Editing reality in the brain

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Abstract

Recent information technologies such as virtual reality (VR) and augmented reality (AR) allow the creation of simulated sensory worlds with which we can interact. Using programming language, digital details can be overlaid onto displays of our environment, confounding what is real and what has been artificially engineered. Natural language, particularly the use of direct verbal suggestion (DVS) in everyday and hypnotic contexts, can also manipulate the meaning and significance of objects and events in ourselves and others. In this review, we focus on how socially rewarding language can construct and influence reality. Language is symbolic, automatic and flexible and can be used to augment bodily sensations e.g. feelings of heaviness in a limb or suggest a colour that is not there. We introduce the term 'suggested reality' (SR) to refer to the important role that language, specifically DVS, plays in constructing, maintaining and manipulating our shared reality. We also propose the term edited reality to encompass the wider influence of information technology and linguistic techniques that results in altered subjective experience and review its use in clinical settings, while acknowledging its limitations. We develop a cognitive model indicating how the brain's central executive structures use our personal and linguistic-based narrative in subjective awareness, arguing for a central role for language in DVS. A better understanding of the characteristics of VR, AR and SR and their applications in everyday life, research and clinical settings can help us to better understand our own reality and how it can be edited.

Keywords: suggested reality (SR); natural language; direct verbal suggestibility (DVS); virtual reality (VR); augmented reality (AR); source code

Introduction

Our experience is primarily one of living in a 'real' world and having 'real' experiences of it and of ourselves within it. While so much is clear from a first-person perspective, answers to the broader question of the nature of reality are less straightforward and are often the bone of much philosophical contention. Are only physical objects real or is reality fundamentally immaterial? Do abstract objects exist and are other worlds possible? Does the world exist outside the mind? Is reality malleable, and if so to what extent? These are long-standing issues and recent information technologies, as well as challenging and questioning further our notions of reality, can give us new insights of how it can be experienced and altered.

In what follows we briefly review recent Information Age advances which humans use to represent and edit reality. We then discuss in more detail how an older evolutionary technology i.e. human natural language also represents and shapes reality in similar but often more subtle ways. First, we describe how information technologies are used to represent and mould our experiences of reality using techniques such as virtual reality (VR) and augmented reality (AR). We then consider how language and

in particular the use of direct verbal suggestion (DVS) i.e. forthright statements given verbally and which can produce the experience of involuntary movement or cognitive changes, at the time or later (Oakley *et al.* 2021), can be used in both everyday and hypnotic contexts, as a typically human means of altering perceived reality in ourselves as well as others, and can also manipulate the meaning and significance of the objects and events in our world. Typical examples of suggestions taken from a standardized scale measuring DVS range from those involving a simple motor response (e.g. 'your hand is getting heavier – a weight is forcing it down' – which can produce an involuntary movement) to cognitive experiences (e.g. 'a fly is buzzing around your head – annoying you' – which can produce an auditory hallucination) (Oakley *et al.* 2020). DVS does not include other forms of suggestibility or 'suggestibilities' such as non-verbal, placebo, interrogative suggestibility, or social compliances (Kihlstrom 2008; Tasso and Pérez 2008; Tasso *et al.* 2020). We discuss the nature and effects of DVS more fully in the section 'Perceptual symbol systems and editing reality' below.
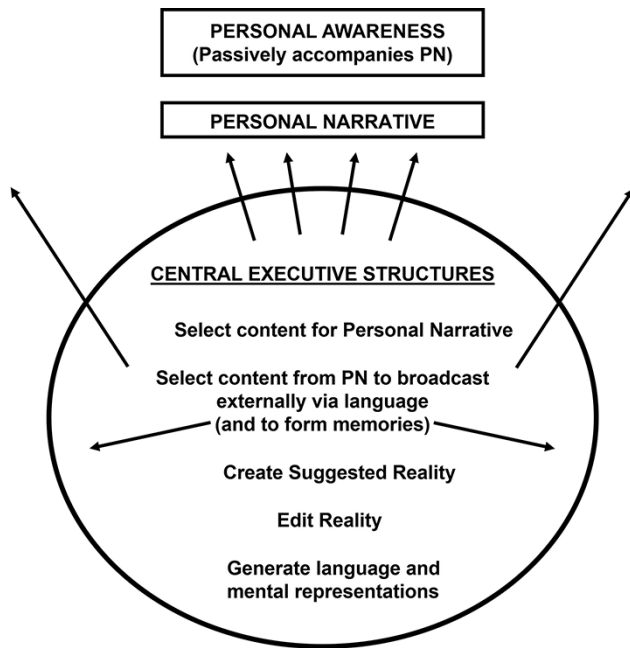
We adopt the term edited reality (ER) as a blanket term for the experiential outcome of the range of information technology and

Figure 1. A schematic view of the main functions of the brain's Central Executive Structures (CES) in relation to language, Edited Reality (ER) and Suggested Reality (SR). The CES selects from ongoing neurocognitive processes those that are relevant to the individual's current situation for inclusion in the Personal Narrative (PN), which is accompanied by awareness – our sense of the 'here and now'. The CES also selects some content from the PN to broadcast (typically linguistically) to others and to form and maintain memories. The CES is also directly and solely responsible for the mediation of choice, free will and personal responsibility (not shown in the figure), for coordinating all task-related executive decisions and actions and for creating constructs of self, agency and embodiment (Figure adapted from Oakley and Halligan 2017)

linguistic techniques, procedures and processes reviewed below that can result in an altered subjective experience of ourselves and of the world around us. We go on to discuss the relationship between language, ER and 'suggested reality' (SR), with particular reference to the trait of DVS, which can be demonstrated with or without a hypnotic context, and the role of language in the construction and maintenance of mental representations (MRs). We also integrate our earlier model of cognitive/brain function (Oakley and Halligan 2017; see Fig. 1) that emphasizes the role of central executive structures (CES) of the brain in controlling the above processes independently of an ongoing personal and linguistic-based narrative that is accompanied by subjective awareness.

ER using information technology

An early example of ER is computer-generated imagery (CGI) that applies computer graphics to create or contribute to images, particularly in cultural settings to create characters, special effects and virtual worlds in movies, television programmes, commercials and printed media. CGI has demonstrated that agent-based, interactive environments are not necessarily constrained by the laws of physics and need not represent just one possible sequence of events. In this section, we provide an overview of two more recent forms of computer-generated ER, namely VR and AR, and describe the programming techniques used in creating them.

VR; simulating new or existing worlds

A long-established and more immersive example of ER is 'virtual reality' (VR) – a computer-simulated experience that can be identical to or different from the real world and is experienced through an immersive device worn by the user. Simulators can be convincing so that viewers can no longer tell what is real and what has been artificially generated. More recently, VR has been adopted by neuroscientists to create interactive multimodal, sensory, clinical, experimental and social environments. VR also offers the advantage of a high level of control over the environment in neuroscientific research (Bohil et al. 2011).

In clinical settings, applications of VR for acute and chronic pain management have shown that participants undergoing painful medical procedures report reduced levels of pain and distress when immersed in VR experience, promising a new non-pharmacologic technique for pain control. VR has been used to augment other clinical interventions, such as those using hypnosis and biofeedback. VR and hypnosis used together prove more effective than VR or hypnosis alone (Patterson et al. 2006, 2010). Patterson and colleagues (Patterson et al. 2006) combined VR technology with hypnosis (virtual reality hypnosis; VRH) during burn wound care. Patients who listened to an audio recording of a hypnotic induction followed by suggestions for pain relief while immersed in a virtual world reported lower levels of pain and anxiety (Hoffman et al. 2001; Patterson et al. 2010). These techniques have been shown to be continuously effective at reducing pain over time and do not habituate with repeated use (Hoffman et al. 2000). VR training is also used as an adjunct to therapy for people with motor and mental health dysfunctions (Teo et al. 2016), and the use of VR combined with neuroimaging is enabling researchers to identify and understand the brain areas implicated in schizophrenia (Waters et al. 2004). However, VR-induced relaxation may produce opposite results. Konstantatos et al. used VR relaxation (calming visual scenery with an instruction for participants to concentrate on a moving spiral) with morphine for pain reduction during burn wound dressing changes and found an increase in pain intensity ratings for participants (Konstantatos et al. 2009).

The exact neurobiological mechanisms behind the effects produced by exposure to VR remain unclear. One hypothesis with reference to pain is that VR acts as a non-pharmacologic form of analgesia through attentional distraction and emotion-based cognitive processes acting on the body's pain modulation system (Li et al. 2011). A related concept underlying VR therapy as a treatment is that it may promote brain neuroplasticity by engaging users in multisensory training (Teo et al. 2016). Cheaper and smaller VR systems are being developed, which will allow the measurement of neural activity in the real world and advance our understanding of the role of the body in cognitive performance i.e. during embodied cognition (Bohil et al. 2011; Wilson and Golonka 2013). Theories of embodied cognition propose that cognition is shaped by the body and is understood in terms of a physical body that interacts with the world (Wilson 2002). Sensory and motor systems integrate with cognitive systems to process high-level mental constructs such as concepts and MRs (Jirak et al. 2010). Research has established a strong relationship between language and embodied cognition, and language has been shown to activate motor simulations (Gallese 2008) and sensorimotor systems (Pulvermüller 2005; Barsalou 2008; Fischer and Zwaan 2008). We discuss later the role of DVS in editing reality – much of which involves engagement with embodied cognition.

AR; supplementing the real world

An important and arguably more powerful variant of VR is AR, which rather than simulating or substituting reality blends the virtual and real worlds into a single compelling experience. AR provides a live view of an existing environment where real-world objects are 'augmented' or enhanced by computer-generated perceptual information. Virtual digital details are overlaid onto the natural environment. Sensory information may include multiple modalities i.e. visual, auditory, haptic, somatosensory, and olfactory. Elements of the real-world environment can be added or subtracted by the computer depending on the programmer's objective and seamlessly interwoven in such a way that these changes or 'augmentations' are perceived as aspects of the actual environment and with which the user can interact in their real-world location. AR is helping to transform rehabilitation, e.g. to help patients recover function in a damaged limb by displaying a virtual limb alongside, whose movements are matched, to motivate and guide recovery. VR and AR therapies are promising and may offer unique non-pharmacological alternatives and environments to traditional treatment. However, some limitations should be acknowledged. Large clinical studies are required to test VR and AR in different clinical populations. Much of the existing literature lacks appropriate control comparisons (Reid 2002; Teo *et al.* 2016). Also, while immersive visual and auditory displays are developing quickly, sensory displays for taste, smell and touch are lagging behind.

Source code; how to edit reality

What VR, AR and other information technologies have in common is that their graphical representations of reality rely on an underlying code, a programming language. When this code, usually written as human-readable plain text (and which looks nothing like the resulting display), is executed by the computer, the effects are generated as a displayable environment. What makes VR/AR techniques so powerful is that programmers can edit or modify the code to bring about changes to the display to match ongoing requirements. Different display effects can be achieved. For example, not only variations in landscape and architecture but also dynamic and subtle changes such as (visually) sunlight falling at different times of day or (acoustically) the increasing sound of the wind can be created. All these changes are achieved using the same source code. Code can be 'hacked' by an expert to achieve a goal by non-standard means. Code is also vulnerable to 'bugs' or defects that can prevent correct operation – which has parallels with hallucination and clinical disorders in humans. In the following sections, we show how natural language is used in a similar way to represent and generate different realities and how DVS uses language and linguistic devices as its 'source code' to 'suggest' and 'edit' our shared constructions of reality.

Linguistic worlds

Since language first developed 50 000–150 000 years ago offering *Homo sapiens* an evolutionary edge, its function has been to link symbols with information in the real world or information already stored in memory (Burton 2009). Language thereby activates internalized cognitive models, real-life experience, rich and complex multimodal memory processes, and cultural knowledge (Ryan 2015; Oakley and Halligan 2017), conjuring up a vivid representation of immersive, compelling and often language-independent worlds. While characters in, e.g. a good book, are merely linguistic constructs, this does not prevent us from interacting and reacting to them as if they were real embodied humans with actual experiences. These language-generated worlds are not experienced as fragmented but rather as a totality or an immersive whole (Ryan 2001). For the individual they are experienced as 'real'.

In the rest of this section, we consider how language is involved in constructing and editing reality. We then go on in the section 'Self-models, language and MR' to discuss the role of language in MR, with particular reference to an earlier model of human brain function. We address the role of language in the form of DVS in modifying the experience of reality in the section 'Perceptual symbol systems and editing reality' and the role of instruction in the experience of 'reality' in the section 'The effects of DVS'.

Constructing and editing reality

The role of SR in the formation of brain-based representations has a long experimental history. A widespread and well-established example is the process of associative conditioning in which an external stimulus that is repeatedly presented just before a significant event comes to represent that event and to evoke the response previously associated with it. A simple non-linguistic example is that of 'classical' or 'Pavlovian' conditioning famously demonstrated in dogs by I. P. Pavlov (1927) in which an auditory stimulus frequently associated with a subsequent event such as the delivery of food can itself in due course elicit salivation. Interestingly, Charles Richet 'was very close to formulating classical conditioning, before Pavlov, as he demonstrated in 1878 a psychic reflex that produced an abundant flow of pure gastric juice on a fifteen-year-old boy' (Evrard *et al.* 2021; final paragraph page 10). It is important here to note that Pavlov also considered spoken language and its consequences as the best example of a conditioned response in humans (Pavlov 1927). As part of their evolutionary progression, humans have become a symbolic species and are distinguished from other animal species in communicating via a formally constructed language, although some rudimentary grammatical understanding is present in our closest primate relatives (Seidenberg and Petitto 1987). We acquire language through extensive practice and/or exposure. Language entails learned relationships between signifiers (i.e. words) and what is signified (e.g. objects or concepts in the environment). The ability to form highly complex networks of associations or compositions between elements means that language provides us with enormous capacity to represent the world. Language transcends time – recognizing past, present and future. Language is referential, meaning that we can use it to communicate information about people, creatures, objects and actions. Because of its symbolic, fluid and flexible nature, language can be used to describe and explain phenomena that cannot be reduced to physical facts. Narrative allows us to extend, share or supplement (rightly or wrongly) incomplete accounts. Language retrieved and propagated in the narrative form is integrated into most aspects of our social and cognitive lives (Burton 2009). As well as being central to our cognition, another important feature of language production and comprehension is that it is highly automatic, effortless and rapid, and much of it happens largely outside of our awareness (Shiffrin *et al.* 1981; Favreau and Segalowitz 1983). Language-learning mechanisms are strongly coupled functionally and anatomically with subcortical reward systems (Syal and Finlay 2011; Ripollés *et al.* 2014). Subcortical reward processing circuits extending from the limbic emotion areas of the brain to the prefrontal cortex governing executive thought activate when learning language (Ripollés *et al.* 2014). Thus, language provides us with an important source of information and understanding of our world and is also socially rewarding (Panksepp 2004; Tomasello 2009; Ripollés *et al.* 2014) –

all of which helps explain why DVS has taken root and can be so effective.

In summary, language augments 'representational power' and can simulate (similar to VR) as well as augment (similar to AR) the experienced world. Language offers an additional way of representing information in the world that goes beyond overt visual and/or spatial representations. Language can encode what is not visible e.g. an object in another room, or what does not exist e.g. a unicorn. Language can augment bodily sensations e.g. feelings of heaviness in a limb or suggest a colour that is not there. Language can be used in an ongoing (online) manner to modify perceptual representations of objects in the environment, including our own bodies. Verbal codes can influence neural codes within the internal MR. Overall, language serves to create transient novel representational resources.

Self-models, language and mental representation (MR)

According to philosophers, the 'phenomenal self' is the conscious experience of a self that emerges from information-processing representational modelling processes in the central nervous system (Metzinger 2007). These self-models, which give us our first-person perspective, may be adaptive products of natural evolution (Metzinger 2007). Phenomenal self-models emphasize the experience of inhabiting and controlling a body which is ours, and which is located in time and space, and capable of purposeful action (Metzinger 2005; Blanke and Metzinger 2009). Thus, we 'see with our eyes' and 'act with our hands' and while we are aware of these experiences, we are usually not aware of the brain processes which drive them. These self-models thereby serve as a 'user interface' with their associated covert brain processes. Mental and phenomenal models can explain how a certain subset of activated information is readily available to consciousness, enabling the selective and flexible control of behaviour, producing the experience of 'a virtual window of presence' (Metzinger 2007) and enabling us to experience a continuous 'here and now'. Importantly, this information has a linguistic correspondence that helps explain how a conscious experience of a self can emerge with a distinct role for the body that shapes the mind (Metzinger 2007).

Towards the close of the 20th century, the construct of mental models or situation theoretical models were introduced into language comprehension (Bransford et al. 1972; Johnson-Laird 1983; Van Dijk and Kintsch 1983; Glenberg et al. 1987; Bower and Morrow 1990; Kintsch and Walter Kintsch 1998; Zwaan and Radvansky 1998). MRs are hypothetical symbols of how the brain encodes external reality (Marr 2010; Morgan 2014). MRs enable us to experience things that are present but also things that are not present and may not even exist. Things that have never happened or are impossible can be mentally represented. MRs can involve all sensory modalities, and their fluidity may be important in problem solving (Sternberg et al. 2012). Mental models (Johnson-Laird 1983), also known as situation models (Van Dijk and Kintsch 1983), are integrated MRs parsed from the structures of information present in texts and discourse (Carley and Palmquist 1992). The surface form of a narrative can be transduced into underlying conceptual propositions using multimodal knowledge of the world stored in our long-term memories. When we listen to a discourse or when we read, mental models of characters and their situations are constructed in our minds. Mental models can also represent spatial situations such as a mental map of the places which the characters can then move through and objects as they occur in space

(Bower and Morrow 1990). These mental models facilitate comprehension and allow us to better understand causal relations in the narrative and the motivations of the characters. Mental models are malleable and are adapted online to accommodate developments in the narrative. Incoming information serves to update elements of the model, including the development of characters and change or addition of scenes. There is no one-to-one correspondence between the narrative and the mental model, and people tend to remember the mental model they constructed from the discourse rather than the words or events literally (Johnson-Laird 1983; Van Dijk and Kintsch 1983). Mental models give humans an adaptive advantage and allow us to plan, understand and act upon the world, as well as the ability to create counterfactual realities. The co-occurrence of language and perceptual representations means that language can activate and control representations about an ongoing specific event or situation in the working memory of the listener by integrating multimodal information in a mental simulation (Barsalou et al. 2008; Dove 2011; Louwerse 2011; Andrews et al. 2014).

Discourse events used in the construction of mental models are thought to include time, space, causation and motivation dimensions (Zwaan 2016). As incoming discourse is processed by the human brain, an event representation is formed and based on these dimensions is integrated into the mental model currently activated in working memory. Importantly, these dimensions can be additive and can contain a mixture of concrete and abstract concepts. Further, DVS can be used cataphorically (forward-looking) to integrate upcoming information into a perceptual or sensorimotor simulation or anaphorically (backward-looking) to integrate previously presented information into a simulation. Such versatility means that DVS can access MRs readily (Gernsbacher and Shroyer 1989).

Perceptual symbol systems and editing reality

Arguing against amodal approaches to knowledge, Barsalou in his influential perceptual symbol systems framework (Barsalou 1999) posits that internal representations regarding perceptions, actions and introspective states can be re-enacted in the same neural systems in which they are encoded. This is achieved as incoming multimodal sensory information is encoded in sensory cortices during perception to produce a sensory representation via feature neurons located in sensory and sensory association cortices. These feature neurons are monitored by so-called conjunctive neurons which receive sensory information, including vision, audition, olfaction and gustation (Barsalou et al. 2003; Morey et al. 2011). Conjunction neurons offer limited-capacity, multimodal storage of information in one neural location and can re-activate original features of a stimulus. The activity of conjunctive neurons can represent different things as synaptic weights change (Manohar et al. 2019). A central brain mechanism called a simulator compiles memories of instances captured across a category (Barsalou 1999). For example, a simulator for 'chair' contains information about different chairs and aspects of chairs encountered in many situations and from many multiple perspectives over time. Simulations can develop for any aspect of experience including actions, events and mental states (Barsalou 1999). Importantly, when a simulation is activated, it can recreate the original perceptual state in sensory cortices in the absence of any sensory input. The simulation can also re-enact several aspects of a category, which tend to share features, derived from multiple instances of experience (Barsalou 1999; Barsalou et al.

2003). Once these conjunctive neurons are established (simulations), they can be activated by cognitive stimulation, such as DVS, and in the absence of bottom-up input. Simulations are partial reconstructions rather than facsimiles and can contain distortions (Barsalou 1999). This indefinite nature of simulators allows for great cognitive flexibility but also leaves them susceptible to alteration from outside. We propose that Barsalou's perceptual symbol systems framework (Barsalou *et al.* 2003; see their Figure 2) provides a plausible mechanism for how DVS might operate in the human brain. DVS may trigger shared conjunctive neurons which in turn energize simulators to activate stored sensory representations which re-enact perceptual experience. 'Once simulators for words become linked to simulators for concepts, they can control simulations' (Barsalou 1999; page 592). In other words, once a simulation has been evoked, language in the form of suggestions can then be used to edit, add or delete aspects.

An interesting question is how DVS might interact with VR and AR. We have seen how VR and hypnosis used together can prove more effective than VR or hypnosis alone (see the section 'VR; simulating new or existing worlds'), but also how 'calming' VR scenery can have an opposite effect. The assumption here is that DVS will have an additive effect when it is appropriately coordinated with a VR or AR display. This would lead to a more effective intervention as the incoming bottom-up (AR or VR) streams successfully fit with the top-down DVS-activated and controlled internal simulation. In contrast, DVS that is incongruent with the incoming sensory information from the displays would have an opposite effect. It is assumed that constraints will arise when sensory information is not applied effectively to a DVS-evoked simulated entity. Future research could confirm these assumptions which are relevant for clinical practice.

How MRs are shared and modified

Humans use words and language to communicate ideas and feelings and to share and process their MRs. Most of this psychological processing is not represented in awareness. As shown in Fig. 1, the contents of subjective experience are generated outside awareness within central executive systems of the brain in the form of a continuous and self-referential personal narrative (PN) – an account of events and experiences that relates to the ongoing task and is accompanied by a sense of awareness (see Oakley and Halligan 2017; for the background to this model). The PN, its contents and the awareness that accompanies them are passive, non-agentive epiphenomena (Halligan and Oakley 2021). The PN itself arises from the 'internal broadcasting' of information derived from executive systems within the brain that operate outside awareness to supervise all cognitive processing, sensory analysis and motor control. The PN and personal awareness in combination represent what has been traditionally labelled 'conscious awareness' – which despite the prominence given to it in PNs 'is but the tiny tip of an immense iceberg … on the great tide of information which flows unceasingly into, around, and out of …the human nervous system' (Dixon 1987; p.16, Para 3, line 8).

In this model, the CES (Oakley and Halligan 2017) mediate choice, free will and personal responsibility and select information from the PN for inclusion in autobiographical memory. Most importantly from an adaptive, evolutionary perspective, the CES selects content from the personal narrative and communicates ('externally broadcasts') that information to others, thereby promoting species fitness and enabling individuals to predict and influence the behaviour of others and to develop adaptive socio-cultural and political structures. It is primarily natural language that enables the successful communication and transmission of information to others (Oakley and Halligan 2017) and via external broadcasting, language, especially DVS, can be used to influence the internal broadcasts of others. The CES uses language to represent reality, which can then be communicated to others. Language enables the rendering of reality to reach a shared consensus of meaning. The CES is also responsible for generating new realities in response to suggestion, editing realities, engagement in imagination and controlling action. We propose that the model shown in Fig. 1, comprising CES, personal awareness (PA) and PN is more useful in cognitive psychology, particularly in cognitive neuropsychology, than the traditional notion of 'consciousness' as an independent agentive force (Oakley and Halligan 2017; Halligan and Oakley 2021). While we propose that 'consciousness' is not a helpful concept in scientific accounts, we agree that it remains important as a topic for philosophical and psychological debate as a powerful cultural belief or meme.

While language is a significant development in the evolution of human brain function, it is worth reiterating that the brain indulges in VR and AR even without linguistic input in creating an expected world by adding experiences that are not there or deleting ones which are. A classic example of this is change blindness in which an individual who is asked for directions by a stranger does not register the substitution of a different interrogator part way through their interaction (Simons and Levin 1998), a substitution effect easily programmable in VR and AR. In terms of the model shown in Fig. 1, this can be seen as an example of the CES creating a short-hand/edited environment for representation in the PN, which among other advantages arguably saves on cognitive computing capacity. Our subjective experience (PN plus PA) is that we live in and interact with a 'real' world and have 'real' thoughts and experiences. Even our misperceptions have a feeling of 'reality' about them. The brain expediently deletes or does not register novel stimuli in a familiar environment if they are not central to the task in hand. The fact that the brain has evolved its own form of AR is an important human evolutionary development. Our capacity to use language to create new VR, AR and SR experiences in our own brains and, via the process of DVS, in the brains of others taps into these pre-existing systems and processes. As noted earlier, DVS represents a significant ability that can be deployed with and without a hypnosis induction procedure (Oakley and Halligan 2013; Oakley *et al.* 2021). In the following sections, we discuss further the role of language and DVS in modifying and maintaining our experience of reality.

Language is omnipresent in the brain

Traditionally, language was thought to be processed in the left hemisphere (Geschwind 1970). Much turn-of-the-century work stemming from Broca's and Wernicke's earlier studies has specified language mainly in terms of left-lateralized 'modules' within the brain (Petersen *et al.* 1988; Vigneau *et al.* 2006). Language pathology has also shown how disorders and breakdowns in language, such as aphasia and dyslexia, relate to physical characteristics of the brain. The dominant model for language processing in the brain throughout much of the 20th century was the Broca–Wernicke–Lichtheim–Geschwind classical model, which is based on the analysis of brain-damaged patients (Nasios *et al.* 2019). Towards the end of the 20th century, studies typically involving neuroimaging were primarily confined to measuring the brain's response to simple verbal stimuli such as single words or sound stimuli (Petersen *et al.* 1988; Price 2010). Due to improvements in intra-cortical electrophysiological recordings

of animal and human brains, as well as developments in non-invasive neuroimaging techniques such as functional magnetic resonance imaging (fMRI), positron emission tomography, magnetoencephalography and electroencephalography, a new understanding of language in the brain is emerging. Unexpectedly, many fMRI studies find only modest lateralization for language areas (Binder *et al.* 2009). More recent neuroimaging studies using narratives, where verbal information is presented over time as in real-life activities such as watching a movie, engaging in conversation or DVS, have shown dispersed and extensively bilateral patterns of activation. For instance, a voxel-wise modelling of fMRI study by Gallant and colleagues mapped the semantic systems of the brain in detail while participants listened to stories for over 2 hours (Lerner *et al.* 2011; Huth *et al.* 2016). These studies found that a single word can activate several brain regions across the brain and in both hemispheres. The distribution of semantically selective areas was symmetrical across both cerebral hemispheres and, in contrast to the traditional studies reviewed above, was not left-lateralized. Furthermore, words were grouped by meaning into rough categories e.g. numbers or social words, such as 'wife' and 'family'. The organization of semantically selective brain areas was consistent across individuals, reminiscent of Penfield's cortical localized mapping of the sensorimotor homunculus (Penfield and Rasmussen 1950). These studies indicate that the human brain responds readily and in an extended and selective way to verbal information.

Language and perception are intrinsically linked

Language shapes the way we think about the world. The language we speak divides up the world in specific ways in respect to, e.g. colour, space, numerosity, objects and events (Bowerman *et al.* 2001; Casasanto 2008; Gentner and Goldin-Meadow 2003; L. Gleitman and Papafragou 2005, 2012; Gumperz and Levinson 1991; Whorf 1956; Wolff and Holmes 2011). When language is used to perceive and encode the world, it has the power to highlight or augment certain aspects of that world through encoding those components, while simultaneously de-emphasizing other non-encoded components. Therefore, language can act as a 'lens' for reality, promoting salient aspects (Gentner and Goldin-Meadow 2003; L. Gleitman and Papafragou 2005) while selecting certain aspects over others (A. N. Landau *et al.* 2010). Individuals attend more to the features of the world that their specific language enables them to understand, and as a result, linguistic categories influence cognitive processing (L. R. Slobin 1996; Griffin and Bock 2000; Gleitman *et al.* 2007). Speakers of different languages seem to perceive and conceptualize events subtly differently. For example, English and Greek speakers allocate their attention to components of unfolding motion events differently in order to describe these events, in accordance with the way the two languages differentially encode movement (Papafragou *et al.* 2008). Language also affects non-linguistic cognition. Further to vision and spatial representations of the world, language offers an additional way of representing information from the world and thus augments representational power. Language interacts with visual and spatial and perceptual processes, although the nature and extent of these interactions remain unclear and is a topic for ongoing research. Language affects the way speakers conceptualize the world even when they are not speaking or understanding speech and can lead to enduring changes in MRs. Importantly, language is a means of 'enrichment' (A. N. Landau *et al.* 2010), but this enrichment can come at a cost, as language can deceive us and manipulate our perceptions (Walker *et al.* 2021).

How and when language exerts its effects

Language is a temporary interaction between linguistic and other MRs. Importantly, language can help encode, store and manipulate a representation. Within the context of a specific task, linguistic information and linguistic devices (e.g. repetition) can be used to exert online, powerful, transient effects on cognitive processes as the task unfolds. Additionally, language can create entirely novel representations that would not otherwise be possible. Language can also influence non-linguistic representations such as colour and spatial frames of reference. These effects occur 'online', i.e. at the moment of performing the specific task (Ünal and Papafragou 2016). Language-driven differences in colour perception have been observed at the behavioural level, and electrophysiological neuroimaging research (ERP; event-related potential) has indicated that even early stages of colour processing are influenced by rapid linguistic feedback. Cross-linguistic studies have shown that colour categorical perception is linked to language indicating that despite their physiological basis, perceptual processes can be modulated by language (Athanasopoulos *et al.* 2011). Language-specific colour codes seem to shift perceptual colour processing so that the boundaries of colour categories (e.g. green and blue in English) can transiently align with verbal codes rather than within-category perceptual distinctions. As we have noted earlier, DVS uses language to interact with and manipulate certain language-independent MRs, to re-encode aspects of the perceptual world, and activate (shared) memory systems. On this basis, DVS works by selecting certain aspects of the world and encoding those components, while simultaneously de-emphasizing other components through not encoding them. We propose that DVS operates as a type of editor that uses language to activate mental models and can then insert, delete, modify or replace aspects of their contents. During SR, DVS activates perceptual and sensorimotor representations, which in turn activate corresponding lexical representations (Zwaan and Madden 2005) via reciprocally connected brain systems (Pulvermüller 2005). We discuss DVS at greater length below.

Language is embodied

Traditionally, cortical systems for language and actions were believed to be independent and located in separate circumscribed areas, namely left perisylvian language regions and bilateral motor and premotor cortices, which are dissociable by neurological disease (e.g. aphasia versus paralysis, respectively; Pulvermüller 2005). Modern theoretical perspectives posit that cortical functions are performed by a distributed and interactive network of neuronal assemblies rather than separate local encapsulated modules (Hebb 1949; Braitenberg and Schüz 1998; Mesulam 1998). The reciprocal flow of information is possible between the cortical systems for language and action. Listening to words such as 'lick', 'pick' and 'kick' can rapidly and automatically activate the motor system in a somatotopic (respectively, mouth, hand and foot) manner. Functional directional links exist between the motor cortex and core language areas at the neuronal level (Mollo *et al.* 2016); semantic information can be stored in distributed neuronal networks including sensory and motor systems of the brain (Barsalou *et al.* 2003); and language can engage specific areas of motor cortex that control the effectors involved in action (Ehrsson *et al.* 2003; Hauk *et al.* 2004). Studies suggest that language and motor processes share neural resources that co-operate bidirectionally so that language processes affect motor processes and reciprocally motor processes affect language processes (bidirectionality hypothesis; Pulvermüller 2005; Aravena *et al.* 2010; Ibáñez *et al.* 2013). Furthermore, language–motor networks are

not restricted to somatotopically defined brain areas. There is also increasing evidence that disease-related motor impairment affects language processing in conditions such as progressive supranuclear palsy (Bak *et al.* 2006), fronto-temporal dementia (Rhee *et al.* 2001; d'Honincthun and Pillon 2008), Parkinson's disease (Boulenger *et al.* 2008; Péran *et al.* 2009) and amyotrophic lateral sclerosis (Neary *et al.* 2000), suggesting reciprocal interactions between motor areas and language systems. Such bidirectional language–motor couplings may provide the neurological mechanism through which the effects of DVS operate.

The effects of DVS

There is a long history of research into the effects of what we have identified above as DVS in the literature on hypnosis, traditionally published in specialist journals (see Oakley *et al.* 2021 for an overview). We give examples of two suggestions from one of the standardized measures of hypnotic 'susceptibility' (see Oakley *et al.* 2020) in our Introduction above. A further example is that of 'arm heaviness' in which suggestions are given, such as 'your arm is getting heavy …. very heavy … like lead … much too heavy to lift'. These 'arm heaviness' suggestions are followed by a request that the participant 'try to lift your hand up'. This item is passed if the participant reports that they were unable to lift their hand when requested to do so. Most participants report experiencing the suggested effects in this and other similar 'motor' suggestions. 'Cognitive' suggestions also included in the test are responded to by fewer of the participants and include experiencing an auditory hallucination and amnesia for aspects of the procedure. These tests are preceded by a 'hypnotic' induction procedure that typically emphasizes focusing on attention, relaxation and involuntariness, and all suggestions are reversed once the test is completed. In the context of our discussion, it is first of all important to note that the traditional suggestibility scales can be administered without a hypnotic induction procedure with very little reduction in responsiveness to the suggestions (Braffman and Kirsch 1999; Kirsch and Braffman 2001). Conversely, identifying the context as 'relaxation' before delivering a traditional induction procedure results in lower responsiveness to suggestions than labelling it 'hypnotic' (Gandhi and Oakley 2005). One conclusion from this is that the creation of a positive expectancy of responsiveness to suggestion is important irrespective of the introductory procedure.

Our overarching label of DVS is intended to identify responsiveness to suggestions of this sort that can be measured with or without a 'hypnotic' procedure. It is also worth noting that many of the effects of DVS are mirrored in clinical conditions such as schizophrenia and conversion disorders, manifesting as psychogenic pain, amnesia, paralysis delusion and hallucination. Despite the opportunities it offers (Oakley and Halligan 2013), there has been relatively little work to date involving hypnosis and the types of suggestibility typically associated with it in cognitive psychology. However, there is evidence that this is changing particularly in neuropsychological studies in which suggestion given in a hypnotic context had been used as a means of creating analogues of phenomena such as psychogenic pain (Derbyshire *et al.* 2004), functional paralysis (Deeley *et al.* 2012), alien control of movement (Walsh *et al.* 2015), colour perception (Kosslyn *et al.* 2000), synaesthesia (Terhune *et al.* 2010) and delusions (Connors *et al.* 2013) – see (Oakley *et al.* 2021) for a listing of such studies. The form of suggestibility underlying phenomena such as the Chevreul pendulum effect (Chevreul 1833; Easton and Shor 1976) does not correlate with DVS (Tasso *et al.* 2020) and appears to involve processes enacted outside higher neurocognitive processes. In demonstrations of the phenomenon described by Chevreul, the participant is instructed to hold the string attached to a pendulum weight in their outstretched hand, keeping their arm and body completely still. Information is then given by the experimenter, which is consistent with the pendulum moving in particular ways (e.g. the pendulum weight is being blown from side to side by a breeze). The result in most participants is that the implied pendulum movement begins to actually occur whilst they continue to experience complete immobility in their hand and body. Arguably, the pendulum movement is generated via low-level sensorimotor systems as a form of embodied cognition. Other forms of suggestibility, such as body sway, the odour test, progressive weights, placebo, conformity, persuasibility and interrogative suggestibility, do not correlate with DVS as measured by the Harvard Group Scale of Hypnotic Susceptibility (Tasso *et al.* 2020). This indicates that DVS is one of many means of editing reality using suggestions deployed by the central nervous system in humans (for further background and discussion on DVS and its measurement see Kallio 2021; Oakley and Walsh 2021; Oakley *et al.* 2021). In conclusion, while not yet wholly acceptable to cognitive science, the fact that hypnosis as a procedure provides a powerful experimental tool (Halligan and Oakley 2013; Oakley and Halligan 2013) and 'hypnotic' suggestion produces similar effects even without the induction of hypnosis has reinforced the view that DVS is a more general human trait of suggestibility that is of direct relevance to cognitive science and cognitive neuroscience generally (Oakley *et al.* 2021).

The role of instruction in the experience of 'reality'

Suggestion as typified by DVS above is one means of altering an individual's experience of 'reality' in often predetermined and specific ways. The experience of reality, however, is also influenced less directly by tasks and instructions and by the addition of supplementary stimulation. In what follows, we explore some examples of these procedural effects.

Inattentional sensory inhibition

Verbal instruction and direction of attention have the capacity to block out much information in one's visual field perception. When a complex visual scene is presented to individuals who are instructed to attend to a task associated with elements of the scene, inattentive blindness can result as they are incapable of attending to all of it. Already referred to above (Section 'Self-models, language and MR'), change blindness is the failure of individuals to notice stranger substitution in a social interaction (Simons and Levin 1998). A similar and perhaps more dramatic example is the failure to see unexpected but salient objects or stimuli, such as the presence of an individual dressed in a gorilla costume in a task where participants watched a video in which people dressed in either white or black passed around basket balls and the viewer was given the task of counting the number of passes between the participants in white (Simons and Chabris 1999). These outcomes are not associated with vision defects or deficits but result from a verbally directed increase in attentional focus on one aspect of a scene at the expense of other salient aspects. These results indicate that verbal suggestion in the form of an implicit or overt instruction has the capacity to 'cloak' part of a visual scene, in a similar way to digital editing of a scene in a movie, and without the individual being aware of it. Similar

Table 1. Summary of some techniques for editing reality. Examples of recent information technologies (VR and AR) used to represent and edit reality. We coin the term 'suggested reality' to refer to the important and evolutionary role that natural language – specifically DVS – plays in constructing, maintaining and manipulating our shared reality. All techniques for editing reality rely on an underlying source code (programming language for VR and AR and natural language for SR), which bears no resemblance to the output 'display' or the 'reality' generated. The human brain transforms all inputs into neural code which is integrated and then updates our MRs. These iterative loops of reflective 'codes within codes' (see Fig. 1) are a feature of processes mediated by CES of the brain underlying the ongoing Personal Narrative (PN) and the experience of Personal Awareness (PA) associated with it

Type of reality	Output/Display	Source code	Multisensory	Technical devices
1. VR	Replaces reality	Programming language	Yes, although primarily visual	Headset usually
2. AR	Adds or removes elements and characters within existing scene	Programming language	Yes, although primarily visual	Headset or mobile device
3. SR	Can replace (cf. VR) or augment reality (cf. AR)	Natural language, DVS	Yes	None

effects have also been observed for listening, in which the content of a verbal message can be selectively blocked. In situations where people are verbally instructed to direct their attention to the reception of a message from one ear, participants are unable to report any of the content of the unattended message sent to the other ear. Even when the information has been presented many times, recognition tests reveal that almost none of the verbal content of the rejected message is able to penetrate the block. Verbal content of the rejected message effectively cannot be recalled. The exception is subjectively 'important' content presented to the unattended ear, such as a person's own name, which can penetrate the block suggesting that the block in such dichotic shadowing tasks occurs at a higher cognitive/cortical level (Cherry 1953; Moray 1959).

Suggested reality

Here, we have introduced the term SR to refer to the process of augmenting experienced reality by the use of DVS (Oakley *et al.* 2021). Borrowing from our earlier discussion of VR and AR, we propose that SR is an interactive experience of a real-world environment where an ongoing experience is verbally augmented using suggestion, including self-suggestion. The verbal suggestions can refer to any sensory modality, including visual, auditory, haptic, somatosensory and olfactory. SR can alter one's perceptions of what is happening in the real world. The overlaid verbal information can be additive to the actual experience (i.e. the real world which can be described using language) – e.g., by the addition of colour (Kosslyn *et al.* 2000). Kosslyn and colleagues have shown how DVS caused highly suggestible participants to experience the saturation of colour into a monochrome Mondrian-esque panes image. In contrast, when presented with vivid panes of colour, DVS was now used to 'drain' all colour from the image, resulting in the experience of a monochrome effect (Compare this form of editing with the colourization of old black and white archive movie footage using digital technology). These effects are not purely subjective as they are also accompanied by metabolic changes in relevant, lateralized visual fusiform brain areas (Kosslyn *et al.* 2000). Thus, verbal suggestions can be seamlessly interwoven into our reality such that the suggested effect is perceived and experienced as 'immersive' and 'real'. SR alone can offer perceptually enriched experiences, or suggestion can be used with artefacts to manipulate or augment information about the surrounding real world (as is commonly the case with placebo effects).

An important aspect of SR is that the effects it produces are not only subjectively 'real' but, in contrast to simply imagined effects and as we have seen, can be accompanied by corresponding changes in brain activity. In one study that compared suggested

with imagined pain, e.g. brain activation in the suggested pain condition was very similar to that accompanying 'real' pain produced by an intense heat stimulus (Derbyshire *et al.* 2004; Oakley and Halligan 2009). This was in in sharp contrast to the pattern of activation seen in the imagined pain condition. Interestingly, the participants in this study reported the 'imagined pain' as subjectively 'real' on a rating scale. Similarly hypnotically suggested hallucinations of human faces have been shown to produce greater right-hemisphere activity compared to mental imagery (Lanfranco *et al.* 2021). Although the process of imagining could be arguably construed as a form of self-suggestion, the effects of the two appear to be different at a neurological level. To emphasize this difference in the context of our model presented above we have described responses to externally generated DVS as resulting from the engagement of CES within the brain 'in a socially-driven role-play by creating neural activity consistent with the suggested change itself' (Oakley and Halligan 2017; col 2. para 3, line 14). The effects of DVS are also relevant to the aetiology of 'conversion' disorders such as psychogenic paralysis. In early neuroimaging studies, e.g. patterns of brain activity seen when a patient with medically unexplained paralysis attempted to move their affected limb (Marshall *et al.* 1997) were found to be reproduced in an individual with a directly suggested arm paralysis (Halligan *et al.* 2000); for further discussion of this and other examples see Oakley and Halligan (2009). In contrast to DVS delivered by another person, similar effects seen in a clinical context, such as in conversion disorder, are arguably due to self-suggestion mediated by language or internal dialogue. Table 1 summarizes (VR, AR and SR) techniques for editing reality.

Conclusion

We have reviewed two recent information technologies that humans use for editing and investigating our relationship with reality. VR uses technology to substitute reality while AR augments an existing scene by adding new elements. We described how humans over the course of evolution have constructed an artificial niche or a world of symbols consisting of natural language, which we use to augment our biological niche in the world. We have seen that language is symbolic, fluid, flexible, socially rewarding and powerful and has enormous capacity to represent the tangible and abstract phenomena we experience. Language can be directed at objects in the world and even at our own bodies to produce perceptual and somatic effects. Much of this happens outside awareness and feels effortless and rapid. Language can insinuate itself into the presentation and interpretation of data or an event. The narrative used to describe the event and the event itself automatically become fused with fragments from different sensory and cognitive streams to update existing or create new MRs in

the receiver's brain. We introduced the term 'suggested reality' (SR) to refer to the important role that natural language – specifically DVS – plays in constructing, maintaining and manipulating our shared reality and have discussed how DVS can be used in hypnotic and non-hypnotic contexts to alter ongoing experience. Similar to AR, language can enhance an ongoing experience or augment an existing environment. Importantly, phenomena produced by DVS are not imagined – they are experienced (Terhune and Oakley 2020) .

Historically, theories of hypnotic suggestibility fall into two main categories – state and non-state (Hasegawa and Jamieson 2002; Lynn *et al.* 2007). State theories propose that the hypnosis procedure creates an altered psychological condition which is conducive to responding to suggestion while non-state theories propose that the hypnotic induction procedure serves primarily to focus attention and raise expectations of outcome (Spanos and Barber 1974; Wagstaff 1998). Our model is consistent with both views but argues for a much more central role for language in DVS. Moreover, in our earlier account of the use of a well-established version of the Harvard Group Scale of Hypnotic Susceptibility (HGSHS:A) to measure responsiveness to verbal suggestion, we noted that it and other similar scales can be delivered both with and without the traditional hypnosis induction procedure with little if any effect on the outcome (Oakley *et al.* 2021). Recently, proposals have been made to update and revise or even replace scales such as the HGSHS:A with scales which take into account perceived problems such as the confusion between suggestion and instruction, an over-emphasis on simple motor suggestions compared to more cognitive ones and the difficulty in objectively measuring responses to suggestion (Kallio 2021; Oakley and Walsh 2021). We would add that any such attempt must carefully consider a central role for language. This review asks for a re-examination of the role of language in suggestion. Most of the research on 'verbal' suggestion in everyday and hypnosis contexts ironically does not discuss the role of language or does so only tangentially, perhaps reflecting the lack of emphasis on language in cognitive science generally (Skipper, J. I. 2021). In particular, our account argues that language and linguistic devices such as repetition and metaphor should produce measurable effects on perception and behaviour.

In practical terms, the model we have presented may provide a ground plan for developing Artificial Intelligence (AI) systems that more closely replicate the complexities of human cognitive processing and experience. Arguably all parts of the model could be created in artificial systems. There is of course a 'hard' problem (Chalmers 2006) associated with the latter in that we do not explain the origins of subjective experience, but categorize it simply as an epiphenomenal accompaniment to the PN. Our presumption has to be that computational processes of the complexity and form attributed to the activity of the CES may eventually be shown to generate subjective experience as an emergent property. This may of course only be true of biologically based systems replicating the activity of neurones as seen in the human brain. There would be a further problem in that if we asked the artificial information-processing system if it was 'aware' and it said 'yes', we would arguably have no option other than to believe it – as we currently do when we receive the broadcasting of a similar response from other humans. The advantage of our model in the context of AI is that it is parsimonious and does not include any additional, mysterious agentive system within brains that is responsible for high-level 'conscious' processing of information, control of action or the generation of experiences per se.

All informational techniques both technical and biological, for editing reality, rely on an underlying source code that bears no resemblance to the output 'display' of reality generated. In the case of VR and AR this consists of programming language, while for SR this consists of natural language (i.e. DVS). These source codes are assimilated by the brain, which transforms them into neural code that is integrated into our internal MRs, which we use in the form of a continuous and self-referential PN to interact with the world with appropriate perceptions, behaviours and actions (Buonomano and Maass 2009; Panzeri and Diamond 2010; Kayser *et al.* 2012; Harvey *et al.* 2013; Shamir 2014; Luczak *et al.* 2015; Oakley and Halligan 2017). These reflective and iterative loops of 'codes within codes' may form the basis of human subjective experience. Our capacity to use language to create new VR/AR experiences in our own as well as other brains (SR) taps into that pre-existing system/process and represents a significant ability that can be deployed with and without a hypnosis induction procedure. A better understanding of the characteristics of VR, AR and SR and their applications and when they are effectively used in everyday life, research and clinical settings will provide us with a better understanding of ourselves, our own shared social reality and also of how this reality is being edited.

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