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# The application of augmented reality in print media

*Merkourios Margaritopoulos and Elissavet Georgiadou*

Hellenic Open University – School of Applied Arts,
Thessaloniki, Greece

mermar@ekdd.gr
elisag@otenet.gr

**Abstract**

Augmented reality is a growing research field aiming to enhance the elements of the real world by overlaying additional virtual information. The paper presents augmented reality as an efficient tool of renovating the traditional print media. It includes an introduction to its concept, covering its fundamental principles and technologies, and focuses on its application in print media. It examines the 'augmented print media' in terms of the related technologies and reports on distinguished examples of augmented newspapers, magazines, books and packaging products. Finally, the paper attempts to point out the role of augmented reality in redefining the position of print media in the digital world. It studies the differences between print and digital media and proves the contribution of augmented reality in upgrading print media to modern communication media.

**Keywords:** augmented print media, smart mobile devices, fiducial markers, computer vision, virtual information

## 1. Introduction

Augmented reality (AR) refers to a live view of physical real-world environment whose elements are merged with augmented computer-generated images, creating a mixed reality. The augmentation is typically done in real time and in semantic context with environmental elements. By using the latest AR techniques and technologies, the information about the surrounding real world becomes interactive and digitally usable (Carmigniani and Furht, 2011). Augmented reality aims at simplifying the user's life by bringing virtual information not only to his/her immediate surroundings, but also to any indirect view of the real-world environment, such as live-video stream (Furht 2011, p. vii). Augmented reality is not considered to be restricted to a particular type of display technologies, such as head-mounted display (HMD) or limited to the sense of sight. It can potentially apply to all senses, augmenting smell, touch and hearing as well. Augmented reality can also be used to augment or substitute users' missing senses by sensory substitution, such as augmenting the sight of blind users or users with poor vision using audio cues, or augmenting hearing for deaf users using visual cues (Carmigniani and Furht, 2011).

Augmented reality is an innovation that will almost certainly turn out to be as powerful and broadly applicable as was the Internet itself. This is the eventual, self-evident conclusion reached when anyone, upon achieving a basic level of comprehension, spends a few moments considering the limitless potential that AR promises. Augmented reality is a medium that allows the user to interact with digital data in a visual and spatial manner that is utterly seamless with his/her environment and everyday life (Mullins and Dempsey, 2013, p. xv).

Augmented reality has already many functional applications in a wide range of fields, including education, science, business and manufacturing, medicine, public safety and military, art, advertising and entertainment. The application of AR in the print and publishing sector is a relatively new idea gaining attention by increasing its penetration speed into the field with technologies and products being established in rapid rates. One can say that it is a corollary of situations in which the necessary content to adequately cover a subject is too big to fit into the limited space of a printed medium. For example, AR in the form of QR codes can be applied to a flyer to create a web link between the flyer and a web page with additional digital content. Nevertheless, the importance of AR is not limited into saving print space by 'condensing' large amounts of information into the small space of a printed surface, but it is extended by augmenting the user's sensory perception offered by interactive digital media that complement and enhance the printed media.

The paper presents a brief introduction to the concept and technologies of AR and describes the principles of its application to print media for which selective examples are given, to point out the role of AR in redefining the position of print media in the digital world. It examines the differences between print and digital media in order to prove the contribution of AR in upgrading print media to modern communication media.

## 2. Definitions and technologies of augmented reality

An AR system is a system that creates a view of a real scene by incorporating computer-generated virtual objects, including those with full three-dimensional properties, into the scene. As the user of such a system moves about the real scene, the virtual objects appear as if they exist in the scene. Ideally, the virtual objects should interact with the user and real objects in the scene in a natural manner. In all application domains AR enhances the user's performance and his/her perception of the world. The goal is to create a system such that the user cannot tell the difference between the real world and the virtual augmentation of it. To the user of this ultimate system it would appear that he/she is working in a single real environment (Vallino, 1998).

Several definitions for AR have been proposed by researchers. Milgram, et al. (1994) argue that AR is defined by two approaches: a broad approach and a restricted one. In the broad approach, AR refers to augmenting natural feedback to the operator with simulated cues. In the restricted approach, the technology aspect is emphasized defining AR as a form of virtual reality (VR) where the participant's head-mounted display is transparent, allowing a clear view of the real world. Klopfer (2008) proposed a broad definition for AR, suggesting that this term could be applied to any technology that blends real and virtual information in a meaningful way. Moreover, Klopfer and Sheldon (2010) define AR as a means able to provide users technology-mediated immersive experiences in which real and virtual worlds are blended, while Dunleavy, Dede and Mitchell (2009) state that in an AR environment, users' interactions and engagement are augmented. In a more structured, feature-based definition, Ronald Azuma defines an AR system as any system that has the three following features (Azuma, 1997):

1. combines real and virtual,
2. is interactive in real time and
3. is registered in 3D.

Azuma (1997) also referred to AR applications that require removing real objects from the environment, in addition to adding virtual objects. Such removal of objects from the real world corresponds to covering the object with virtual information that matches the background, to give the user the impression that the object is not there.

Augmented reality has its origin in VR. Virtual reality creates a virtual world that users can interact with. This virtual world is designed in such a way that users find it difficult to tell the difference from what is real and what is not. Both VR and AR are similar in the goal of immersing the user, though both systems do this in different ways. With AR, users continue to be in touch with the real world, while interacting with virtual objects around them. With VR, the user is isolated from the real world while immersed in a world that is completely artificial.

Although the terms are not identical, many people use 'mixed reality' interchangeably with AR. There is no consensus on the exact relation between the two. In some cases, AR is given a more relaxed definition as a technology that only overlays digital information on real-world elements, while mixed reality is additionally awarded with the ability of the user to interact with and manipulate both physical and virtual items and environments, using next-generation sensing and imaging technologies (Intel, 2018). In other cases, mixed reality is considered to be a broader interpretation that consists of anything of both the physical world and the digital world. The specific constraint of registration is relaxed. The registration and interaction features are appointed to AR. In this sense, all AR applications are mixed reality, but not all mixed reality applications are AR (Craig, 2013, p. 30). On top of these three terms, extended reality (XR) is an umbrella category referring to all real-and-virtual combined environments and human-machine interactions generated by computer technology and wearables (Parrish, 2018).

An AR application needs to ensure that always two functions take place. Craig (2013, p. 39) defined that these functions are:

1. The determination of the current state of the physical world and the current state of the virtual world.
2. The display of the virtual world in registration with the real world in a manner that will cause the participant(s) to sense the virtual world elements as part of his or her physical world.

Figure 1 shows an example of a common AR system and the data which is acquired, computed, and presented. To register the virtual monster, the AR system derives tracking information from the video input. After rendering the registered 3D structure, its overlay allows to generate the impression of a virtual figure standing on a real-world paper card (Kalkofen, et al., 2011).


*Figure 1: Data flow in a common augmented reality system (Kalkofen, et al., 2011)*

There are three major components in an AR system to support the above functions. The three core components include (Craig, 2013, p. 40):

1. Sensor(s), to determine the state of the physical world where the application is deployed. Types of sensors range from the ones that exploit inertial methods (gyroscopes, accelerometers) or the electromagnetic spectrum (GPS, RFID, Bluetooth, etc.) to those that make use of cameras and computer vision methods.

2. A processor, that coordinates and analyzes sensor inputs, stores and retrieves data, carries out the tasks of the AR application program, and generates the appropriate signals to display. Computing systems for AR can range in complexity from simple handheld devices such as smartphones and tablets to laptops, desktop computers, and workstation class machines all the way through powerful distributed systems. In some cases, a handheld computer is in communication with a high-performabce server that might be located at a distance (Craig, 2013, p. 51). Furthermore, the necessary software to develop and consume AR applications falls into one (or more) of three categories: Software Development Kits (tools for creating stand-alone AR applications), Browsers that allow for the discovery and consumption of AR content and Content Management Systems that offer a simple interface for the non-technical user to create and publish content to an AR browser (Kilby, et al., 2012).

3. A display suitable for creating the impression that the virtual world and the real world are coexistent and the effect on the participant's senses that he/she senses the combination of the physical and the virtual world. Examples of displays used by AR applications are head-mounted displays (HMDs), computer monitors, tablet and smartphone screens, as well as video projectors displaying virtual content on the surface of physical objects.

These core components of an AR system work closely together to create an augmented digital experience. A challenging application field for putting AR on the stand to provide digital interaction to static, in nature, communication media is print media.

## 3. Augmented reality in print media

In today's digital era, the modernized printing and publishing sector is trying to adjust its production by using unified workflows and adopting digital content, along with the traditional products of printing. The final product of this process is differentiated as printed or digital, only at the phase of publishing – the so-called 'cross-media publishing model' (Veglis, 2008). However, in recent years, the application of AR technology in print media makes the discrimination of a published end-product as exclusively printed or digital, invalid and obsolete.

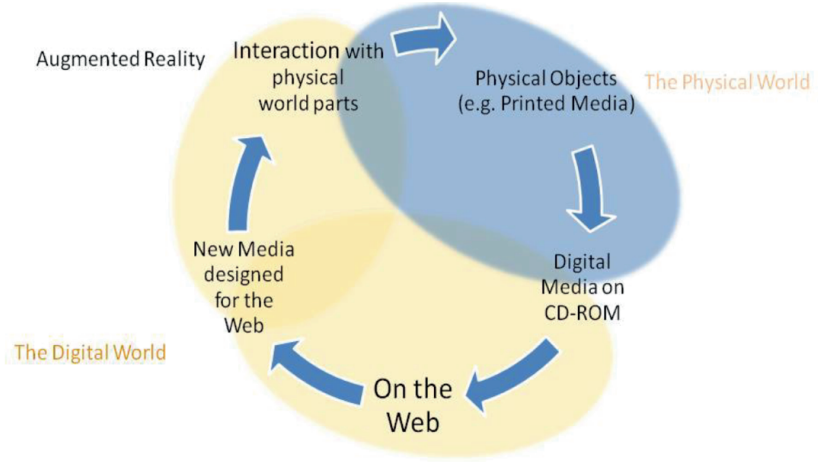


*Figure 2: Relationships between the digital and the physical world (Perey, 2011b)*

The field of AR applications in the print and publishing sector has its origin in a vision in which any printed material, from a poster, a sign or a package to a printed page in a newspaper, magazine or book, can provide its reader more value than what the original material was designed to convey. When combined with a camera, algorithms that detect the content of the page, and platforms that retrieve associated digital data, printed surfaces will provide value beyond what is possible with either print only or digital only content (Perey, 2011a).

In Figure 2 the way traditional print media relate to AR and new media is shown. The strength of AR lies in the ability of the technology to seamlessly close the gap between the digital and the real world. Augmented reality has the potential not only to allow a less dramatic transition to digital media, but also the creation of completely new editorial products with novel and original features (Inglobe Technologies Srl, 2011). Figure 2 shows the relations between the digital world on the one hand and the physical world on the other. Print media are entities belonging to the physical world. Digital media having a physical substance (e.g. a storage medium like a CD or a hard drive) belong to the intersection of the physical and digital world. Web sites and new media designed exclusively for the web belong to the digital world. Augmented reality, which uses the new web media, belongs to the digital world and intersects the physical world in its interaction with the physical entities (e.g. printed media).

An AR process in a print medium makes use of visual recognition as a method to determine the state of the physical world and takes place in three consecutive steps (adapted from Perey, 2011a):

1. The creation of the digital content to be associated with the content of the print medium.
2. The visual recognition of the printed content to trigger the digital augmentation.
3. The display of and interaction with the digital content in such a way that it is in complete 3D registration with the print medium.

The trigger for the digital augmentation in an AR process is significantly easier to be implemented in a print medium rather than in a 3D object, since the third dimension of a 3D object multiplies the object's visual features involved in the recognition process, in comparison with a simple 2D object displayed on a print medium.

Figure 3 shows a diagram depicting the workflow of making AR with print media. After the specification of the interactivity and performance of the digital augmentation, an associated digital medium the user will interact with must be created and the specific 'active' area of the surface of the print medium must be recognized and identified, based on feature extraction and communication with a database residing locally within the application or in a remote server, to trigger the display of the digital content.

The flow of processes involved by Perey (2011b):

1. The user of the AR application points at the specific 'active' area of the print medium.
2. On the other side, the AR application detects the active area of the print medium.
3. The AR application extracts the features of the print medium and sends them to a local database or a remote server for comparison and recognition, which triggers the next step.
4. The AR application receives the digital object and tracks the camera's position and orientation, in reference to the print medium in real time.
5. The AR application displays/renders the digital object in registration with the print medium.
6. The user of the AR application accepts the digital object and interacts.

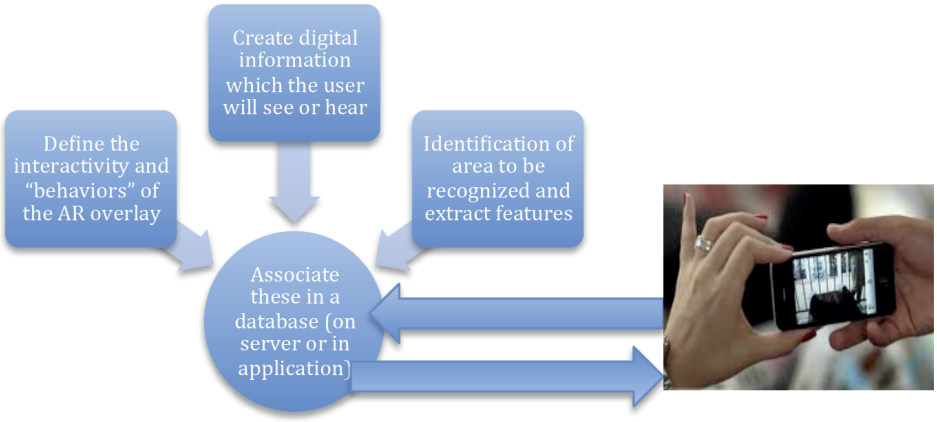


*Figure 3: Workflow diagram of making augmented reality with print media (Perey, 2011b)*

Tracking of the camera's position and orientation is not done using location-based services, since a print medium is mobile. For this reason, as noted before, computer vision techniques are utilized, either by exploiting artificial fiducial markers, e.g. QR codes, placed on the print medium (marker-based AR), or by directly recognizing and identifying its content itself (markerless AR) (Carmigniani and Furth, 2011).

Augmented reality applications for print products including posters, newspapers, magazines, commercial catalogs, business cards, books, flyers and products of packaging are growing in number, technological originality and entrepreneurial innovation. The examples are numerous and new are added every day, as the AR technology advances. However, next, selected examples of such applications are presented, in order to portray the field.

In June 2010, UK publisher Carlton Publisher released 'Dinosaurs Alive!' a book for children with AR capabilities triggered when a computer with a web camera is used (Figure 4). The book contains a CD with the necessary software by Total Immersion that needs to be installed into the computer. As the child reads the book, printed suggestions guide him/her to place the book in front of the computer's web camera. Then the printed dinosaur comes to life in 3D in the computer's screen and the child can interact with the live 3D models using the keyboard to instruct them to perform several movements. The technology works by embedding a series of markers into a page of the book. Software on the computer recognizes the markers when the page is scanned with the camera. These identifying features exploit sharp contrast and corners towards the edges of a page where folding isn't likely to obscure a reading, making the system more robust and quicker to respond than previous versions. As Russell Porter, the company's design director, notes in the New Scientist magazine (Ceurstemont, 2013) "*...once a code is captured, the software only needs to recognize about 10 per cent of those points and still works beautifully.*"

*Figure 4: 'Dinosaurs Alive!' augmented reality book*

The 44-page book 'Between Page and Screen' was created to combine the physical format of a printed book with Adobe Flash, telling a virtual love story via a webcam (Figure 5). The publisher's relevant online-catalog web page provides the following product description (Siglio, 2012): "*Coupling the physicality of the printed page with the electric liquidity of the computer screen, Between Page and Screen chronicles a love affair between the characters P and S while taking the reader into a wondrous, augmented reality. The book has no words, only inscrutable black and white geometric patterns that – when seen by a computer webcam – conjure the written word. Reflected on screen, the reader sees himself with open book in hand, language springing alive and shape-shifting with each turn of the page. The story unfolds through a playful and cryptic exchange of letters between P and S as they struggle to define their turbulent relationship. Rich with innuendo, anagrams, etymological and sonic affinities between words, Between Page and Screen takes an almost ecstatic pleasure in language and the act of reading.*"

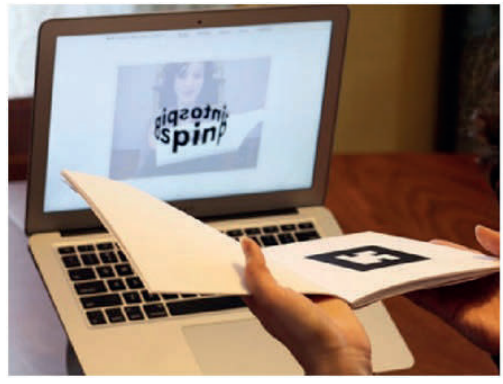

*Figure 5: 'Between Page and Screen' augmented reality book*

Ireland's Metro Herald five editions published between 19 to 30 September in 2011 were marketed as the 'World's first fully augmented AR newspaper.' The newspaper implemented the mobile AR technology of Blippar which triggers the digital augmentation using markerless computer vision in a smartphone application (Figure 6). The AR features included video content for print advertisements, crossword puzzles, polls and promotional contests (O'Connell, 2011).

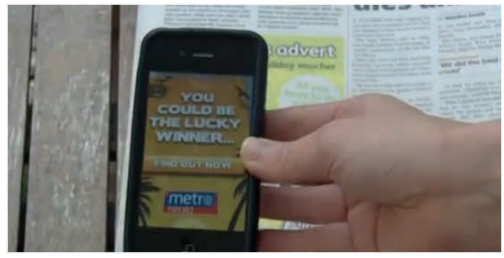


*Figure 6: The augmented reality promotional contest of 'Irish Metro Herald'*

In 2012, 'Metro' newspaper of Sweden implemented AR functionality that allowed readers to use a smartphone's camera for online interaction with the contents of the physical newspaper. The application was based on the PointCloud Browser product from Swedish company 13th Lab. 'Metro' adopted an innovative approach by enhancing print articles with social-media features and interactive polls, current weather information, integration with Facebook pages allowing likes, comments, and sharing (Figure 7), bonus music content, video stories to supplement the print news story and images and interactive art gallery (Greg, 2012).

*Figure 7: Facebook features in Swedish 'Metro'*

In December 2009 the magazine 'Esquire' created an AR-enabled special issue (Figure 8).


*Figure 8: Cover page of augmented reality issue of 'Esquire'*

The AR features which were triggered by printed markers recognized by a webcam were included on the cover and on selected pages. To interact with the AR content, readers could point the webcam at the AR-enhanced printed pages and, through the custom software application, receive the digital content. The AR features included interactions with a 3D version of the actor Robert Downey, Jr. for the film Sherlock Holmes (Curcurito, 2009). The reader could tilt the magazine toward the webcam, and the already walking, talking Downey would climb on top of it to sing a little song. If the reader pulled it toward him/herself, the actor would stand under a cloud of letters from the cover. Furthermore, if he/she turned it any which way, mini-Downey's introduction to the issue (and a trailer for Sherlock Holmes) would turn with him/her (Bell, 2009). Figure 9 shows a reader interacting with the AR features of the magazine.

*Figure 9: Interaction with augmented reality features of 'Esquire' (Curcurito, 2009)*

The magazine and newspapers described above as examples of print media with AR capabilities, represent pioneering efforts of the printed press to engage into this field of innovation, with limited editions. Since then, numerous other attempts have been undertaken with the most recent and noteworthy being the newspaper coverage of the winter Olympic Games in PyeongChang, South Korea from the New York Times and the Washington Post. The newspapers provided an AR presentation that enabled video, animation and even interactive content that practically jumped off the page. It seems that, for the printed press, AR is best used in special coverage, at least in the near future. Due to the time and cost it takes to prepare the AR content, the use cases are limited to key moments. As Todd Richmond, director at University of Southern California's Mixed Reality Lab notes "*...the technology is still more at the proof-of-concept stage than for daily usage... we're still in the infancy of the medium*" (Suciu, 2018).

In 2013, the leading retailer IKEA published a printed catalog with AR features to deal with the problem that 14 percent of its customers ended up taking home furniture which turned out to be the wrong size for its

intended location. Even with the most precise measurements, trying to imagine exactly how that stunning new sofa will look in a living room is not an easy task. Thanks to AR, customers of the Swedish home furnishings giant can now try out select products in their homes with the help of a printed catalog, a mobile app and a smartphone or tablet (Ridden, 2013).

To use the new service, customers need to download the IKEA Catalog App for iOS or Android. After launching the app, a smartphone or tablet camera is used to zone in on an orange cross to the bottom right of selected product pages. Then, an icon will appear on the device display, which gives users access to the AR mode. The app then instructs the user to close the printed version of the catalog and place it in the spot where the customer intends to put the new furniture. The approximate dimensions of the virtual furniture are based on the size of this physical, real-world IKEA catalog. The camera wakes up again and a product outline appears in the frame. This can be rotated, repositioned and manipulated so that it looks just right, before confirming the selection from a scrollable list. Finally, a virtual version of the new sofa, desk or bookcase with the room in the background is shown onscreen, as in Figure 10.

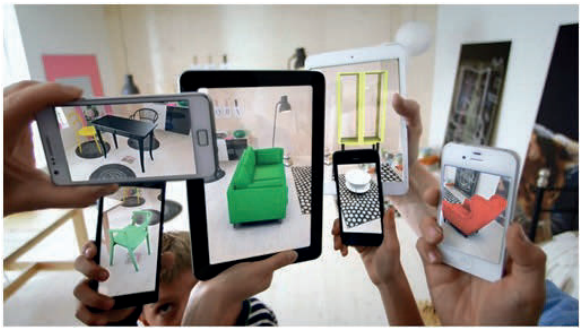

*Figure 10: Using the IKEA augmented reality catalog (Ridden, 2013)*

Seeing lifelike versions of Ikea's products in rooms lets shoppers make a 'reliable buying' decision, said Michael Valdsgaard, leader of digital transformation at Inter Ikea, the holding company for Ikea. Valdsgaard described potential uplift in sales from AR as a 'dream scenario' for Ikea, which is targeting € 5 billion ($ 5.9 billion) in online sales by 2020, up from the € 1.4 billion ($ 1.6 billion) it generated in 2016 (Joseph, 2017). This amount represents a 28 % jump in online sales which accounted for about 5 % of the total (Ringstrom, 2017).

In 2010, Metaio, a company developing AR solutions, created the 'Digital Box' for Lego, the Danish toy manufacturer, to provide consumers with a 3D image of what the toy would look like once assembled. The idea was to hold up a box of Lego to a kiosk that consisted of a webcam, a screen and Metaio's AR technology (Figure 11). Combining 3D animation with a live video feed, the assembled toy would project on screen on top of the box the consumer would hold. It would then be possible to view the finished toy on screen from all angles. According to Lego, purchase decisions in a store are mostly driven by customers' excitement about a product. With toys like Lego, it can take hours of construction to see what the finished product really looks like. The digital box, Metaio argues, gives consumers – in this case, kids – a detailed idea of the toy when it's assembled, thus sparking interest (Manninen, 2010). In terms of financial results, sales of LEGO Group in 2011 rose by 17 % to $ 3.495 billion (from $ 2.847 billion in 2010) (Trangbæk, 2012).

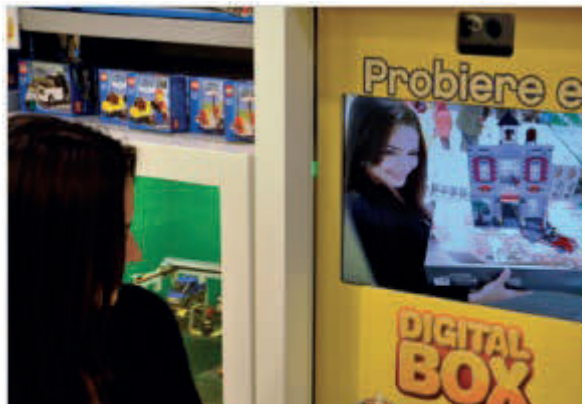


*Figure 11: LEGO's 'Digital Box' (Manninen, 2010)*

In 2011, Heinz food company ran a promotion campaign which was based on the use of AR-featured packaging. Users of a free app for Apple and Android smartphones and tablets, created by the AR technology specialist Blippar, could 'unlock' a pop-out recipe booklet when the camera was placed over the product's packaging, with the recipes featuring 'Heinz Tomato Ketchup' (Figure 12). The recipes could then be downloaded as a PDF, or the user could click through to video recipes on the product's Facebook page. The trial of the app formed part of the company's 'secret ingredient' campaign, which aimed to inspire people to use the tomato ketchup as a cooking ingredient (Macleod, 2011).

Augmented reality transformed the popular condiment into a product that managed to turn packaging into a fun user experience that got 170 thousand people engaged with the brand in a new and exciting way. The campaign boosted Heinz's digital marketing as it added another channel consumers can use to interact with the brand. The campaign came as part of Heinz' increased investment in digital marketing from 3 % to 20 %, and the Blippar campaign generated over 570 thousand blipps with 170 thousand unique global users blipping Heinz packaging around three times each (Digital Training Academy, 2014).

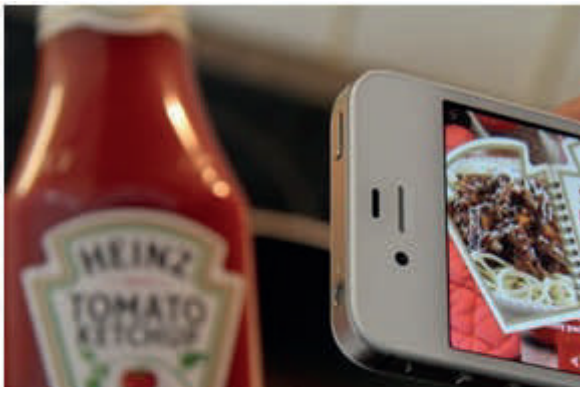


*Figure 12: 'Heinz Tomato Ketchup' augmented reality enabled recipe booklet*

## 4. Augmented reality and the future of print media in a digital world

The use of digital media in comparison to the use of paper as a means to store and convey information continues to draw the interest of the research community. Not, necessarily, in the form of a typical question 'which will prevail?' but more in terms of which performs better when used by a reader. A substantial body of literature comparing the reading of paper versus on-line documents can be found in the psychological, human factors, and ergonomics literature. Most of these studies focus on 'outcome' measures of reading, such as speed proof-reading accuracy and comprehension. Less effort has been devoted to investigating 'process' differences between reading on paper and reading on screen such as how readers look at text in terms of eye movements, how they manipulate it, and how they navigate through it (O'Hara and Sellen, 1997).

Undoubtedly, the technological breakthrough in the field of human-computer interaction underlines the major shift towards the adoption of digital equivalents instead of the traditional printed documents: the World Wide Web, hypertext and hypermedia applications, digital libraries, digital document reading devices. Some have predicted that such advances will make books obsolete, will radically alter the relationship between authors and readers and will change forever the concept of libraries as repositories of physical volumes of text and of publishers as producers and sellers of paper books (O'Hara and Sellen, 1997). The shift from print to digital is confirmed by market data. In a research conducted about the future of the European printing industry, a drop of 9.5 % for the printing market was estimated regarding the years 2005–2015. It is noted that while the issue of overcapacity and price competition impacts the sector as a whole, technology offers both a threat and an opportunity. Changes in customer behavior and a shift to the web are reducing demand for print (Vehmas, et al., 2011). However, the growth in digital printing adoption as well as steady growth in package printing markets has meant that overall revenues are now stabilising, and are expected to grow in real terms from a projected € 159.2 billion in 2016 to € 160 billion by 2021 (SmithersPira, n.d.).

The use of paper as a means to conduct administrational, scientific, commercial or any other type of processes dealing with information has been a controversial issue. At the one extreme, views about a so-called 'paperless office' have been expressed. As Arik Hesseldahl (2008) notes in his Bloomberg article 'The New Push to Get Rid of Paper' the term 'paperless office' entered the business lexicon in a BusinessWeek article titled 'The Office of the Future'. In the article, George Pake, the legendary head of the Xerox Palo Alto Research Center, foresaw that, by 1995, technology would let computer users summon on-screen documents 'by pressing a button' eliminating the need for much if not all the printed paper cluttering workspaces. Indeed, a very rough listing of the advantages offered by the digital functions of a paperless office designate the power of the arguments in favor of the digital media over the print media: easy access to documents, saving in time, saving in space, customer satisfaction, business processes made simple, more time to focus on business, increased levels of security in document access, more environmental friendly (in terms of deforestation to produce paper).

However, George Pake's vision for the paperless office was half-right. Today's offices are full of network-linked computers, loaded with software that lets users create, read, duplicate, and distribute digital documents. But the dream of a workplace where all that technology would eliminate the need for printed documents remains just that – a dream. The reality of day to day life shows that paper continues to be the preferred medium for much of our reading activity. This fact has been recognized and underlined by O'Hara and Sellen (1997) some 20 years ago, although screen technologies had vastly improved, wireless, mobile computing technology were widely available, and new navigational and input techniques significantly had improved the flexibility of interaction with digital documents at the time of their research. Despite the even more rapid breakthrough technological progress that followed up to the present days, paper still is dominant in our reading activities.

What paper does better than digital media is studied by Sellen and Harper (2002), in their book The Myth of the Paperless Office, where they point out four reading-related key affordances of paper. First, paper allows for quick and flexible navigation through a document with the size of a document being a rough indicator for the

amount of information stored in it and the readers always knowing where they are while flicking through the pages. A second affordance of paper for reading is the possibility of marking up a document while reading. Free-form annotations help readers to mark important text passages for easier re-reading and to structure their thoughts. Further, Sellen and Harper mention, that even though the information on paper is fixed, the paper documents still remain mobile. It is possible to read across more than one document at the same time by placing multiple documents next to each other and thereby defining a spatial order on a work space. Finally, paper supports the seamless interweaving of hybrid activities such as reading and writing. For instance, by placing a document next to a notebook we can take notes while reading the document (Signer, 2005).

Moreover, according to scientists (Sappi, 2014), print has more emotional pull for consumers than digital. A neuroscience study discovered that paper-based marketing – i.e., direct mail – leaves a 'deeper footprint' in the brain than digital – and that difference can even be pinpointed on functional MRI brain scans. The physical act of handling tangible material feels more 'real' to the brain. It produces brain responses that trigger emotional reactions, which get internalized in memory. In other words, the printed piece itself becomes part of the subliminal messaging. The brain associates the tactile quality of the piece with its perception of the brand.

However, it seems that these important advantages of paper are not always recognized. In many organizational settings, paper is seen as a problem. It is argued that there are three distinct problems with paper. The first is a symbolic problem whereby paper functions as a signifier of the past and, thus, as a symbol of the computer illiterates. The second problem is cost, especially for the storage and maintenance of large amounts of paper. Finally, the interactional problem is associated with restrictions in delivery, accessibility and modification of paper (Sellen and Harper, 2002, pp. 25–32).

The intrinsic incapacity of paper for interactivity is a consequence of its very nature. Paper is characterized by a unidirectional and linear communication circuit in which information is encoded and transmitted by a sender, who plays an active role in the communicative process, and is received by a receiver, who, on the other hand, plays a passive role. Information is transmitted as a product (newspaper, book, flyer, etc.) in a channel and then decoded by the recipient in such a way that he/she cannot respond in any way to the sender during the communication episode. In addition, the information transmitted is static, since the contents of the printed surface do not change over time, i.e. they do not have a dynamic (time) dimension (Inglobe Technologies Srl, 2011).

On the other hand, the worldwide spread of computers and networks (especially Internet) has triggered a radical change in the way information is created and used. This new technology enables a completely new way to communicate. New media, unlike traditional media, embody a bidirectional model of communication. According to this model, the sender and the recipient build, by means of interaction, a consensual domain of meaning. In such an interactive communication type, an essential characteristic of these kinds of media is that the participants play an active role which is enhanced by new 'social features'. Another important feature is their multimedia character, i.e. the possibility to integrate different types of content (text, audio, video, 3D, etc.) in one medium (Inglobe Technologies Srl, 2011).

As it was described in Sections 2 and 3, AR, as a new medium, was confirmed to have all what is required to provide print media with interactive and dynamic characteristics. First, it is rather apparent that the technological background and the widespread use of associated technological devices by large portions of the world population can already be taken for granted. As a print medium can always be at the hand of a reader to serve its purpose, such is the case with modern technological devices necessary to run AR applications and digitally augment print media. Today, smartphones and tablets equipped with all kinds of sensors, computing power and display capabilities can always be side by side to print media to perform digital augmentations and provide interactivity to paper. Up until 2012, desktop computer was the dominant online platform and the central hub for consumers' digital activities. With the proliferation of smartphones and tablets, however, mobile has become a dominant force (Pellow and McAbee, 2015). The statistics tell the story. For 2019, the number of smartphone users in the United States is estimated to reach 265.9 million (Statista, 2019), with the number of smartphone users worldwide projected to reach 2.87 billion by 2020 (Statista, 2015).

In a research conducted by hi-tech analysts of Juniper Research (2013), it is noted that the mobile AR market is set to increase dramatically from 60 million unique users in 2013, to nearly 200 million in 2018. The market will expand from the early adopting gaming segment and navigation-based utility to becoming an integral part of the consumer's ecosystem. Juniper Research (2013) forecasts AR to become a key future platform for communication and commerce, since it has a potential to engage a new generation of consumers in a unique manner, combining the personal nature of mobile devices with the Internet's wealth of accessible information. Augmented reality and virtual reality (mentioned with the umbrella term XR) is a mobile market that's gaining momentum as VR and AR markets may combine to create a $ 108 billion market by 2021 (Parrish, 2018).

Moreover, Omaid Hiwaizi (2015) in the article 'How augmented reality can drive engagement and monetization for publishers' points out some key benefits for publishers by an augmented print medium:

- Expanding advertising space – Publishers are no longer confined to a limited print space; they are using AR to supplement, enhance and bring physical content to life via smart devices. Layering digital content on top of print pages solves an age old problem for publishers and advertisers alike: it creates new ad formats for brands and additional monetization opportunities for publishers. This technology allows for magazine readers to learn more about the products that interest them and scan the content to access information, including how and where to buy a product.
- Reforming the Print Model – AR techniques are not only reviving revenue streams for advertisers – they are transforming the print publishing business model. By activating digital content on top of pages, readers can flip through their favorite magazines as they always have, but with the added bonus of being empowered to immediately buy their favorite items from their smart devices. Augmented reality technology allows them to use a mobile device to scan the image and make the purchase seamlessly.
- Measuring Reader Behavior – While tracking user behavior and Return on Investment (ROI) for ads has previously been an elusive science, AR technology makes analyzing user behavior a simple process. By evaluating data received from these platforms, advertisers can better tailor their future campaigns, targeting demographics and user habits.

In the context of marketing, the ultimate goal of AR marketing is to achieve 'consumer engagement', a term used to describe the process of involving consumers in specific interactions and/or interactive experiences in order to build and enhance consumer relationships. Augmented reality, by entangling branded content within consumers' social and physical environments, offers marketers a dynamic way to interact with consumers and to insert branded content into consumers' conversations (Scholz and Smith, 2016).

The power of AR in advertising has been tested in a research experiment reported in The Drum magazine (Staff Writer, 2011). The experiment conducted by marketing communications consultancy Hidden Creative Ltd. to find the effectiveness of AR versus traditional sales confirms the potential for revenue of AR. One hundred parents were shown a marketing communication and a display advert for a child's toy, while another 100 parents were shown the child's toy as an interactive AR experience. Each person was then asked if they would consider buying this toy for a child and how much they would consider paying for the toy. It was discovered that of those who saw the 2D printed advert, 45 % said they would consider buying the toy for a child, with estimates of the price leading to an average of £ 5.99. Of those who saw the AR experience, 74 % said they would consider buying it for a child, with the average estimated price being £ 7.99.

In a more recent study reported by Yaoyuneyong, et al. (2016), seven advertisement properties were measured – informativeness, entertainment, irritation, advertising value, time-effort, novelty, and ad effectiveness – in order to compare consumer response to three different ad formats: a traditional print ad, a quick response (QR) code print ad, and an AR print ad. Results showed that the AR print ad was preferred, yielding higher perceptions of informativeness, novelty and effectiveness, whereas the QR print ad resulted in higher irritation and the traditional print ad resulted in higher time-effort. The authors concluded that consumers prefer critical product and convenience information to be included on print ads, letting the ad serve its purpose with no need for an external device as an intermediary interface. Augmented reality or QR hypermedia can then serve as an extra feature, letting consumers gain access to added content and, ideally, ways to interact with the brand.

In accordance with the above research findings, it is obvious that, however powerful AR can be in its role as a connecting bridge between print and digital media, it should not create wrong impressions and pointless expectations. A print medium cannot gain any prospective for survival just by putting a QR code in a page or any other AR content. Bob Sacks, a veteran of the print and publishing sector in USA, speaks eloquently about this idea (Sacks, 2013): "*I support the use of AR in that it is a wonderful tool and can be a bonus for any printed product for either ads or editorial… Innovative use of AR can supplement a magazine's content, where print cannot. Of that, I am a big fan… It can actually deliver more timely information than print can…my argument is that augmented reality with its many uses is good…, but it is surely not going to be the savior of print. We will live or die upon our own sword.*"

With new AR technologies and other innovative techniques, which are beneficial from both monetization and reader/consumer engagement perspectives, print media is facing a critical turning point. Quoted from Hiwaizi (2015), "*The media that adopt new approaches, enabling readers to interact with content long after issue dates fade, are the ones that will emerge victorious in digital media's new era.*" Paper can preserve its position in the modern digital era. Not as a rival to digital

media, but as an ally. Paper cannot be totally replaced by digital media, but it can continue its evolutionary course within digital environments. Augmented reality can offer solutions so as the intrinsic capabilities of print media (i.e. the key affordances of paper mentioned by Sellen and Harper (2002), along with its emotional pull and deeper footprint in the brain, compared to digital media) be augmented and enhanced with new digital features. However, the survival and development of print media cannot be relied only on AR. It is up to print media to maintain high quality levels as pure printing products, first, and then allow AR to augment and enhance them. Augmented reality can bridge the gap between the traditional world of print media and the new digital world by harnessing the best from both in order to create a cohesive, tangible, dynamic and interactive communicational experience.

## 5. Conclusion

The world of print has experienced a shift in recent years as a result of the rapid growth of digital media. With AR, this shift can simply be a transition from traditional print to a new-age print industry. Augmented reality extends the sensory experience of a traditional printed product creating an emerging new world in the printing and publishing sector with great opportunities and potential. This article presented AR as an innovative and efficient tool of renovating and modernizing the traditional print media and re-identifying paper as an equivalent and privileged partner in the modern communication media. More specifically, after a general introduction into the research field of AR, covering the fundamental principles and the technologies it is based on, the article focused on its application in print media. It examined the new 'augmented print medium' in terms of the necessary processes and technologies to implement such systems and described distinguished applications in newspapers, magazines, commercial catalogs, books and products of packaging. Furthermore, the article underlined the role of AR in redefining the position of print media in the modern digital world. It studied the differences between print and digital media and proved that AR can upgrade print media into modern communication media seamlessly connected and integrated into the digital activities of the new era. However, it was made clear that AR cannot totally carry a print medium on its back, if the print medium itself does not comply with minimum quality standards as a pure printing product that provides the affordances a reader expects from paper.

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