted, decrypted and re-associated inside a mind. In other terms, a memory and a trigger for that memory may be different things: *remembering* is an active, exploratory process. The same set of triggers can end up producing different remembrances if read by different minds. A-me strives to reproduce, or at least to represent metaphorically this exploratory exercise.

Locating where memories that do not require an external record to be experienced are, *in the brain*, is also a subject of much debate among neuroscientists. The reason for the debate is that the model of encoded data (situated somewhere) + a decoder machinery (situated somewhere else) is an extreme oversimplification of what may be happening - not to say perhaps plain wrong. To start with, the decoder contains information about the thing to decode – in other terms; it *is* part of the 'record'. Comes then the problem of locating a *mind*, which may be just a vain pursuit, at least if we look just inside the skull [Beaulieu 2000].

Still, locating were a memory is in the brain is a problem that needs to be *practically* addressed in neurosurgery. Wilder Penfield, considered one of the greatest neuroscientists of his time, described some of his most ground-breaking research in the chapter "*Gateways to the Mind"* [Crump 1958] of the Bell Labs TV series. He explains the idea that all conscious events are permanently recorded in the brain. In the documentary he explains:

> "There is recorded in the nerve cells of the human brain a complete record of the stream of consciousness. All those things of which a man was aware in any moment of time are recorded there, and all the sights and sounds which he ignored and the thoughts which he ignored are absent from that record."

During surgical brain operations performed by him, the patients were conscious and were able to talk. While the patient's brain was exposed, a "gentle electrical current" was applied with an electrode and then a very vivid memory could be re-experienced. When Penfield asked how those experiences seemed to them, they reported that these were "much more real than any remembering", which seemed to imply that the brain is somehow capable of recording multimodal experiences in perfect detail (eidetic memory), and that those memories are stored in precise locations in the brain.

The results of these experiments are regarded today in a more critical manner by the scientific community, but the idea that memories are 'dormant' and can be elicited, erased, modified or even that new memories can inserted by physical means (i.e., by tampering directly with the brain tissue) is pervasive in science-fiction novels and films. In the SF film "*Strange Days" (*Kathryn Bigelow, 1995) experiences are recorded, exchanged and finally reproduced by others. Michel Gondry's "*Eternal Sunshine of the Spotless Mind"*(2004) builds a story around a machine capable of erasing memories at will, briefly bringing peace to the souls of former lovers. (Interestingly, memories are represented as colored spots in a brain scan, and can be selected by a simple pointing device, very much like in the present installation A-me). In Vim Wenders's "*Until the End of the World"*(1991), a machine is used to record human dreams: the characters become addicted to the device, living only to see their own dreams during the day. In "*Total Recall"* by Len Wiseman (2012) or Paul Verhoeven (1990), a factory worker discovers that his memories are in fact fabrications implanted by the government.

Will we be able in the future to recall, modify, and/or insert human memories in such a way? Some futurists such as R. Kurzweil [2005] are convinced it will be so. By the way, we may be already in the verge of visualizing memories exactly like in *Until the End of the World*, as demonstrated recently in [Nishimoto et al. 2011] using non invasive Brain Machine Interfaces (BMI). In the meanwhile, using AR techniques, A-me simulates this possibility in the present, giving us the opportunity to reflect on its consequences.

3 Scientific approach

The field of neuroscience has intensively grown during the last twenty years. Nowadays the mapping techniques are much more powerful than those used in Penfield's experiments. Brain atlases are being used in the field of neuroscience to study the regions of the brain creating limits to divide areas of functionality. Therefore, modern neuroscience represents the triumph of a method: *reductionism*.

There is currently a vigorous debate on how the brain/mind-problem is approached from different disciplines. The reductionist approaches to the brain/mind are controversial and are currently being countered by more holistic views. For instance, phenomenological approaches assume that the human cognition is active, dynamic, and always requires a meaningful context.

On the other hand, what cognitive scientists use as a method to study the brain, namely "the black box approach", aims at describing the underlying processes of a unknown system (seen as an object) by stimulating the inputs while isolating concrete tasks and measuring the outputs. This way of looking at human matters is prominently contrary to phenomenology. A deeper examination of the brain/mind controversy has been illustrated by Beaulieu in her dissertation: "*The Space Inside the Skull"*, where the definitions of the mind and their mappings into virtual brains are extensively discussed [Beaulieu 2000].

At this point, it is important to emphasise that A-me is not a science communication project nor intended to communicate how current neuroscience explains the mnemonic phenomenon. A-me is a science inspired artistic intervention aiming at a self-reflective activity of the visitor about the neural substrate of human memories through a playful experience.

4 An art-science project

The development of the device is part of the research project Picturing the Brain and it is used to visualize tomograms of the human brain in Augmented Reality (AR). The development of the device aims at conducting research on Quality of Experience (QoE) in AR.

Augmented reality is already state-of-the-art in neurosurgical planning. Several different technologies are currently being used: displays, tracking systems, interactive systems, and many others. The current challenge is to find successful methods to assess the overall QoE of the end user. Although some work has been performed on perceptual-based audio–visual quality metrics [You et al. 2010], it seems that these evaluation methods cannot fulfill the current needs of AR. However, today's assessment methods seem not to be applicable to AR systems since they usually assume the end user as a passive entity. AR systems are based on interaction and more importantly on active perception and experience of the content. A preliminary discussion about the methodologies employed to assess the quality of AR systems and their challenges has been presented on [Puig et al. 2012]. The article examines the current scientific fields exploring this goal. Some of them employ qualitative assessment as a basis for experimentation e.g. Ethnography or Usability, and some others use quantitative assessment with subjective metrics to evaluate the quality of a system e.g. QoE applied to Multimedia Signal Processing or Acoustics. Therefore, there is a need for new methodologies to assess the quality of AR systems. The development of this installation is a step towards further research on this technical field, but we believe that being able to assess the quality of experience may be a valuable tool helping to develop and improve sophisticated, AR-based media art installations such as A-me.

5 From theory to practice

A-me treats memories in a location-based manner. Using a highly accurate tracking system and a tomographic brain visualization, the user is able to find memories in the displayed volume as tiny glowing particles. The visitor activates them by holding the pointer on the correct position and pressing a button. Triggered by their action, a story is slowly revealed. It consists of a whispering voice (binaurally spatialized sound delivered through headphones), relating parts of intimate stories that were previously stored by another person. The visitor is also able to record his own memories on certain locations of the brain. In this way, A-me also serves as a memory collector (see Figure 2).

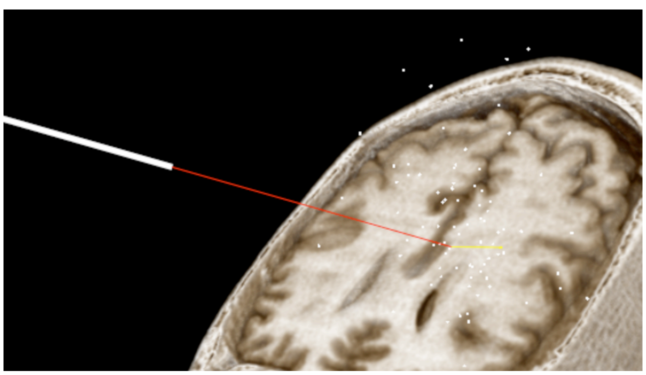

Figure 2: Screen capture of A-me. Each dot is a recorded memory.

The installation requires an exhibition space where there is an area properly equipped to render the experience. One stereo 3D screen, six tracking cameras, a half-silvered glass and a head manikin are standing on a table (see Figure 4). The visitor is equipped with high-end wireless headphones, tracked shutter glasses and a tracked probe. Looking through the glass, the visitor can see the MR volume registered against the dummy-head. The visitor is able to navigate different areas of the brain by manipulating the probe. Active hotspots indicating the location of the memories are visually merged with the real data. Immersive auditory responses are triggered by pointing and clicking at any of them. When moving further away from the hotspot, the device will merge more and more soundscapes of neighboring aural memories resulting in an overlapping of multiple voices. This is similar to the cocktail party effect, where by selective attention (i.e., by approaching the hotspot again), the user is able to *focus* and make sense of a particular memory.

The device is composed of three parts: the tracking server, the visualization server and the audio server, which will directly react to user interactions (Figure 3).

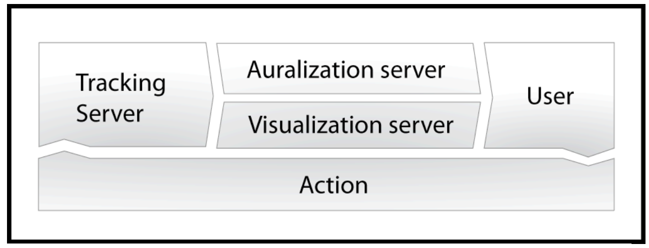

Figure 3: Software and interaction diagram

6 Tracking system

The information flow starts on the tracking cameras, which are sending video frames at a very high frame rate (250fps) to the tracking server. Two groups of cameras are located on top of the installation, each group pointing at the user from one side. This positioning is required to cover the possibility of both right- and left-handed users. The cameras have large overlapping fields of view, and each video frame is 832 by 832 pixels. These specifications ensure a precision for the extraction of 6DoF (six degrees of freedom) information for tracked objects to be below 1mm (depending on the area).

The latency of the tracking system is in the range of 4 to 10 milliseconds. Once the tracking server has extracted the 6DoF information for each tracked object, the data is sent over a UDP socket to the other servers. This transmission will occur 120 times per second.

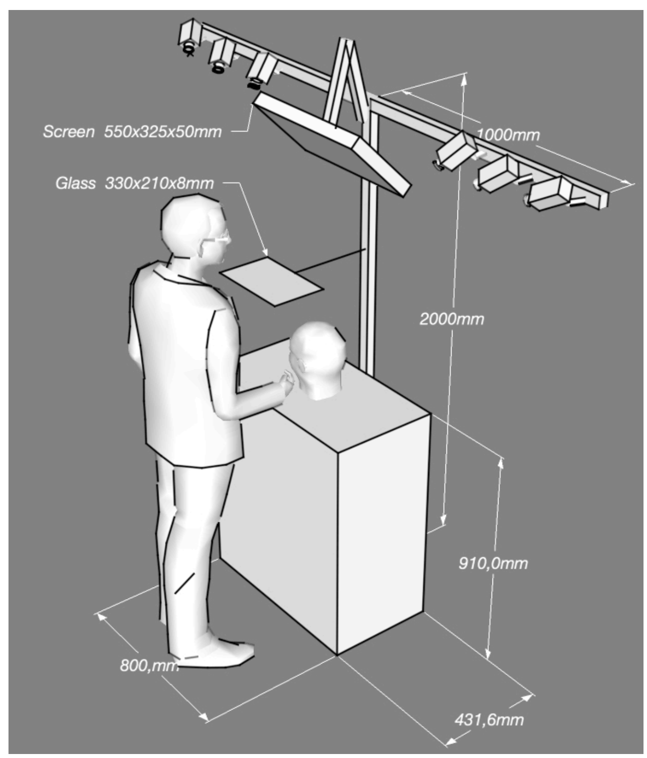

Figure 4: Hardware setup

7 The Optical See-Through AR display

To merge the virtual data from the tomography with the reality we used a device based on The Pepper's Ghost Effect (PGE). PGE is a well-known technique in theatre productions to make objects magically appear or disappear. This technique, created by John Henry Pepper in 1682, consists of placing a half-silvered mirror in an angle, in such a way that depending on the lighting intensity in the scene, translucent objects appear to float in the air. Lately, this setup has been used with electronic displays in AR allowing interactions between real and virtual environments [Bimber and Raskar 2005; Kanten et al. 2011]. This setup is particularly interesting when used in AR because it can solve the known problem of "accommodation and convergence" [Drascic and Milgram 1996].

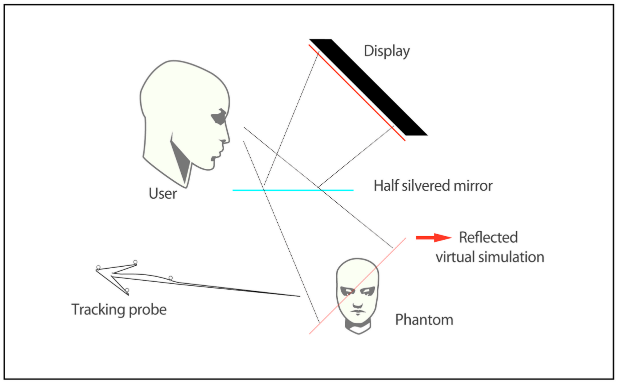

Figure 5: Diagram of the Pepper's Ghost AR system

Depending on the implementation several terms have been used to refer to this technique. The terms: "holographic display" **Error! Reference source not found.**, "fixed optical see-through (OST) display" and "mirror based display" are amongst the most widely used. The diagram depicted in Figure 5 exemplifies the disposition of the half-silvered mirror in respect to the screen and the real object where the blending occurs. The red line refers to the 2D image displayed by the screen and its corresponding reflection, which will fall at the opposite position in respect to the mirror. This position and orientation of the reflection appears fixed in the real space independently of the user's point of view.
The development of the device is a work in progress that can be divided in three phases, each of one providing the opportunity of a separate assessment of QoE for independent aspects of the interactive AR system:

7.1 Phase 1: OST AR with tracked probe.

The first phase is a prototype of an OST AR device displaying three-dimensional (3D) static graphics. No stereoscopy is involved at this stage. Reflections of the display on the glass are used to overlay the real object with the virtual stimuli. Controlled illumination (self illumination or light projection) is used to adjust the similarity between real and virtual stimuli.

7.2 Phase 2: Interactive 2D AR

An additional degree of complexity is added by transforming the previous prototype into an interactive device. The user is able to navigate the virtual content by physically moving the dummy head which position and orientation is being registered; this means that moving it physically will affect the virtual stimuli. This implementation necessitates the use of a tracking system in order to register the position and the orientation of the dummy head accurately.

7.3 Phase 3: Interactive stereo 3D AR

The final phase is a prototype presenting the virtual simulation in stereoscopic 3D. This will allow the use of volumetric objects on the real stimuli. In order to achieve AR with a stereo pair of images we will also need to track the glasses' position of the user. At this point, the user is able to alter his point of view and to manipulate the real object freely while the system updates the virtual overlaid simulation in three dimensions in real-time.

Figure 6: A-me on the Phase 1 development.

8 Realism of the rendering

As stated in section 4, this device is also part of scientific research on QoE in AR devices. Some perceptual issues can be addressed depending on the physical characteristics of such displays. On the other hand, different kind of perceptual issues derived from semiotics and visual design can also be assessed.

There are visualization aspects in AR being approached from a designer's perspective. Usually computer graphics developers can solve the need for a visual feedback using a number of different metaphors. Strategies like masking, zooming, highlighting, or offering different levels of visual information load can be highly determining on the final quality of an AR system. Examples of these solutions have been shown in **Error! Reference source not found.**. To summarize this point, there are different levels of quality for an AR system, from physical properties of the device to the visual aspects of the virtual information displayed. These aspects of quality in AR, especially in PGE devices will be addressed using A-me's equipment in further research publications.

The purpose of A-me is to display a real tomography with an added interpreted visualization, which refers to the location of the memories. The tomography is displayed by using a volume rendering technique based on a fast ray casting procedure **Error! Reference source not found.**. This is a well-known technique, widely used in the computer graphics community. In addition we use a tailored CLUT (color look up table) to reinforce the attention of the user to certain areas of the brain. Meaning that we will color certain group of voxels depending on their weight to let the user see through some specific regions across the tomography.

9 Exhibitions and discussion

The random access to memories stored in the physical volume had the effect that each user ended up having a different 'reconstructed experience' (e.g., different sequences of audio recordings). This points to an inherent characteristic of this 'spatialized storage system': unless the user can associate specific brain locations with a certain kind of memories, then the reconstructed 'experience' will be just a patchwork of random episodes, with unexpected loops and comebacks - essentially a non-linear narrative, which is exactly what happens in most of the SF movies described above. On the other hand, a visual layout of the memory items may speed up retrieval and narrative building if the volume itself could somehow give cues of the content. This is the principle behind the "method of loci" **Error! Reference source not found.**, a mnemonic technique that relies on human capacity to quickly and efficiently store new information on an imaginary (and personal) 3d space, sometimes called a "memory palace". A-me points to the possibility of making this "memory palace" an interpersonal, shared space to store and retrieve public instead of a personal, mental one.

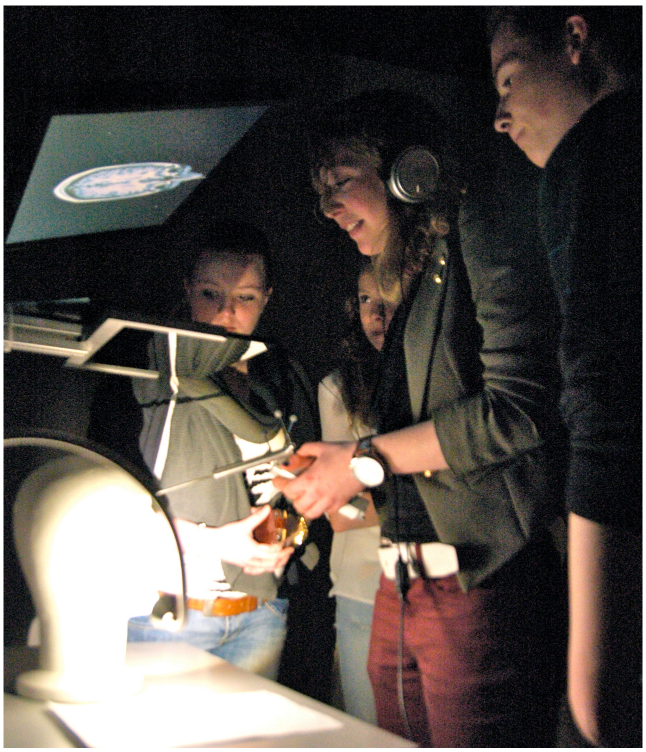

Figure 7: A-me exhibited at the STRP 2013.

A-me was experienced by thousands of visitors during the exhibition at STRP festival 2013, in the Netherlands, for a period of 10 days. The population was generally using native Dutch language and the age groups where very distinct. During daytime many student groups attended the exhibition and during evenings the younger where slowly replaced by older adults.

The most relevant feedback from the exhibition was given through comments from the visitors. Most of them were intrigued by the functionality of the technology at first. After making use of the installation and discovering its capabilities, they were usually surprised and fascinated with the treatment of the memory metaphor.

At the same time, during the exhibition, the tracking system was recording the interaction (position and orientation) of the probe 60 times per second. This data is currently being analyzed to assess the quality of the device. It will provide a good insight on the quality of the depth perception experienced by the users when using the PGE display in this particular setup. The amount of data produced during the exhibition (see Figure 7) would not be possible in a laboratory experiment. For this reason we believe that scientific exploration can also benefit from artistic interventions.

10 Conclusion

By providing a game like scenario, A-me creates the opportunity for a playful reflection on serious topics ranging from philosophy of the mind to technical aspects of neurosciences. The user is able to navigate the brain by handling a tracked probe similar to the probes that neurosurgeons use to examine brain injuries. While navigating the brain, the user can find active spots in specific parts of the nervous structure; pointing at the spots triggers the recording of an aural memory left at that location by the previous visitors. In this sense, A-me proposes an alternative to the information cloud: a physical, shared repository of *private* memories.

This work raises questions on the dominant trends in cognitive neuroscience that seek to map aspects of the mind to the physical world, and therefore raises awareness on the possibility, in the near future, of *manipulating minds*.

References

BEAULIEU, J.A. 2000. *The Space Inside the Skull*.

BIMBER, O. AND RASKAR, R. 2005. *Spatial augmented reality*. A K Peters Ltd.

BJÖRK, J. 2010. Evaluation of a Holographic 3D Display.

CASARES, A.B. 1974. *L'invention de Morel*.

DONALD, M. 1991. *Origins of the Modern Mind*. Harvard University Press.

DRASCIC, D. AND MILGRAM, P. 1996. Perceptual issues in augmented reality. *Proceedings-Spie The International Society For Optical Engineering*, 123–134.

GATEWAYS TO THE MIND. 1958. Gateways to the Mind.

KALKOFEN, D., TATZGERN, M., AND SCHMALSTIEG, D. 2009. Explosion Diagrams in Augmented Reality. 71–78.

KAUFMAN, A. AND MUELLER, K. 2005. Overview of volume rendering. *The visualization handbook*, 127–174.

KLANTEN, R., EHMANN, S., AND FEIREISS, L. 2011. *A Touch of Code*. Die Gestalten Verlag.

KURZWEIL, R. 2006. *The Singularity Is Near*. Penguin.

MENDEZ, E. AND SCHMALSTIEG, D. 2009. Importance masks for revealing occluded objects in augmented reality. *Proceedings of the 16th ACM Symposium on Virtual Reality Software and Technology*, 247–248.

NISHIMOTO, S., VU, A.T., NASELARIS, T., BENJAMINI, Y., YU, B., AND GALLANT, J.L. 2011. Reconstructing Visual Experiences from Brain Activity Evoked by Natural Movies. *Current Biology 21*, 19, 1641–1646.

PUIG, J., PERKIS, A., LINDSETH, F., AND EBRAHIMI, T. 2012. *Towards an Efficient Methodology for Evaluation of Quality of Experience in Augmented Reality*. Proc. of Quality of Multimedia Experience (QoMEX). IEEE.

YATES, F.A. 1966. *The Art of Memory*. *Yates*.

YOU, J., REITER, U., HANNUKSELA, M.M., GABBOUJ, M., AND PERKIS, A. 2010. Perceptual-based quality assessment for audio–visual services: A survey. *Signal Processing: Image Communication 25*, 7, 482–501.