Don't Extend! Reduce! The Sound Approach to Reality

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Don't Extend! Reduce! The Sound Approach to Reality

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ABSTRACT

In this paper we propose a *reduced reality* concept of *less-is-more* that VR designers can use to create technological frameworks that reduce sensory overload and allow for better concentration and focus, less stress, and novel scenarios. We question the approach taken by scholars in the field of XR research, where the focus is typically to design and use technology that *adds* sensory information to the user's perceptual field and we address some of the confusion related to the typical uses of the term *reality*. To address the latter terminological muddle, we define reality as our conscious experience of the environment as emergent perception and we use this definition as the basis for a discussion of the role of sound in balancing sensory information and in the construction of a less cluttered and less stressful perceptual environments.

CCS CONCEPTS

• ***Human-centered computing*→HCI theory, concepts and models**

KEYWORDS

Reduced reality, diminished reality, extended reality, augmented reality, listening, sound, presence, environment, cognition, crossmodality

1 Introduction

. . . human kind
Cannot bear very much reality . . .
T.S. Eliot [1]

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The act of sticking your fingers in your ears to prevent sound waves from arriving at your ears, is probably the simplest and oldest form of sound stimuli reduction, while the earplug is probably the oldest technology that allowed humans to achieve this without using their fingers. The first known mention of such an earplug-like technology is from Homer's Odyssey composed 8th century BC:

> First you will come to the Sirens who enchant all who come near them. If any one unwarily draws in too close and hears the singing of the Sirens, his wife and children will never welcome him home again, for they sit in a green field and warble him to death with the sweetness of their song … Therefore pass these Sirens by, and stop your men's ears with wax that none of them may hear [2]

Interestingly, this story links the use of the earplugs – a technology that controls mind-external sound stimuli – with the ability to maintain cognitive control. The seamen on the ship did not use earplugs to prevent physical damage to their ears due to great sound pressure or to reduce annoying noise. The earplugs were used as a shield against the cognitive distraction the particular sound of the Sirens may cause to them, leading to negative impact on their cognitive control (executive functions). Thus, the story highlights the need to reduce the world's sensory potential in order to avoid its dangers.

Extended reality [XR] (the umbrella term representative of Mixed Reality [MR] and Augmented Reality [AR] techniques within the broader field of Virtual Reality [VR]) is often used to add virtual objects to the user's surroundings or to create hyper-realistic situations. These technologies may allow users to immerse themselves in *realities* removed in time and space from their actual location, or to experience how virtual objects visually (and it is almost always *visually*) interact with actual objects in their surroundings.

Our contribution to the conference theme is an essay proposing the antithetical position – opposing the motivations and need for XR. The essay is provoked by two questions with regard to the topic of XR: which reality is under discussion and why would it need to be extended? Each of these two questions covers a host of others – what is reality? can it indeed be extended? and so on – and these we answer along the way as we argue the case not for *extended* but rather *reduced* reality [RR]. The increasing complexity of sensory stimuli in our daily life calls for new ways to cope with potentially stressful situations, for instance in nursing (see [3; 4; 5] for example), and one way is to reduce sensory and thus cognitive clutter. Could VR design and technologies be used beneficially to *subtract* something from experience rather than *add* something to it?

We argue that a focus on addition – the purpose of most XR – will not lead to better engagement, let alone presence, in virtual worlds when used with present day approaches. Instead, an approach that focusses on what is important to the perceiver can reduce clutter and allow the required perceptions to emerge. This is one of the reasons we propose an RR concept that focuses on filtering things out and balanced equalization (to use a term from the art of sound engineering). This has the secondary benefit, we believe, of reducing the need to excessively direct the power of CPUs, GPUs, and sound chips towards providing a sensory, so-called *realistic* virtual world such that that processing power could be used for other purposes.

We aim to show that VR designers would benefit from a *less-is-more* approach and we discuss different ways to *equalize* our daily environment using VR technologies to make them more manageable. An intelligent reduction of our sensory and thus perceptual field will improve the differential processing of external stimuli (selective attention) and will allow for better concentration, focus, and ability to achieve flow and presence. This is relevant, for instance, for people working in stressful surroundings or for people unable to filter sensory information (see [6] for a study of the inability to select specific sensory inputs for enhanced processing in people with autism spectrum disorders), but it is also relevant to the design of virtual worlds such as computer games.

Our approach involves an understanding of the nature of reality, listening, and crossmodality, and the role of sound in the creation of a reduced reality. We begin with a brief discussion of reality and related terminology as a means to make a case for a future paradigm shift in VR design. This discussion includes an argument for the need to reduce reality in artificial worlds such as those found in VR and suggestions for how to utilize the auditory domain to accomplish this reduction.

2 What is Reality?

While we do not argue for a definitive answer to the question *what is reality?* – this has been argued over for millennia and no doubt will be argued over for millennia to come – we are prepared to state that there is no one reality but rather multiple realities that are conceptions of a subset of an external world or externality which is ungraspable in its full extent. In other words, although there is a common substrate to our realities, each individual has their own conception of reality due not only to their unique spatio-temporality in relation to that externality but also to their unique cognitive alchemy formed through their own experiences.

In this essay, reality is related to the perceiving self's *beliefs* and *directedness* about the world, and these are connected to the process of forming a perceptual environment. Reality is what we seek to comprehend when we choose to – or are made to – become aware of the world. The perceiving subject is already bodily embedded in the world in the process of constituting reality. Reality, however, is something different from the world. The world is connected to reality only through the environment that functions as a perceptual model of the world – a model that maps onto reality in a metaphorical sense. When the environment is remodelled, reality changes, the world does not.

We expand this further below but first must deal with the confusion in the field of XR research and development over the concept of reality.

2.1 Reality According to XR

Our brief definition of reality above might seem a matter of philosophical semantics that places us somewhere on the spectrum of constructivist phenomenology were it not for the fact that it is vitally important to get definitions right in the field of XR in order to ensure its foundations are built on rock rather than shifting sand. That the field of XR *is* built on shifting sand will become clear as we discuss the multiple meanings of the term *reality* in XR and the broader VR field.

In most studies of *extended reality,* the concept *reality* equals *the empirical world (virtual* or *actual).* As we have noted before [7], our conception of the environment is that it is an emergent perception resulting from a hypothetical modelling of a subset of the world. We acknowledge that this externality is what is normally referred to as *reality* in the XR field. This belief is apparent in the terminology itself – extended reality, augmented reality, virtual reality– and the uses to which XR technologies are put (the claims that they emulate and enhance reality). Yet there remains ambiguity and inconsistency.

Take the term *virtual reality*. Leaving aside arguments as to whether the correct understanding of 'virtual' has *ever* been used in VR (see [8] for further discussion), we assume the term refers to an emulation of something outside virtuality that, today, uses digital techniques (what might be called *digitality*). What precisely is being emulated is something that is external to the digital world of the emulation (assuming the ideal is achieved or achievable otherwise the digital world is merely a simulation). As most VR systems (for the purposes of this essay, this encompasses XR systems) provide the same pool of stimuli to all users, then it must be assumed that VR designers have the conception of a reality that is uniform and singular and that this comprises externality.

There are several issues here. First, putting to one side the solipsistic philosophers who deny any externality, one of the main philosophical threads from Plato to Kant through to the phenomenologists of the 19th and 20th centuries, is that it is not possible to perceptually fully grasp the external world. Our sensory modalities, those boundaries between our selves and externality, filter out much of what could be sensed and is sensed by other creatures even before our cognition gets to fashion the remaining sensory paucity into something perceptual. How then can we seek to simulate reality, let alone emulate it, where that reality is equated with an ungraspable externality?

Second, if reality according to XR is the sum of externality to our selves, then, obeying the law of conservation of energy, it certainly cannot be changed in any way. If the world is the totality of existent things (perceivable or not) – there can be no reduction or augmentation of it. The world is always already everything there is.

Third, and here lies the ambiguity in the VR field, *mixed reality* presupposes two or more realities combined to produce another. Yet, in VR, there is only the *one* externality/reality and that is the one apparently being modelled in VR or added to in XR.

Fourth, there is a thread in VR presence research stating that presence in such worlds is enhanced by increasingly immersive technologies [cf. 9]. Thus, the better the fidelity of sensory stimuli delivered by the VR technologies to similar stimuli in externality, the better the chances of presence being achieved in the VR world. However, as we cannot grasp all of externality and so cannot emulate it with digital tools, it will never be possible to be present in such worlds. Surely this is a dead-end route to presence and so, if we are indeed present in VR related worlds, immersive fidelity must refer to something else.

2.2 Clarifying the Terminology

In an attempt to sort out this conceptual muddle, we build on our previous work on definitions [7]. We have stated that there is an external world, an externality, that is available to sense (it has sensory potential). Humans, as a species, have sensory horizons that differ to other creatures and thus our sensory apparatus filters out much of what is available to be sensed by other organisms (see [10; 11], for instance). An individual has a certain sensory horizon by dint of corporeal spatio-temporal positioning in that externality and their particular sensory aptitudes and this sensory horizon encloses sensory potential (what could be sensed in a sensory modality were we aware of it). We focus on and/or are made to be attentive to a subset of sensory stimuli and so have a lesser, highly dynamic salient horizon encompassing a salient world (a horizon is sensorially multimodal and thus is spatio-temporal in nature – our hearing, for example, allows us to sense the past in order to create the present). It is from within the salient world that we sense and attempt to model what we sense. These models are perceptual hypotheses [cf. 12] which we call environments. The environment is thus an emergent perception, fashioned from sensation and cognition (knowledge and reasoning), that is a fair working approximation of that part of externality that is within our salient horizon. It is within the *experience* of the environment that we are present because the formation of the environment is the process of distinguishing externality from self and the sense of presence in a world must have somewhere for our self to be present in.

The world itself is ungraspable and we only perceive what is inside our saliency horizon. This forms the basis for our definition of environment, a perceptual construct which arises from a confluence of sensation and cognition and which functions as a metonym for the world. Thus, we will never experience the *world* itself and, accordingly, – if the world does indeed equal reality – we will never have a direct experience of such reality where this would be defined as a direct experience of the world.

Taking this further, we can now define *reality* as our conscious experience of the environment as emergent perception. From this experience and past experiences of previous environments (salient memories of which are stored in our cognition), we have a conception of externality that we might term the 'world.' Such a definition of reality – the experience of a perceptual environment – accounts for our different conceptions of the world because each of our environments has a strong element of our different cognitions and our different sensory capabilities. We each have different pasts the experiences of which affect the creation of our environments as do the facts that we have different auditory and visual sensory capabilities (to name just two senses). Such a definition also accounts for our common conception of the world because each of our environments is formed in part from similar sensory capabilities (most of us as adults have a hearing range somewhere between 20Hz and 15kHz) and a heritage common to our species (we learn what animals are, what is good to eat, what writing is, how a single concept can encapsulate complex philosophies, we might have a theory of mind, and so forth). See figure 1 for a schematic of our conception.

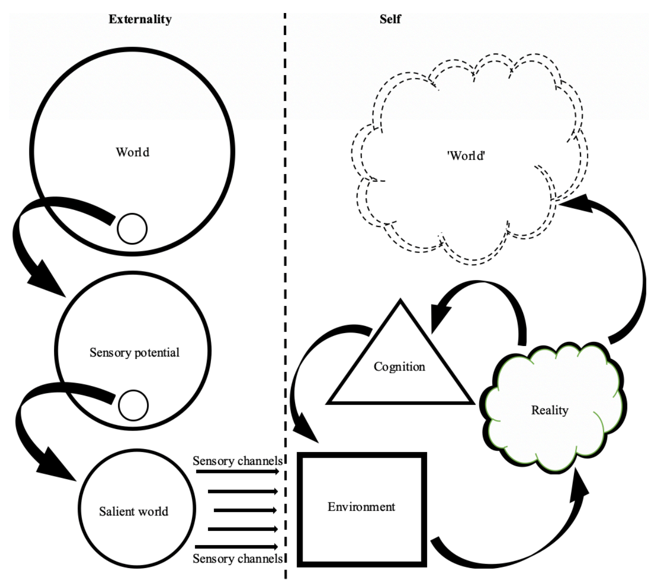

Figure 1. The world as we know it

Accordingly, if the term extended reality, and its counterpoint reduced reality, are to have any meaning in the field of VR, the design of virtual realities – reduced or extended – must be something different from merely designing sensory worlds. In actuality, VR technologies (part of the external world) are used to create the potential (viz. *virtuality*) from which to model perceptual environments, the experience of which forms our reality.

Even if we take reality to be a perceptual experience – rather than a mind-external world of sensory things – one may claim that the merging of the virtual with the actual is essentially a reduction of reality as much as it is an augmentation of it. Changes in the design of worlds (actual or virtual) lead to a change in our awareness of that world – that is, simultaneously a reduced awareness of something and an augmented or enhanced awareness of something else.

3 Why Reduce Reality?

In this section we will discuss some of the pitfalls of XR technologies and argue how our concept of RR is better suited to address some of the key challenges associated with attention, presence, and stress in the world.

Scholars have found much promise in the idea of XR technologies: the ability to form a representation of how a place or person might look like in the future; the ability to feed the user with navigational information without shifting attention from the field of agency; and much more. In 2011, Hugues et al. [13] devised an augmented reality taxonomy based on the functionalities of augmented realities. The taxonomy was grounded in the belief that a better grasp of reality is achieved through the path of more information:

> Although any increase in the quantity of information ‐ and consequently, any increase in our understanding of reality ‐ admitted by AR aims for greater mastery of what is real, it is clear that, from a technological point of view, AR can offer interfaces which propose either, more explicitly, information, or, more explicitly [sic], a better mastery of our actions with regard to real events. [13]

The question remains if the ambition behind AR technologies – greater mastery over what is real – is achievable with AR technologies? Or even, if mastery over reality is an achievable goal given the multiple conceptions of what reality is?

So far, most approaches to XR design focus on adding more sensory information: Mihejl et al. [14] argue that "the purpose of augmented reality is to *improve* user perception and *increase* his/her effectiveness through *additional* information" (our italics). Bae et al. [15] argue that the purpose "is to provide *additional* information and meaning about observing the real object or a place" (our italics), and Corvino et al. [16] state that "The goal of Augmented Reality systems is to *add* information and multimedia elements to the natural space and to '*increase*' the natural space through digital contents" (our italics). Thus, the main AR design principles that can be deduced from these purpose-statements include: addition of information, addition of meaning, 'increase' of natural (i.e., actual) spaces, and improvement of perception.

We believe the focus on addition is the wrong approach. Achieving greater mastery over what is real often entails (paradoxically) perceiving *less* of what is 'real' rather than *more* – in our terminology, reduce the salient world in order to achieve a more focussed reality. To avoid the temptations of new technologies to add more information, with the risk of creating cognitive clutter and overload, we propose that XR designers shift their focus to the creation of conditions for perceptual environments that enhance the ease of working and living for users or ability to focus on tasks or achieve presence in virtual worlds such as games (something different from the ease of access to as much information as possible).

The concept *diminished reality* has already flourished in several papers that describe technologies to conceal or see through objects in the visual field [see 17]. While 'diminish' and 'reduce' are often considered synonyms, we prefer the latter. Both diminish and reduce may refer to the process of making something smaller or lesser in amount, volume, or extent. To reduce, however, more often refers to the process of removing something from an object or phenomenon in order to enhance the qualities of the remaining – non-reduced – part. The analogy is found in cooking where you make gravies, syrups, and stocks by reducing a liquid to a thicker consistency resulting in a richer and more concentrated flavour. Related to this, the tradition of phenomenology that emerged with Husserl argues for a *perceptual reduction* characterized by a focus on the essential horizon of consciousness – a form of shift in attitude where the facticity of the world is bracketed [18]. Perception, thus, is not diminished but rather restored to a primordial mode where the perceived world is reduced to *presences*, and this allows for new experiences to emerge.

Reduced reality is the antithesis of extended reality. It emerges from a specific form of directedness to the world that changes appearances and alters the process whereby the perceiving self is constructing an environment. Designing the conditions for reduced realities, thus, is to facilitate a *perceptual reduction* through sensory and cognitive alterations. In what follows, we briefly argue for a paradigm shift from extending reality to reducing reality where enhanced attention is required for specific tasks, where presence in a virtual world is desired, and where stress might result from cognitive overload, before moving on to discussing specifically auditory strategies to reduce reality.

3.1 Attention

RR technologies may be used to reduce the sensory complexity of the surroundings by removing or diminishing the impact of specific sensable things in order to allow for an enhanced focus on other things (beyond what our cognitive system, already capable of the cocktail party effect, for example, is able to do). And a reduction of irrelevant sensory input could free up cognitive processing power to enhance the performance of other tasks. What is wanted and what is not wanted depends on the particular domain and the task at hand and, in some cases, is a matter of subjectivity.

Several studies [e.g., 6] have argued for the need to filter sensory information in order to improve selective attention (e.g., in patients with autism). RR technologies could serve to minimize failure both to notice relevant sources of information (by reducing perceptual clutter) and to focus attention (by reducing the impact of potentially distracting objects or events in the user's externality) (see [19] for more on selective attention in cognitive engineering). Also, RR is a useful concept in the design of sensable externalities that create the optimal conditions of the flow experience, where users invest all cognitive energy in a specific task and "forget" everything else [20].

3.2 Presence in VR

As noted above, Hugues et al. [13] argue that more information in AR leads to greater mastery over reality. A similar more-is-more paradigm is implicated in concepts of presence in virtual worlds [e.g., 9] and in computer games [e.g., 21]. In both cases, the belief is that increasing the realism (that is, fidelity to the sensory characteristics of externality) delivered by the digital technology will increase presence: as Slater states, "[o]ne way to induce presence is to increase realism" [9].

There are several issues to do with this approach to attaining presence including the limitations of technology in emulating the sensations of the world in all their potential. However, as the purpose of our sensory apparatus is to filter externality and to direct attention to certain aspects of it while creating the conditions for presence in externality [22], it becomes apparent that the more-is-more approach is the wrong approach. Rather, we would argue, focus on reducing technologically derived sensation in virtual worlds (thereby freeing up processing power for other tasks) in favour of fine-tuning our perceptual environments by designing such worlds in accord with our fundamental filtering of externality and crossmodal perception.

With regard to crossmodality (which we discuss further below) in the context of presence, it should be noted that, in these days of video-conferencing and stressed digital networks, using the auditory modality only (thereby reducing or omitting entirely the visual modality) lessens the occurrence of the cognitive dissonance and loss of presence experienced with drop-outs and image-audio synchronization issues. Reality, as the experience of environments modelled from externality, is fragile and does not readily tolerate cognitive dissonance.

3.3 Stress

Excessive noise or unwanted sound has been implicated in stress and in both negative health issues and disease arising from that stress. For example, the *WHO Environmental Noise Guidelines for the European Region* [23] highlight noise from road traffic, airplanes, railways, wind turbines, and leisure activities and their potential health consequences: "cardiovascular and metabolic effects; annoyance; effects on sleep; cognitive impairment; hearing impairment and tinnitus; adverse birth outcomes; and quality of life, mental health and well-being." As a specific example, noise, as unwanted or excessive sound, is a particular problem in hospitals (for a review, see [4]). This can lead to stressful lives for health professionals such as doctors and nurses (see, for example, [3]), mistakes in operating theatres [see 5], and negative health outcomes for patients (see, for instance, [24; 25]).

It seems quite clear that an RR paradigm that targets excessive or unwanted sound in hospitals would contribute to better outcomes for both staff and patients. Approaches so far mainly comprise the use of music in operating theatres (a form of XR which might have a masking effect but the efficacy of which studies have yet to find conclusive results for [see [5] for instance]) and treatment of the operating theatre or ward acoustics [e.g., 26]. The use of VR technologies to reduce everyday auditory realities perceived in hospitals either through masking or filtering unwanted stimuli remains to be comprehensively tested.

4 Strategies to Reduce Reality

While research articles specifically on auditory RR (or auditory diminished reality for that matter) are virtually non-existent (on noise cancellation techniques, see below), several studies have presented interfaces that alter the user's visual field and applications for mobile devices that remove undesired objects or persons from real-time video recordings [see 17; 27]. Future generations of smart glasses are likely to be able to identify specific unwanted elements and remove them from our visual surroundings. Examples of possible uses include the removal of any non-essential objects, background colours, and so forth from the driver's vision in cars [28], the removal of irrelevant body parts in anatomy teaching to increase the learning effect [29]; and real-time, real-life ad-blockers [30]. Other similar technologies aim to change the user´s perspective rather than removing objects. Sakata et al. [31], for instance, proposed an RR system that allows the user to control the visual distance to other persons, thus reducing the discomfort when other people are getting too close you (although, in these pandemic times, this form of virtual social distancing might give potentially fatal false assurance).

In the following subsections, we discuss the role of auditory and listening strategies that reduce or alter auditory stimuli and aid the user's construction of a less cluttered and potentially less stressful perceptual environment.

4.1 Current Auditory Strategies

Maintaining a personal space while still being physically present in externality by removing only distracting or uncomfortable elements from reality (derived from externality or not) is one of the big challenges for today's auditory reduction technologies. There are several examples to demonstrate what is currently possible or at least attempted of which we briefly describe just a few. While most of the strategies are thoroughly entrenched in other fields, they figure little in the VR field because of that field's more-is-more paradigm.

To start with a somewhat unpleasant example, Luke Windsor's [32] study of interviews with former war detainees shows how music in interrogation is used for sensory deprivation and perceptual distortion of the world. When detainees are exposed to loud and foreign (i.e., unfamiliar) music, cognition is interrupted and background sounds are masked. This situation, Windsor argues, not only masks causal relations in the external world but makes the search for causation pointless: "The only causation to be perceived is that of the interrogator choosing to play or stop playing the music" [32].

Altering or reducing our everyday mode of listening [see 33], where we listen for sound sources (locations and characteristics of things in the world), however, might serve a more noble purpose. Different forms of aestheticization and medialization processes [34], for example, promote listening modes that reduce or remove our awareness of certain sound sources in the external world in order to focus on other auditory elements of that world. Famously, Pierre Schaeffer [35] argued that a new listening mode – reduced listening – emerges from the removal of our everyday causal listening strategies (i.e., the 'search' for sound sources in the listener's externality) and this allows the listener to focus on the appreciation of the sonorous (timbral) qualities of sounds. Reduced listening is achieved by perceptually removing a direct reference to externality – either cognitively (by insisting on reduced listening to otherwise recognizable sounds) or by designing sounds that promote reduced listening.

The use of acoustic isolation technologies must be mentioned here not only because such usage is long-standing but also because it is so pervasive an approach to auditorily reducing our perceptual reality. Such technologies traditionally comprise building materials and construction techniques but more recently include active noise cancellation devices (more on this below) in specialist settings such as concert halls. The physical construction of public and personal space is the primary means by which humankind, over millennia, has used auditory strategies which filter sonic externality and so reduce our realities. Yet, it is costly, time-consuming, non-portable, and generally inflexible once built.

Tinnitus (that is, subjective tinnitus) and its treatment are good instances with which to exemplify the perceptual basis for our realities and strategies to reduce those realities. Tinnitus, as a result of prolonged exposure to damaging sound pressure levels or certain cases of hearing damage such as illness or physical trauma, manifests itself as anything from a high-pitched, sinewave-like sound to a low-volume, white noise-like sound. There are no sound waves present but such disturbing sounds are very much a part of the individual's reality so much so that the sounds themselves often reduce the complexity of that reality by masking. They can be disturbing enough that a variety of devices and therapies of varying efficacy are available to sufferers all of which function by reducing reality – devices use external sounds to mask or distract the patient and habituation therapies modulate any neural hyperactivity and trick the brain into treating the tinnitus as an unimportant sound [36].

Headphones with active noise cancellation are good examples of technologies that cancel out only a part of the incoming audio frequency spectrum (generally static, low-frequency noise) which might allow for better intelligibility of other sounds (presently, it is used mainly in combination with music listening). There have also been attempts to produce earphones which equalize and filter incoming sound waves (e.g., the ill-fated Hear One earbuds). Sound masking – the opposite principle of noise cancellation – functions by adding unstructured noise (white noise) to the disturbing sound signals. This diminishes the intelligibility of, for instance, speech sounds in the room, and the impact of other abrupt sounds. Thus, sound-masking systems *hide* sound sources by reducing the listener's cognitive awareness of existing abrupt sounds (specific sound sources) in the external world, while active noise cancellation reduces the amplitude of sound waves before they reach the listener's ears, thus functioning as a form of *hear-through* technology.

Yet, while active noise cancellation and sound masking reduce the impact of incoming sounds, thus preventing them from interfering with the user's mind-internal cognitive tasks (e.g., imagination) or music listening through headphones, they do little to guide the user's attention to specific events or tasks in that part of externality that is within the user's auditory sensory horizon. In the following section, we discuss potential auditory strategies that could form the basis for future audio RR technologies.

4.2 Potential Auditory Strategies

The strategies and technologies discussed above involved filtering and/or masking solely in the domain of sound. More promising, we suggest, is the use of filtering and/or masking approaches that are crossmodal or multimodal in concept and design.

Examples of technologies that aestheticize the world's sounds and promote reduced listening include the smartphone app *Hear* and the now terminated app *RjDj* (from the same company – Reality Jockey Ltd.) which generate a non-linear form of music or sound design that reacts to, and is created from, the listener's immediate externality and the listener's movement in that externality in real-time. This form of sound generation has latterly been defined as reactive music [see 37]. While the makers of *RjDj* and *Hear* call the auditory feedback of their products *augmented sound*, we argue here that the apps point towards a reduced reality paradigm since the primary effect is the *filtering* of sensory stimuli rather than *addition*. The potential of apps such as *RjDj* and *Hear* is not only to auditorily aestheticize externality, and thereby *filter out* its causal contextual features, but also, by creating the foundation for the emergence of reduced listening, to further a renewed focus on the intrinsic features of sound. This renewed focus also leads to new forms of reasoning about sound: when listening to sounds-in-themselves (i.e., perceptually detached from their physical source) listeners access new forms of crossmodal perceptions grounded in embodied sensory-motor experiences [see 38].

Such a concept of the intentional activation of action-oriented cognitive images might form the basis for a strategy for RR designers. For instance, in a number of experimental studies, Eitan et al. [39; 40] have shown how sound can be used to activate motor-areas of the brain and aid in the performance of specific gestures and specific tasks. Furthermore, theories of neuronal grouping have shown that if different sensory stimuli (processed cognitively at the same time) fit into the same overall cognitive scheme, the stimuli are not only easier to process, they also make more sense and are more easily recalled from memory. Contrarily, if two stimuli afford two inconsistent ways of perceiving these stimuli, one stimulus can sometime *inhibit* or *reduce* the experience of the other [see 41]. Here, and as noted above, such cognitive dissonance has negative consequences for a required perception and consequent cognition but, we suggest, it might be possible to use certain forms of cognitive dissonance as a strategy VR designers can use to create technologies that *balance* the user’s environment.

Spence and Wang [42] noticed a similar principle in a study of the effect of sound on the taste of food. Here they observe how specific auditory stimuli reduce the effect of specific taste stimuli – a cognitive effect called *crossmodal masking*; for example, Yan and Dando [43], found that loud, low-frequency noise (such as noise from airplane cabins) significantly reduce the sweetness of food. Hence, if these same sounds are reduced, for instance, with noise cancellation systems it is possible to bring back the full potential of the sweetness experience.

Future technologies will likely provide us with more sophisticated ways of segregating external sound stimuli according to the user’s needs. For instance, using eye-tracking technologies to decide what the user is looking at (see [44] for an example of such a system) in combination with future audio-scene segregation technologies, it might be possible to enhance or even isolate sound sources the user is looking at by reducing the impact of sound sources outside the user’s visual horizon.

5 Summary

We have attempted to clarify exactly what reality is being discussed in the broad field of VR, which includes XR and RR, by defining reality as the conscious experience of a perceptual environment that itself is an abstraction of an ungraspable-in-its-entirety externality, that is, the world. Such a concept allows for the very different experiences of worlds, both virtual and external, that individuals have due to their different spatio-temporalities in that externality, past experiences, and varied sensory capabilities. Equally, the concept of reality as the experience of a perceptual environment allows for a more nuanced approach to VR design that includes the effects of crossmodality on our perception.

The need to reduce reality, in cases where attention to the task at hand is required, presence in VR is desired, and stress is to be avoided, has been argued for. We have briefly listed and discussed some past and current approaches to RR that are solely sound based and then have provided some examples where a crossmodal approach to RR might have advantages or allow for new VR designs. In our opinion, in most cases the more-is-more approach of XR and VR generally is the wrong approach and we propose instead the RR concept of *less-is-more*. While we do not suggest the complete elimination of the XR paradigm – it has its uses – we hope we have argued convincingly enough to persuade the reader of the benefits of a reduced approach to reality particularly where the increasing digitalization and commercialization of the world, and an always-on existence, have the deleterious consequence of increasing our exposure to more varied, insistent, and saturated sensation.

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