Everything Augmented: On the Real in Augmented Reality

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ABSTRACT

What is augmented in Augmented Reality (AR)? In this paper, we review existing opinions and show how little consensus exists on this matter. Subsequently, we approach the question from a theoretical and technology-independent perspective. We identify spatial and content-based relationships between the virtual and the real as being decisive for AR and come to the conclusion that virtual content augments that to which it relates. Subsequently, we categorize different forms of AR based on what is augmented. We distinguish between augmented environments, augmented objects, augmented humans and augmented content and consider the possibility of augmented perception. The categories are illustrated with AR (art) works and conceptual differences between them are pointed out. Moreover, we discuss what the real contributes to AR and how it can shape (future) AR experiences. A summary of our findings and suggestions for future research and practice, such as research into multimodal and crossmodal AR, conclude the paper.

KEYWORDS

Augmented Reality; Augmentation; Real; Virtual; Media Art; Media Theory; Perception; Interaction.

1 | INTRODUCTION

What is augmented in Augmented Reality (AR)? What forms of augmentation do exist? This paper addresses these questions, discusses what it means to augment something and illustrates the variety of manifestations that AR can take.

AR can be understood as an environment in which virtual and real elements appear to coexist. This understanding has, for example, been promoted by Milgram and Kishino's (1994) much-cited virtuality continuum. The continuum ranges from purely virtual environments to entirely real environments. AR is placed within this continuum and describes an otherwise real environment that is augmented by virtual objects. Likewise, Azuma's (1997, p. 356) widespread survey of Augmented Reality summarizes AR as a field that "allows the user to see the real world, with virtual objects superimposed upon or composited with the real world."

While researches tend to agree that in AR, virtual content appears to exist in a physical environment (or the so-called 'real world'), there is surprisingly little consensus on what is actually augmented by this virtual content. In this paper, we address this question

and explore the conceptual characteristics and possibilities of AR.

The paper approaches the question of what is augmented in AR in three ways. In section 2, we present a review of existing opinions on the subject. This review reveals many different views on the matter, such as the understanding of AR as augmented perception or as an augmented environment.

In section 3, we set out to find our own answer. We do this by returning to the fundamental questions "What does it mean to augment something?" and "What forms of augmentation do exist?". By comparing non-AR scenarios to instances of AR, we conclude that *relationships* between the virtual and the real are the decisive factor for AR. In particular, AR is the result of spatial and/or content-based relationships between virtual and real elements in our physical environment. As a preliminary answer, we propose that the virtual augments that to which it relates.

Section 4 determines what this means for actual AR works and identifies the real component(s) that are at play. We categorize possible manifestations of AR based on what is augmented and distinguish between augmented environments, augmented objects, augmented humans and augmented content. Furthermore, we consider the possibility of augmented perception. The different categories are illustrated with AR (art) works. Conceptual differences between the proposed categories and in particular the varying roles the participant can play in these different AR scenarios are pointed out.

Section 5 discusses the characteristics of the *real* component in AR. We illustrate what the real contributes to AR and show how it can shape (future) AR experiences. The paper concludes with a summary of our findings and suggestions for future research (section 6).

This paper is an extended version of work published by the authors in the proceedings of the xCoAx 2014 conference (Schraffenberger and van der Heide, 2014). Whereas much existing research in the field focuses on the *creation* of AR, this paper is concerned with the perceptual and fundamental characteristics of AR – the *phenomenon* AR. It is our understanding that AR not necessarily requires advanced computational technologies and potentially engages all (human) senses. Our research is driven by our personal interest in better understanding the qualities and possible manifestations of AR. At this, we are especially interested in the intersection between AR and media art. The paper aims to provide a theoretical foundation and foster reflection, experimentation, artworks and exchange rather than final results.

2 | WHAT IS AUGMENTED IN AR?

The term itself – Augmented Reality – indicates that reality is augmented. However, Hugues, Fuchs and Nannipieri (2011, p. 2) argue that this is not the case: "If reality is by definition everything that exists, then strictly speaking reality cannot be augmented since it is already everything. So what is augmented?"

In existing AR literature, we can find different views on the matter. Many argue that it is not reality but the *perception* of reality that is augmented. For example, Normand et al. (2012, p. 1) point out: "Reality can not be increased but its perceptions can. We will however keep the term 'Augmented Reality' even if we understand it as an 'increased perception of reality'." Similarly, Ross (2005, p. 32) refers to AR as that "what should be called augmented perception of time and space." Also the widespread survey of AR by Azuma (1997) claims that AR enhances a user's perception of and interaction with the real world. Hugues et al. explicitly address the question as part of their AR taxonomy and distinguish between AR environments that augment the perception of reality and environments that aim at immersing users in an artificial environment.

Furthermore, there is the notion that in AR, our real physical *environment* is augmented. This has for example been stated by Milgram and Kishino (1994, p. 1322): "As an operational definition of Augmented Reality, we take the term to refer to any case in which an otherwise real environment is 'augmented' by means of virtual (computer graphic) objects […]". (Unfortunately, the authors are not completely consistent and also refer to the augmentation of the *display* of an otherwise real environment.)

Besides the idea of an augmented environment, we also find the notion of augmented *space*. The media

theorist Manovich (2006, p.219) introduces this more general concept and describes it as "physical space overlaid with dynamically changing information, multimedia in form and localized for each user". Manovich lists AR as one of the technologies that already create such augmented spaces.

In addition, there is the conception of an augmented *physical world*. This idea is expressed by Craig (2013, p. 16) in his book "Understanding Augmented Reality". Here, he places AR in the context of the human desire to alter and make adornments to the physical world. He lists several key aspects of Augmented Reality, among which the view that "[t]he physical world is augmented by *digital* information superimposed on a view of the physical world" (italics in original).

Looking at Wikipedia's current definition of AR ("Augmented reality"), we again find a different opinion on what is augmented in AR. As of October 7, 2014, AR is described as "a live, copy, view of a physical, real-world environment whose *elements* are augmented […]" (italics added by the authors).

Mackay (1996) approaches the topic in yet another way. The author considers the carrier of the physical equipment as augmented (e.g., the user is augmented when he/she carries a helmet and an object is augmented when sensors are embedded in it) and consequently distinguishes between an augmentation of the *user*, an augmentation of the *physical object* and an augmentation of the *environment* surrounding the user/object.

3 | AUGMENTATION

As the reviewed literature illustrates, there is little consensus on what is actually augmented in AR. One potential reason for this is the different underlying understandings of what it means to augment something. Does augmentation refer to the mere addition of virtual content to our (view of the) physical world, does it imply an improvement or enhancement (for example of the world or of our senses) or is it something else entirely? More than that, can we actually conclude that something – anything – is augmented just because Augmented Reality is called *Augmented* Reality? Maybe we are simply misled by a badly chosen term. In the following, we address this problem, define what it means to augment something and use this definition as a basis to explore what is – and potentially can be – augmented in AR.

3.1 TWO TAKES ON AUGMENTATION

One problem with the use and meaning of the term 'augmentation' is that it can refer to two different processes. Firstly, augmentation can refer to the *addition* or *integration* of virtual content (in)to physical space. In this context, augmentation refers to the *creation* of Augmented Reality, or, in other words, to the external process that turns something 'unaugmented' into something augmented. Secondly, it can refer to what the virtual does to the real. Here, *augmentation* is used in the sense that the virtual *augments* the real (and, as we will argue, vice versa). This time, augmentation is an internal process. It refers to what happens *in AR* and concerns the *phenomenon* Augmented Reality.

Both uses of the term are equally legitimate and both sides of augmentation are crucial to AR. However, if we look at existing AR research, much focus is placed on augmentation in the former sense and addressing how to *create* AR or how to *add* the virtual to the real. For example, there is plenty of research into technologies and techniques that enable or support the integration of virtual objects in our view of the real physical world, such as tracking or calibration techniques (cf. Zhou, Duh, and Billinghurst, 2008).

Notably, this former understanding of augmentation does not match our experience of AR. When experiencing AR, we ideally do not experience the *addition* or *integration* of virtual content but its result: the apparent *presence* of this virtual content in the real space, and, as we will show later, the spatial and content-based relationships between this virtual content and its real surroundings. (Of course, in many existing AR implementations we are made aware of the fact that the virtual is added to our view because of technical imperfections such as timing delays or spatial alignment problems. However, in an ideal scenario, the virtual would simply appear to be there.) In other words, we experience a hybrid virtual-real environment. If we want to understand the fundamental characteristics of AR, we also have to find out what happens in such an environment and investigate the dynamics between the virtual and the

real – we have to explore augmentation in the latter sense.

In the remainder of this section, we set out to do this. We build on the idea that augmentation is what distinguishes non-AR scenarios from instances of AR. By comparing the former to the later, we identify when the virtual augments something real and what constitutes augmentation. This will then allow us to present a general answer to the question of what is augmented in Augmented Reality.

3.1 UNAUGMENTED VERSUS AUGMENTED REALITY

AR requires virtual content that can be perceived alongside with the real environment. However, this is not sufficient for AR. Let us consider a text message, website or advertisement that is part of our view of the world (as, for example, possible with a head-mounted display). Even though virtual content is presented together with (or on top of) the real world, we would not consider this AR. Similarly, if we turn on the radio, we might hear a newsreader speaking, who is not really present in our physical environment (Schraffenberger and van der Heide, 2013a). Just like in typical AR scenarios, we perceive something that is not really there. Nonetheless, we do not call this AR. Why not?

The answer becomes clear if we slightly modify the examples. Imagine that the newsreader appears to be sitting at your table or that his voice seems to originate from right behind you. This certainly can be considered AR. What has changed? This time, there is a *spatial relationship* between the newsreader and the environment: he is part of the environment; he appears present in the space. Spatial relationships are thus decisive for AR.

Another possible AR scenario is that the newsreader says something that relates to your environment. He might, for example, comment on your breakfast, refer to the color of your shirt or otherwise relate to you, your environment or something in your surroundings. This time, the newsreader relates to the environment *content-wise.* (And as a consequence, the newsreader might again feel present to some degree). In this way, AR can be a result of *content-based relationships* as well.

The same principals apply in the case of visually overlaid information. If we replace the random text-message, website or advertisement in our view by a message that informs us about the historic background of the building in front of us, we are dealing with an AR scenario where the virtual relates to the real *content-wise*. Spatial relationships are likewise possible: advertisement figures might appear as if they were part of the real environment and walk on the real street (most probably they lead the way to their associated shops).

3.3 WHAT THE VIRTUAL AUGMENTS

Relationships between the virtual and the real distinguish AR scenarios from other cases where virtual content coexists on an *independent layer*. Possible are *spatial relationships* between the virtual and the real as well as *content-based* relationships. As discussed in depth in our previous research (Schraffenberger and van der Heide, 2013a), we believe that augmentation is the result of such relationships between the virtual and the real. [2]

On the basis of this, we can present a preliminary answer to the question of what is augmented in AR: *The virtual augments that, to which it relates.* However, this is only one half of the story. The virtual not only relates to the real, the real also relates to the virtual. The spatial and/or content-based relationships are *between* them. Rather than claiming that something is augmented in AR, it would thus be appropriate to say that there is a real component and a virtual component to AR. Their relationship constitutes the augmentation. Unfortunately, this view is conflicting with the language associated with AR. Even the term “Augmented Reality” implies that something (reality) is augmented rather than a relationship *between* two components.

Based on the preceding considerations, we propose to replace the question “What is augmented in AR?” with the questions “To what does the virtual content relate?; What is the real component in the augmentation?; What is the real in AR?”. In lack of better alternatives, we will continue using the already accepted terms and language.

4 | MANIFESTATIONS OF AR

We have proposed that the virtual augments that to which it relates. But what does the virtual relate to in actual AR scenarios? In this section, we determine the real component(s) that are at play in existing AR (art) works. We categorize possible manifestations of AR into augmented environments, augmented objects, augmented humans and augmented content. Furthermore, we consider the concept of augmented perception. Differences between the categories and the varying roles the participant can play are pointed out.

4.1 AUGMENTED ENVIRONMENTS

In an augmented environment, there is a relationship between virtual content and its real surroundings. As pointed out, this relationship can be spatial and/or content-based. A spatial relationship is common in cases where virtual visual objects are integrated in a real 3D space. When, for example, a virtual chair is added to a real desk (cf. Azuma 1997) there is a spatial relationship between the real environment and the virtual chair: the chair is part of/integrated in the real environment.

Content-based relationships between the environments and virtual content are also common. For example, the mobile app *Layar* (http://www.layar.com) shows site-specific information such as nearby restaurants, metro stops and ATMs and overlays this data onto the real world using a mobile phone's screen. Of course, this concept is not restricted to the visual domain. Apps like *Shazam* (www.shazam.com) listen to our surroundings and display information about what songs or TV shows are currently playing in the environment.

Besides visual augmentations, we can also find various examples of sound-based augmented environments: Cilia Erens' sound walks are designed for a certain walking route and mainly use unprocessed binaural recordings of everyday-sounds (Erens; cf. Schraffenberger and van der Heide, 2013a) [1]. When the participant navigates the environment and listens to the composition on headphones, the recorded sounds merge with the sounds present in the existing environment and invite the participant to make connections between the added sound and his or her surroundings.

Another example of an audio-based augmented environment is Edwin van der Heide's (2000-) *Radioscape* (van der Heide, 2000-; Schraffenberger and van der Heide, 2013a). The installation makes use of multiple radio transmitters that are distributed over a part of a city, each transmitting one layer of a meta-composition. By navigating through the city with a custom-made receiver (see Figure 1), a listener can pick up several signals at a time. The volume of the single layers depends on one's distance to the corresponding transmitters. For the participant, there is a clear relation between the content and environment. What one hears depends on one's own location, the position/placement of the transmitters and the shape of the city. Small movements of the receiver lead to repeatable changes that happen in the space around the listener. Besides experiencing the city in a new way, the participant discovers and experiences the relationships between sound and space.

It is crucial that linking virtual content to specific locations alone is not enough to result in the experience of a spatial augmentation. This can be concluded from *Wormhole Dordrecht*, another concept by Edwin van der Heide, which was realized in 2008 (van der Heide and Rekveld, 2008-2009; van der Heide, 2014). For this project, ten artists were invited to each make a sound environment consisting of multiple sound files that were linked to locations in the center of the city Dordrecht with GPS coordinates. The Wormhole environment was experienced with a custom developed iPhone application, which used GPS coordinates to start, stop, fade and mix the sound files. In *Radioscape*, the surrounding buildings

Figure 1 | A participant is experiencing Radioscape as part of the Electromagnetic Bodies exhibition in Rotterdam, 2006. Image courtesy Studio Edwin van der Heide.

work as resonators and reflectors for the transmitted radio waves, resulting in detailed changes that relate to the environment. However, in *Wormhole* the individual sounds are only linked to GPS coordinates and there is no further influence between the sounds and the spatial environments within the city. Although the resulting soundscapes depended on the participant's position in the city and although it was clear that the sound files were triggered and mixed depending on the listener's location, there was no experienced tangible relation to the physical space. This, however, does not mean that there was no augmentation. An augmentation could also take place on a content level (for instance, in the form of narratives that relate to the space) and thereby still result in an AR experience.

Augmented Environments generally offer the participant or observer to walk around, navigate and explore the environment. A change in the observer's position usually results in a change of what is/can be perceived. In the case of content-based augmentations, the presented content adapts to what is present in current environment and, for example, allows the participant to learn more about his or her current surroundings. If one moves around in spatially augmented environments, virtual objects might be seen from different perspectives or soft sounds might get louder if one walks into the direction of their origin.

4.2 AUGMENTED OBJECTS

The fact that virtual elements (appear to) exist in a real environment does not necessarily mean that the virtual content also augments this environment. There are cases where the virtual relates to, or becomes part of, a particular physical object rather than the general environment.

One example of an augmented object is the augmented zebrafish by Gómez-Maureira and Teunisse (Gómez-Maureira, Teunisse, Schraffenberger, and Verbeek, 2014). In this project, the zebrafish's skin is projected on a physical bigger-than-life zebrafish (see Figure 2). The audience can look inside the fish and reveal additional information (for instance, an X-ray visualization and a basic anatomical schematic) by stepping in front of the projector and moving their shadow over the fish's surface. This is realized with a kinect sensor and a secondary projector. The kinect detects the shadows and the secondary projector fills in the shadows with the additional content. Here the virtual content primarily relates to (and becomes part of) the fish, rather than to the general surrounding space. Both components, the virtual and the real, are designed in a way that deliberately leaves out certain characteristics. These 'missing' aspects are filled in by the other component, resulting in one hybrid virtual-real model (cf. Schraffenberger and van der Heide, 2013a).

Mixed virtual-real objects are also used in the field of Augmented Prototyping. Here, too, digital images are projected on physical models, resulting in a tangible prototype to which, for example, different material and lighting conditions can be applied (Verlinden, De Smit, Peeters, and van Gelderen, 2003; cf. Schraffenberger and van der Heide, 2013a).

As the augmented objects in turn are part of their environment, the virtual also – to some degree – relates to this environment. Due to this, a clear distinction between augmented objects and augmented environments is not always possible. This shows for example in Pablo Valbuena's site-specific intervention *N 520437 E 041900 [the hague city hall]* (Valbuena, 2008). In this work, the The Hague city hall serves as a canvas for projections that appear to

Figure 2 | The augmented zebrafish (length approximately 1,75 m). The fish's skin is projected on a physical model. The shadows of the viewers reveal the inside of the fish (X-ray view). Image courtesy of Marcello Gómez Maureira and Carolien Teunisse.

dynamically transform the architecture of the building. However, as this building is an integral part of its surrounding space, the immediate environment is also affected by the intervention.

The distinction between augmented environments and augmented objects becomes clearer when we consider the 'user' or the participant/audience. Whereas viewers are part of the environment, they are usually not part of an augmented object. Where environments usually invite the audience to *navigate* them, augmented objects often facilitate *interaction* with the objects.

4.3 AUGMENTED HUMANS

In the same way that the virtual can relate to real objects, it can also relate to humans (who essentially can be seen as a special kind of object). For example, the art installation *Cloud Mirror* merges the online identities of visitor's with their physical selves (Gradman, 2010). It accesses Internet web services to identify visitors by name and find photographs of and facts (dirt) about them. When visitors approach the digital mirror, the found data is superimposed in an on-screen comic book-like thought bubble that follows the visitor's motion. The virtual content relates to the human both spatially and content-wise.

While visitors in *Cloud Mirror* have no influence on what data is displayed, we can also imagine scenarios where AR allows us to modify our own appearance. An early example of this is the AR-tattoo (Archer, 2010) that displays an animated 3D tattoo above a marker, which is physically tattooed onto someone's arm.

A more serious example is the Skinput interface (Harrison, Tan, and Morris, 2010). This technology allows the skin to be used as an input surface. In a proof-of-concept, a numeric keypad was projected onto a user's palm and allowed the user to tap on the palm to dial a phone number (see Figure 3).

From a technological perspective, augmented humans do not differ much from augmented objects. However, this category differs from the perspective of the participant. There are two potential roles the participant can fulfill. As usually, he or she can be an observer of the augmentation. However, additionally, the participant can also be the 'object' who is augmented. Given this fundamentally different role of the participant, it makes sense to treat this as a separate conceptual category.

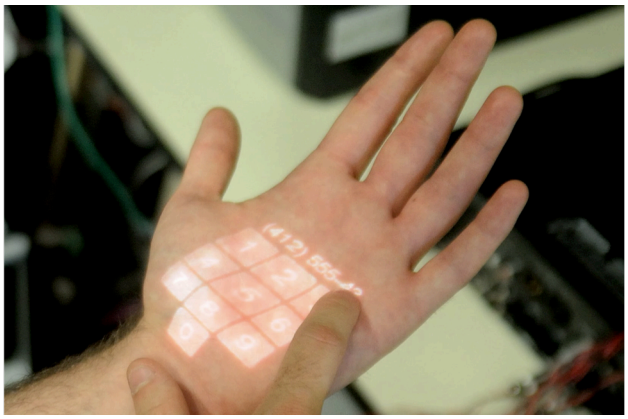

Figure 3 | A virtual keypad is projected onto a user's palm and allows the user to dial a phone number. Image courtesy of Chris Harrison.

4.4 AUGMENTED CONTENT

In AR, texts and images are often displayed to inform us about our real surroundings. However, images, texts and other forms of information or content can also get augmented. In other words, information and content can also act as the real component in the virtual-real relationship. For example, the software *Layar* allows publishers of print media to add digital content such as links, videos, 3D illustrations or polls to the analogue information found in magazines or text-books.

One early example of augmented content is the MagicBook project by Billinghurst, Kato and Poupyrev (2001). Here, virtual sceneries pop up when the pages of the children book are viewed through a handheld display. The virtual sceneries appear spatially attached to the pages and become part of the book (and hence, augment the book). However, besides this spatial relationship, the images also relate to the content of the book; to the text and images that are featured in the book and to the story told through the text and images.

Another approach of adding virtual content to the pages of a book is found in Scherrer, Pilet, Fua and Lepetit's (2008) *Haunted Book*. Their so-called "Augmented Reality Book" consists of a physical book that features full size printed images. When the pages of the book are viewed on the computer screen by pointing a webcam on them, animated illustrations are displayed on the pages: virtual flying fish jump out of a

cupboard, virtual insects run over a sofa, a virtual bird takes its place on a candlestick (see Figure 4). The concept of the *Haunted Book* differs from that of the *MagicBook* in the sense that the virtual images are integrated in the space that is shown on the images. For example, the tail of the virtual bird is occluded by the printed candlestick, while the bird's body in turn occludes those parts of the images that contain the space behind the bird (see Figure 4). This way, the bird appears integrated in the environment that is depicted in the image – until it flies out of the page, into the space surrounding the book only shortly later.

If we take a closer look at what the virtual augments or relates to in the *Haunted Book*, it becomes apparent that the animations relate to some of the same elements that have already been discussed in previous sections. Spatially, the virtual animations appear to become part of the book (its pages). Hence we can speak of an augmented object. Furthermore, they also become part of the real environment (when they fly out of the pages). Finally they are also part of another sort of environment, the environment depicted in the images. We are hence dealing with an augmented *mediated* environment as well. (Strictly speaking, the real environment is mediated by the laptop screen as well.) On the content level, the animations relate to the images, or better, to what can be seen on those images: the environments and objects such as the sofa or the candlestick and we can hence identify augmented *mediated* objects. However, that is not all of it. The virtual illustrations also relate to the less tangible – the story that is told through the images and things that are going on in our imagination.

The discussed examples illustrate that AR is not restricted to the physical content of our real space but that the virtual can also relate to our thoughts, knowledge, concepts, ideas or stories. It can relate to what is happening in our imagination or to what we could call the 'cognitive space'. Furthermore, it becomes clear that the virtual can also augment mediated content, such as a mediated environment or a mediated object. Last but not least, the projects illustrate that the real in Augmented Reality does not even have to be 'real' after all. In fact, we can augment a fictional ghost that is displayed on the pages of a book just as well as a real, physical object.

The concept of augmented content also includes the use of other modalities. For example, virtual musical improvisers can improvise with real musicians (e.g., Walker, 1997). In such a case, the behavior of the virtual improviser relates to the present musical content. Although systems like this are certainly no new development, they are usually not considered in the context of AR.

4.5 AUGMENTED PERCEPTION?

It has been argued that AR is in fact an augmentation of our perception (e.g., Normand et al., 2012; Ross, 2005). In our understanding of AR, this is not the case because the virtual does not relate to our perception but to something that is perceived. Nonetheless, we can find examples where AR is used to extend our perception as well as examples of sensory extensions that show interesting similarities with AR. In the following we will explore the possibility of "Augmented Perception" and show how it relates to the field of Augmented Reality.

Figure 4 | The virtual bird appears to be part of the space depicted in the image. A scull flies out of the page and enters the space surrounding the book. Images: Scherrer et al. 2008.

Perceiving more

There are many things that we cannot perceive as humans due to the way our senses work. To name just a few examples, we cannot hear ultrasound, we cannot see in the dark and we are insensitive to magnetism. However, there are devices that help us to overcome some of those sensory limitations and that allow us to perceive things about the environment we normally cannot perceive.

A well-known example of such a device is a hand-held Geiger counter. The device produces audible clicks that correspond to the amount of radiation that is present at the current location (cf. Schraffenberger and van der Heide, 2013a).

We will use the term *Augmented Perception* when we refer to the perception of additional information that becomes part of how we perceive the space. An emerging field of research in this context is sensory augmentation. Sensory augmentation systems translate information that we normally cannot perceive into stimuli we can perceive and thereby allow humans to perceive more and 'new' aspects of the environment.

An example of a sensory augmentation device is the vibrotactile magnetic compass belt (Nagel, Carl, Kringe, Märtin, and König, 2005). The belt is worn on the waist and indicates the direction of magnetic north with vibrations. Unfortunately, research regarding the effects of wearing the belt did not yet yield conclusive results. None of the participants in Nagel et al.'s study experienced a local magnetic field. However, two participants, after wearing the belt for a longer period of time, reportedly experienced the input from the belt as a property of the environment rather than as mere tactile stimulation. Despite the fact that this study requires follow-up research, it addresses many interesting questions, such as whether new senses can be developed and learned. With respect to AR, it is particularly interesting to distinguish between information that simply informs participants about the environment and information that is perceived as part of or as a property of the environment. [3]

Augmented Perception has some important similarities to AR. Whether it is a Geiger counter, night vision goggles or sensory augmentation systems: the additional information provided by such devices (e.g., information on the amount of radiation) relates to and informs us about the environment/space in a similar way as virtual content can inform us about the surrounding space in AR.

Augmented Perception and AR also relate to one another in the sense that AR concepts and technology can be used to translate what is hidden from our senses into something we can perceive. In other words, AR can be used as a method for Augmented Perception. For example, in the context of visual AR, there is research into applications that make it possible to see hidden or occluded objects (e.g., Sandor, Cunningham, Dey, and Mattila, 2010). However, certainly not all AR applications aim at making the imperceptible perceivable.

Essentially, both Augmented Reality and Augmented Perception allow us to perceive more. A key difference between them is that Augmented Perception aims at making something perceivable that is already there – a real but imperceptible information inherent in the environment is translated into something we can perceive. In contrast, AR applications add new additional content to the environment. Simply put, Augmented Perception allows us to perceive more. In AR, there is more to perceive.

5 | THE REAL IN AR

In the course of this paper, we have gained fundamental insights about AR, about what it means to augment something and about the real component in AR. In our understanding of AR, the virtual and the real augment, relate to, add to or complement one another. In the following, we have a closer look at what the real contributes to AR and how it can shape AR experiences.

5.1 MULTIMODAL AR

If we look at common AR scenarios such as augmented environments or augmented objects, it stands out that the real often has a visual appearance. However, at the same time, the real usually is more than just 'something visual'. For example, in a simple AR scenario, a virtual bird might appear to sit on a real tree in a real garden. This garden is something we can see. However, the garden is not merely a visual thing. It can be touched, it has a smell and if we listen to our

surroundings, we might hear real birds singing. Even if the virtual bird is visually integrated in our *view* of the garden, it nonetheless relates to and becomes part of the garden as such – it is not just experienced as part of what we *see*. This means that although AR is often focused on vision, it is – just like reality – first and foremost a *multimodal* phenomenon. [4]

The fact that multimodality in AR is the norm rather than the exception is especially interesting in the light of existing research into multimodal AR. Here, the idea of multimodality is mainly used with respect to multimodal user-interaction. This means that a user or participant can interact with the AR scenario in a multimodal way; either by giving multimodal input such as gestures and speech, or by receiving multimodal output from an AR system such as a combination of visuals, tactile feedback and sound.

These forms of multimodal AR are certainly interesting. However, if we restrict multimodal AR to those scenarios where the virtual addresses more than one sense, and cases where participants can interact with virtual content in a multimodal way, we seem to overlook the most fundamental way in which AR can be and often *is* multimodal – the fact that the real component in AR often stimulates more than one sensory modality. Future AR can acknowledge this and actively work with the fact that our environment engages all our senses. This can be done by relating the virtual content not just to what is seen but also to the other aspects of the environment. In our example of the virtual bird, this might mean that the bird responds to the songs of real birds, that its feathers move corresponding to real wind or that you might scare it away by making a sound. Multimodal AR is thus not just about user-interaction and it is not just about multimodal virtual content. It is likewise about sensing the real multimodal world, about listening to it, registering the temperature, the wind or even the smells present in the space and relating the virtual to these aspects.

5.2 INTERACTION

The fact that we can interact with, or at least, have an influence on our real environment, also offers many possibilities for interaction in AR. One might argue that moving about real objects in an AR scenario or changing the physical aspects of the AR environment already are a basic form of interaction in AR. However, more interestingly, the fact that we can interact with or influence the real does not only allow for interaction with these real objects but likewise enables interaction with virtual objects. If the virtual and the real are interrelated, one can also interact with the virtual content, simply through interacting with the real content (Schraffenberger and van der Heide, 2013a, 2013b). A basic example of this is a virtual marble on a real table that can be moved around by lifting one side of the table (causing the marble to roll to the lower side and fall off to the ground). Of course, again, there are even more possibilities if we incorporate more modalities and relate the virtual and the real not just in a visual manner. Imagine, for example, virtual creatures that are attracted by light, that change color according to the color of the objects behind them, that move faster if it is warm and that fear certain sounds. In such a case, simply interacting with our environment in a natural way will offer us a variety of possibilities to interact with the virtual content as well.

6 | CONCLUSION AND FUTURE DIRECTIONS

Little consensus exists on what is augmented in AR. In this paper, we have found that there is not just one right answer to this question. In fact, everything can be augmented. The possibilities range from augmented environments, objects, humans and (media) content to intangible, non-physical entities such as augmented stories, concepts or ideas. In the most general sense, the virtual augments that to which it relates. More importantly, the virtual and the real relate to, add to and augment one another.

Regarding the fundamental characteristics of AR, we have identified spatial and content-based relationships between the virtual and the real as being decisive for AR. So far, AR research and practice have put much emphasize on spatial relationships. In the future, we can further study the possibilities of content-based relationships and, for example, investigate how the virtual can relate to thoughts, moods and feelings.

We have explored the realm of existing AR works, categorized common forms of AR and illustrated them with AR (art) works. We do not claim that we have presented all possibilities of AR. Are there other – non-spatial and non-content-based – forms of

augmentation? What about augmented events, processes and activities?

Furthermore, we have defined Augmented Perception and discussed similarities and differences between Augmented Reality and Augmented Perception. It has become clear that AR and Augmented Perception are related fields that can contribute to each other.

In the course of our investigation, we have gained many insights regarding 'the real' in Augmented Reality. Strikingly, the real in AR does not have to be real after all – for example, we can augment a fictional ghost that is depicted in a book.

It furthermore became clear that the real provides many possibilities for interaction in AR. If there is a relationship between the virtual and the real, participants can interact with the virtual components through interacting with real objects and by influencing the real environment.

Several discussed projects have shown that it can be fruitful to not just take the real for what it is but to also design, create or modify the real component in AR (for example, in a way that leaves out certain aspects to be filled in by the virtual content).

With respect to the nature of AR, it became apparent that AR is about more than meets the eye. Even in cases where *visual* virtual content is integrated in our *view* of the world, AR is most commonly multimodal. This is because the real component in AR is usually multimodal. The multimodal character of our physical world offers manifold possibilities for future AR works. For example, virtual content can change its appearance or behavior according to non-visual aspects of the environment, such as temperature, wind or sounds present in the environment. In this context, it would be interesting to pursue research into crossmodal AR: When is information of one sensory channel experienced in relation to information of another sensory channel? When do we perceive sounds as related to what we see, when do we perceive smells in relation to what we hear? These questions call for an interdisciplinary research approach that incorporates insights from philosophy, perception and AR.

In the course of our investigation we have encountered the claim that reality cannot be augmented, since reality already is everything (Hughes et al. 2011). However, this claim is only true if we believe that AR is about the *addition* of some *external* content. In our understanding, AR is about the relationships between the virtual and the real. It is not necessary that the virtual is something apart from reality. In fact the opposite is the case: reality is augmented if the virtual becomes part of it, intertwines with it and relates to it. The fact that the virtual is part of reality hence does not make it impossible to augment reality; rather it suggests that our reality is, in fact, already augmented.

Although we have presented many interesting results, the main contribution of this research is the fact that it brings important topics to the attention of AR research and practice. We are convinced that the AR community will benefit from a theoretical discussion and would like to invite other researches and practitioners to join in on the dialogue about the fundamental characteristics of AR.

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ENDNOTES

[1] See, for instance, Hollands Doorzicht (Erens, 2006). This sound walk is made of sounds that were recorded in the Netherlands and took place close to the Dutch embassy in Berlin, 2006.

[2] Other relationships between the virtual and real, such as interaction between virtual and real objects, are possible (Schraffenberger and van der Heide, 2013a). However, to the best of our knowledge, they are all based on underlying spatial or content-based relationships.

[3] It would also be interesting to find out whether the clicks from a Geiger counter solely inform a user of the present radiation or whether the radiation is to some degree also experienced as in the environment and as distinct from the audible clicks.

[4] This does not mean that all AR has to be multimodal. However, in the case of augmented environments and objects, this is usually the case.

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