Phenom Cogn Sci (2012) 11:95–112
DOI 10.1007/s11097-011-9233-z

A qualitative analysis of sensory phenomena induced by perceptual deprivation

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Published online: 16 November 2011

Abstract Previous studies have shown that misperceptions and illusory experiences can occur if sensory stimulation is withdrawn or becomes invariant even for short periods of time. Using a perceptual deprivation paradigm, we created a monotonous audiovisual environment and asked participants to verbally report any auditory, visual or body-related phenomena they experienced. The data (analysed using a variant of interpretative phenomenological analysis) revealed two main themes: (1) reported sensory phenomena have different spatial characteristics ranging from simple percepts to the feeling of immersion in a complex multisensory environment and (2) the active contribution of the perceiver where participants report engaging in exploratory processes even when there is nothing to find. Detailed analysis of the qualitative data further showed that participants who reported more perceptual phenomena were more likely to report internal bodily sensations, move more during the experiment and score higher on the Revised Hallucination Scale than those reporting fewer percepts explicitly linking perceptual deprivation to somatic phenomena. The results demonstrate how the variety of sensory experiences induced by perceptual deprivation can give further insight into the factors mediating conscious awareness and may suggest ways in which the brain imposes meaning on the environment under invariant sensory conditions.

Keywords Auditory · Ganzfeld · Interpretative phenomenological analysis · Misperception · Perceptual deprivation · Visual

Introduction

> ‘A changing sensory environment seems essential for human beings. Without it, the brain ceases to function in an adequate way, and abnormalities of behaviour develop.’
>
> (Woodburn Heron, ‘The Pathology of Boredom’, 1957, pg. 56)

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> 'I soon learned that variety is not the spice, but the very stuff of life.'
> (Christopher Burney, 'Solitary Confinement', 1952, pg. 16)

An organism requires not only stimulation but a continually varied sensory input for the maintenance of normal, intelligent adaptive behaviour. Anecdotal reports from shipwrecked sailors, prisoners in solitary confinement, polar explorers and many others show how the effects of isolation can lead to perceptual hallucinations and cognitive deterioration. However, there was little systematic study of these phenomena until D.O. Hebb's early investigations in the 1950s. In a series of studies with colleagues at McGill University, he showed how an invariant sensory environment can lead to disturbances in attention, organisation of thought, labile and extreme affect, and, of particular relevance to the research reported here, illusions of sensory experience. The purpose of the current study is to revisit the work on perceptual deprivation, firstly by creating a restricted sensory environment in the laboratory and secondly by using both qualitative (interpretative phenomenological analysis) and quantitative measures (number of reported experiences and questionnaires) to further investigate the variety and nature of such phenomena.

Sensory restriction can take two forms: sensory deprivation (i.e. that which occurs in complete darkness or silence) or perceptual deprivation (i.e. that which can be induced through homogeneous/invariant sensory stimulation such as white noise or translucent goggles). Perceptual deprivation is easier to control experimentally and does not produce the unwanted effects of social isolation or physical discomfort that sensory deprivation often can. There is also evidence to suggest that perceptual deprivation produces more sensory hallucinations (Heron 1965). The first experimental studies into perceptual deprivation were carried out by a team of researchers at McGill University in the 1950s and the first empirical study on perceptual deprivation was published in 1954 (Bexton, Heron and Scott; reviewed by Heron 1957). In this study, 22 male college students were paid $20/day to lie on a comfortable bed in a lighted cubicle (with time out for eating and going to the toilet). They wore translucent goggles, which produced the effect of diffuse light (no patterned vision), gloves and cardboard cuffs to reduce tactile input, and the cubicle was partially sound-proofed. A U-shaped pillow, the hum of ceiling fans and an air conditioner provided a further masking noise. Many of the volunteers wanted to take this opportunity to have some 'quiet time to plan their next term paper or research' and although this sounded like a holiday from the stresses and strains of life, in fact many lasted only 2–3 days in this environment. At first, participants slept (around 4–8 h), they then quickly became bored and restless and eager for stimulation (they were heard to sing, whistle, or try to explore their surroundings) and soon became childlike and irritable. Under these effects of isolation, participants commonly experienced hallucinations (defined by Hebb and his colleagues as 'perception without object'). Some thought they saw things coming at them and produced a head withdrawal in response. Others thought the experimenters were projecting pictures onto the goggles or they reported feeling someone else in the room.

Although the original aim of the study was to investigate the effects of perceptual deprivation on cognitive and affective abilities, these anecdotal reports of hallucinatory experience became the focus for later studies. Visual hallucinations were most common, ranging from simple dots to viewing complex scenes such as landscapes. Participants had little control over these images, which could last from 20 min to 70 h and were most prevalent with invariant stimuli rather than totally absent visual stimulation. Participants reported it was like ‘having a dream while awake’. The experimenters also made suggestions of possible shapes but the participants could not easily conjure these up and they could be removed if the person simultaneously performed multiplication sums in their heads (arguing against the idea that these phenomena were simply the result of suggestibility). Auditory hallucinations such as hearing people speaking or music playing were also reported. Tactile hallucinations in the form of kinaesthetic and somesthetic phenomena, although less widely reported, were arguably the most compelling, taking the form of illusory touch (an imagined doorknob giving an electric shock), or body doubles such as feeling ‘two of me’ and feelings of ‘otherness’ and ‘loss of self’. Importantly, these sensations were not located in the person’s head, but were situated in extrapersonal space ‘out-there in the world’, suggesting that these experiences may be rooted in everyday sensory experience.

In a subsequent study, three of the experimenters underwent 6 days of perceptual deprivation using the same methods as previously and published their own experiences in more detail (Heron et al. 1956). Common observations after 1 day of isolation included simple visual disturbances such as dots and patterns to more complex experiences (i.e. scenery and people). After 6 days of isolation, they found they experienced a variety of visual disturbances including apparent movement of objects in the visual field, apparent movement associated with head/eye movements, distortions of shape, accentuation of after images and effects on the perception of colour and contrast. In a later study published by Scott et al. (1959), they also found effects on somesthesis and spatial orientation. Tactile acuity (two-point thresholds) improved after prolonged deprivation (which had previously been reported in the limb stumps of amputees by Haber 1955 and more recently by Hunter et al. 2005) but tactile form discrimination and spatial orientation worsened (although this may have been because of visual dysfunction).

These striking effects demonstrated that varied sensory environments were necessary for normal perceptual and cognitive function. However, interest in deprivation research has waned over the years, due in part to the lack of an explanatory theory for ‘why’ these phenomena occur. Instead, subsequent studies have presented a different view of deprivation effects. In these, the reports were categorised as modality specific “reported sensations” of two types: types A and B (Reed 1979; Slade 1984; Zuckerman and Cohen 1964). Only type B reports were considered complex or ‘meaningful’ enough to be described as true hallucinations. When the literature was reviewed using these criteria, only 15–20% of participants gave complex reports, suggesting that hallucinations during deprivation are very rare and only a small proportion of individuals who are predisposed to hallucinate are affected (Zuckerman 1969). The different ways of classifying deprivation reports influences the scope of any theory that attempts to explain the effects of deprivation. The classifying of reported phenomena may be informed more by pre-existing notions of how hallucinations should be defined than the phenomena themselves. This is problematic because, in its broadest sense, the term ‘hallucination’ can apply to any non-voluntary perception that does not match external stimulation. This, however, would place fleeting misperceptions (i.e. perceiving someone to be behind you when they are not) in the same category as schizophrenic or drug-induced hallucinations. In both a diagnostic and an everyday language sense, there is an obvious difference between these two instances. The interesting theoretical question is in what way are the experiences different? The same question applies to the different categories that have been used to classify deprivation reports—in what way are simple and complex hallucinations, or type A and B reported sensations, different? The term hallucination is too vague to convey the essential nature of the experience that is to be explained (Pierre 2010) yet it currently constrains how deprivation reports are understood.

There is a growing movement of cognitive scientists who recognise that first-person phenomenological data is necessary to the study of brain processes underlying experiential phenomena (e.g. McClamrock 1995; Varela 1996). Systematic descriptive analysis of this data can provide the conceptual categories that an explanation should relate to if it is to have any bearing upon the true nature of the process (Marbach 1993). Essentially, to recognise a good explanation it is necessary to have a rigorous description of the thing that we are attempting to explain (Gallagher 1997). Previous attempts to relate deprivation reports to the current concept of hallucination have resulted in conflicting views. Thus, the current study aimed to provide a detailed account of experiences during perceptual deprivation without the constraint of this concept. Although such a description would not itself provide an explanation, it may provide some illumination as to which aspects of experience an explanation should account for (for a review of work on the potential relation between phenomenology and cognitive science, see Gallagher 1997).

In contrast to previous studies, first-person reports were collected in real-time during perceptual deprivation in the current study and then analysed using interpretative phenomenological analysis (IPA; Smith 1996; Smith et al. 1997). This qualitative approach suspends pre-existing notions about what is being investigated, allowing themes and categories to emerge from the data through a two-stage process. Using line-by-line coding, the reports are first extensively annotated with descriptive terms. Then, clusters of characteristics that are consistently associated are collapsed into a single theme until the variation between reports can be accounted for by one structured, thematic account. Both negative and borderline examples must be justifiably located within the account and not discounted as anomalous. This comprehensive focus can often lead to a reinterpretation of the data set as a whole. The focus of IPA extends beyond the content of experience to the way that an experience is reported. Such information reveals participants' intentional orientations during deprivation allowing one to infer the nature of their meaning-making process within that context, for example, whether they are remembering or deliberately using mental imagery. A core benefit of IPA is that all inferences are made via a double-hermeneutic process so that the final account reflects the researcher's attempt to make sense of the meaning-making process of the participants. The reader of this account can then evaluate this against the extracts of the participants' discourse that are provided as evidence. This approach has been successfully used to enhance phenomenological understanding of other non-veridical phenomena such as body ownership during the rubber hand illusion (Lewis and Lloyd 2010). The current study aimed to provide a structured phenomenological account of the range of experiences reported during perceptual deprivation. A questionnaire measure was also used to compare participant's self-reports to a measure of predisposition to hallucinate (the Revised Hallucination Scale; Morrison et al. 2002). Based on similar previous research (Feelgood and Rantzen 1994; Jakes and Helmsley

1986; Young et al. 1987), we predicted a relationship between the number of sensory experiences reported during perceptual deprivation and scores on this scale.

Method

Participants

Thirty-one undergraduate Psychology students from the University of Manchester took part in the study (27 female, 4 male with an age range of 18–21 years) in exchange for course credit. The study was approved by the School of Psychological Sciences research ethics committee and conducted in accordance with the Declaration of Helsinki. Participants were screened for any hearing problems and none reported any visual or tactile deficits.

Apparatus and materials

Auditory perceptual deprivation was achieved by playing white noise through headphones, generated by the computer programme Audacity (www.sourceforge.net). Visual perceptual deprivation was achieved by constructing a pair of goggles (from two halves of a white ping pong ball), which the participants wore creating a diffuse white Ganzfeld field. A lamp was used to provide background illumination in the room, which was partially sound-proofed. Participants were seated in a large armchair, which supported their arms, neck and head. A Dictaphone was used to record participant's verbal reports of their experiences in real time.

The Revised Hallucination Scale (RHS; Morrison et al. 2002) is a 20-item self-report questionnaire used to asses predisposition to hallucinate in non-clinical populations. A typical item for the RHS is "I hear a voice speaking my thoughts aloud". Items are scored on a four-point scale from 'never' (1), 'sometimes' (2), 'often' (3) and 'almost always' (4). RHS scores range from 20 (low hallucination predisposition) to 80 (high hallucination predisposition).

In addition, the study controlled for individual levels in state and trait anxiety using the State-Trait Anxiety Inventory (STAI; Spielberger et al. 1983) following evidence that more anxious individuals are more likely to hallucinate (Morrison et al. 2002). STAI scores range from 20 (not at all anxious) to 80 (very anxious). We also included a measure of suggestibility, the Marlowe-Crowne 2(10) Social Desirability Scale (MC-10; Strahan and Gerbassi 1972) as people who score higher on this scale are more willing to do what is expected or suggested of them in general social contexts. MC-10 scores range from 0 (not at all suggestible) to 10 (highly suggestible).

Procedure

All participants were tested individually in a sound-attenuated room. Participants sat in a comfortable arm chair opposite a computer containing the Audacity software. The experimenter was seated at a desk behind the participant in order to observe and note any overt behaviour and to ensure the participant was not distressed at any point during or after the testing period.

Participants were required to listen to white noise for 30 min. They were told that when listening to white noise for a prolonged period of time, some people have reported hearing various sounds within the white noise as well as other sensory experiences related to the white noise. They were reassured that these sensations are completely normal and the purpose of this study is to assess how common these experiences are and the nature of these experiences. They were told they should concentrate on the white noise and report as fully and as accurately as possible any sensory experiences they were having, for example, any sounds they could hear, bodily sensations they felt or visual imagery they experienced during the experiment. They then placed the headphones on and adjusted the volume of the white noise to a comfortable level. Lastly, they put on the goggles and the Dictaphone was switched on to record their spontaneous verbal descriptions.

After 30 min, the white noise was stopped and the experimenter told the participant to remove the goggles. Participants were then given the opportunity to discuss any perceptual experiences they may have had and were reassured that such sensations were completely normal (this data was not included in the analysis). Finally, they completed the RHS, STAI and MC-10. The entire procedure took approximately 50 min.

Data analysis

The interviews were transcribed verbatim and analysed using IPA (Smith and Osborn 2003). The initial stage entailed repeatedly reading an individual transcript. Once the researcher was appropriately familiar with the data, the left-hand margin of the transcript was used to code all of the important aspects that emerged. Observational data and timing aspects were also coded at this stage. The transcript was then read again and particular attention was paid to how the codes were exemplified in the data. A second thematic stage was then used to develop a psychological understanding of the text; this aimed to be grounded in the data yet sufficiently abstract so as to allow connections between codes to be made and noted down in the right-hand margin. This idiographic process was repeated for each transcript so that a full account of each participant's experience was obtained. Finally, the themes across all of the transcripts were clustered to demonstrate the emergent structure of the experience across the entire sample. The links between themes and clusters were checked against the raw data again to ensure their authenticity and then transformed into a narrative account. Issues of reliability and validity are important considerations in qualitative research. Smith (1995) suggests that these issues can be addressed by assessing whether the results are internally consistent and by judging whether there is sufficient evidence from the transcripts to support the interpretation. As a further evaluation, quantitative measures were used to corroborate the final analysis of the qualitative data and statistical analysis of quantitative data was conducted using SPSS.

Results

As predicted from previous studies, during the perceptual-deprivation procedure, participants spontaneously reported a large number of visual, auditory and bodily sensations (Table 1). Complex auditory experiences were the most commonly reported perceptions, typically of sounds that encompass many frequencies such as moving

Table 1 The content of each type of illusory experience reported and their frequency of occurrence across the sample

Simple auditory	Complex auditory	Simple visual	Complex visual	Bodily
Beep (5)	Train (3)	Blurry vision (2)	Ambulance	Tilting
Drip (2)	Wheels	Mist	Planes taking off	Sinking
Pop	Radar/sonar (2)	Dark patches (6)	Waterfall	Weightlessness
Low grumble	Alarm/sirens (4)	Coloured spots (3)	Roller-skating	Squashed
Squeaky	Whistle (6)	Darker/lighter visual field (4)	Faces	Presence
Tapping (4)	Rain (4)	Flashes of light	Wind through grass	Floating
Buzzing	Ambulance	Blue/yellow lights (2)	Water in pond	Numbness
Clunking	Fireworks (3)		Rising water	Detachment from body
Banging	Birds (6)			Muscle heaviness
Creaking (2)	Laughter			Weakness
Clicking	Party			
Hissing	Rainforest (2)			
Rumbling	Waterfall (7)			
Ringing	Water (8)			
Rustling	Music (2)			
Cracking	Insects (4)			
Scratching	Coughing			
	Crying (2)			
	Planes (10)			
	Roller-skates (2)			
	Wind (7)			
	Filling up (cup/balloon) (2)			
	Voices (5)			
	Play (parks)			
	Razor			
	River (2)			
	Sea (3)			
	Machinery			
	Cars (5)			
	Extraction fan (2)			
	Footsteps (2)			

water or a plane taking off. However, this was not a general characteristic of all auditory phenomena and, in general, the content of the perceptions was not as revealing as the systematic *way* in which they were described. IPA revealed two themes that demonstrate the range of these descriptions, firstly, in terms of their spatial characteristics, and, secondly, in terms of the perceiver's role as an active contributor to the experience. Each theme encompassed a number of categories, which are described in turn and supported using quotes from the transcripts and quantitative measures.

Theme I: reported sensory phenomena have different spatial characteristics

There were clear differences in the way that perceptions were reported such that three broad categories emerged: abstract perceptions of sensory phenomena located internally to the sense organ such as buzzing or slight changes in light quality; situated percepts where the perception of an object is situated externally in space, and thirdly more complex contextual phenomena with layers of percepts, often with different spatial dimensions. In general, the increase in spatial information allowed the participant to communicate more ‘meaning’ in the reported sensation and was therefore more similar to ‘Type B’ phenomena following the distinctions specified by Zuckerman and Cohen (1964).

Abstract perceptions of simple sensory variation

These phenomena contained the least spatial information as they referred to noticed variation within the invariant audiovisual stimulus rather than to an externally located object or event. The visual and auditory perceptions would become obvious but they would quickly disappear, often leading participants to count the number of times a percept was experienced: “I heard a tapping—a thump twice. It’s like sound waves, it feels like it’s hitting in waves, it gets stronger then less so” (P21). There were no descriptions of continuous perceptions and the descriptions would include the start and end point of the perception: “I can hear a crackling in my ears, it’s really weird, but it’s gone now” (P27). Within the auditory modality, the noticed variation was predominantly described by attempting to verbally reproduce what was heard using onomatopoeic words: “that sounded a bit like clunking” (P14), whereas in the visual modality the perceptions were described using intra-subjective comparisons: “it’s started to go a bit dark…It’s started to go hazier around the edges, it’s starting to go misty, like grey or mist” (P19). Bodily perceptions were intermittently reported by roughly half of the participants; these generally referred to noticed changes in somatic state such as changes in their level of tiredness, heaviness or tension: “I can hear a beating sound, I think it’s my own heartbeat and it seems to be getting louder…I can hear a slight pounding in my ear and jaw. My left eye is heating up…I feel like I’m tensing up, like my neck and jaw have become really rigid” (P16), or a diminishing sense of embodiment such that their body perception is no longer as would be expected: “My hands are really floaty like [they’re] not attached to my body…my hands feel really numb like they’re floating…my head feels really heavy like my neck can’t hold it up” (P4).

Collectively, these perceptions appear to lack ‘meaning’ because the participants are attempting to communicate changes in their experience without referring to something external. Further inferences about external causes are made cautiously but they state with certainty that something sensory has been noticed: “I heard a weird buzz sort of noise, I don’t really know how to describe that noise, it was sort of like a futuristic laser noise or something”. (After 10 min) “Heard that weird sound again, it’s really hard to describe it” (P11).

Situated percepts where sensory variation is attributed to an external object

These reports conveyed more than just noticed variation in sensory input; they described things that are physical in nature. Unlike the abstract descriptions that showed the participants attempting to interpret noticed variation, situated perceptions were described by their cause. They seem to convey more ‘meaning’ because they referred to the existence of a physical thing within the participants' surrounding environment: "it sounds like running water, that's stopped. It sounds like someone is pouring a jug of water into another one, and now they are pouring it faster…it sounds like it is bubbling a bit now" (P12). These reports were more detailed because the participants not only identified a whole object, they took more time to describe discernable parts of the whole as if extended exploration could allow greater understanding of its physical form: "I can see a really scary face. Not a skull but a face with black eyes and mouth, with a nose sticking out of its head" (P4). The reports also indicated that the percept, or its cause, was situated somewhere in space or moving in a specific direction: "I just heard someone drop a glass on the floor, like in the next room" (P15). The reports of bodily perceptions indicated that some of the participants felt that their position within the environment had changed as if they had suddenly moved or were moving: "it feels as if I am sinking, I don't know why" (P24) or that they could sense a physical presence near them: "it feels like someone is stood right next to me" (P13).

Immersive perceptions describing complex contextual sensory phenomena

The level of spatial detail conveyed in these reports had an environmental quality because multiple perceptions were reported as if they were located in different parts of the surroundings. Unlike the situated perceptions, which refer to one object, these indicated a 'layered' experience with a foreground and a background: "It's more clearly like water now, like the white noise has disappeared…I heard a whistle, like a bird whistle in the background, it's really quiet behind the water" (P12). Reports that were immersive in quality were often multisensory descriptions of the environment and different aspects had separate start and end points: "I can almost see and hear the wind through the grass, the movement of grass [from] side to side with the wind through the trees. I can't hear it now so much but I can still see waving shapes" (P15). Many reports of visual and auditory perceptions were accompanied by situational 'feels' where the participants indicated that, in addition to their distinct perceptions, they felt that they were located within a very specific situation: "Sounds like water hitting the windscreen then being wiped off, it's like really heavy rain, it's not hissing anymore…I can hear an ambulance. It's really loud, definitely a siren. I feel like I'm in a car, it's raining loads outside and I can hear an ambulance…that ambulance was the most clear thing I've heard" (P1). These reports show a unification of experience. The participants sometimes felt surrounded by their perceptions and they expressed surprise at the immersive quality of what they were experiencing: "I can hear birds tweeting, definitely birds. It sounds like the same pitch as the fireworks. Wow! It really sounds like birds, it's so weird! It's really loud, there are loads of birds. It's so noisy, it sounds like about ten birds all at once" (P1).

Relationship between the number of percepts and the RHS

A correlational analysis was conducted (using the Pearson product–moment correlation coefficient r) to assess the strength of relationship between the total number of distinct perceptual experiences reported during perceptual deprivation and the RHS. There was a positive correlation between the two variables [r=0.61, p<0.001] indicating that participants who scored highly on the RHS also reported more distinct perceptions during perceptual deprivation. The percentage of participants who endorsed particular items on the RHS is shown in Table 2. Importantly, scores on the RHS did not correlate with the STAI (STAI-trait r=0.16; STAI-state r=−0.14, n.s.) or the MC-10 (r=−0.044, n.s.) As such, there is no evidence to suggest that our population was more prone to experience distinct perceptions during perceptual deprivation because they were more anxious or suggestible.

Theme II: the active contribution of the perceiver in generating sensory phenomena

When examining the content of reported perceptions, there is no way to distinguish between whether a participant perceives or *imagines* sensory phenomena. However, when examining the way the content is described, the reports show that participants are constantly trying to check the reality of their perceptions. Overall, they seemed very concerned about the accuracy of their perceptions and their influence upon them. This theme can be exemplified by the following categories.

Reality testing

The reports indicated that participants were not passively describing their mental content; they were actively investigating the invariant stimulus array. At the start of the procedure, the reports indicate that participants' were not experiencing anything notable, just "general hissing" (P19). Even once, they had reported multiple perceptions the participants still frequently described periods where they only perceived white noise and white light: "It's more like white noise now. There are no other sounds" (P12). As with the comparative descriptions used to describe abstract perceptions, this indicates that the participants were experiencing things as distinct from the white noise and they retained the baseline experience of how the stimuli

Table 2 Responses to individual items on the Revised Hallucination Scale (Morrison et al. 2002)

Type of auditory or visual hallucination experienced	Percentage of sample who admitted experiencing these hallucinations (often or almost always)
I can hear music playing when it is not being played	47
The sounds I hear in my daydreams are generally clear and distinct	30
I hear a voice speaking my thoughts aloud	23
I daydream about being someone else	20
I have had the experience of hearing a person's voice and then found out that no-one was there	17
I can hear the telephone ring and find I am mistaken	17
I can hear people call my name and find that nobody has done so	17
I see shadows and shapes when there is nothing there	13
I have seen a person's face in front of me when no-one was there	0
I have been troubled by hearing voices in my head	0

should accurately be heard or seen. As such, their descriptions are specific rather than random.

To some degree, the participants indicated that their perceptions did relate to real events because they made evaluative statements about their perceptual abilities. They often stated that they could get a more vivid perception if they listened or looked more clearly and in some cases this led them to indicate that their earlier perception was erroneous: "It sounds like an alarm clock in the distance beeping. It's fairly fast beeping. I can hear it more clearly now, it's all the same note" (P1). Such perceptual evaluations reveal that the participants are engaging in exploratory processes even if there is nothing to find.

Mental imagery

There were only two instances where a report could be describing the use of mental imagery, however on both occasions, the participant had been previously describing a perception with immersive characteristics: "I can hear like a waterfall, like water moving through different waterfalls and [the] ripples of a stream. And I can picture this big pond of water, and I can see water falling into a big lake, just this heavy gush of water" (P15). Given that all other reports either referred to the participants' perceptual activity: "I can hear…I feel like…" (P16), or the content of the percept: "There's someone coughing…" (P3), "the creaking sound keeps coming back…" (P18) the results strongly suggest that participants were engaged in perceptual activity rather than making use of their imagination.

Attempts to interact

Even though none of the participants ever reported manipulating the content of their perceptions, as would be expected if they were describing the content of their imagination, there were multiple instances where the participants felt that their behaviour was affecting their perceptions. Changes in body position were commonly reported by participants in their verbal descriptions. Some participants had experienced a link between their behaviour and their perceptions: "There are visibly darker pictures moving about, if I keep my eyes straight they get bigger" (P21) and many described how their body movements kept them alert and prevented them from going to sleep. Also, changes in the focus of attention were reported to be linked with the onset and clarity of the percept: "When I concentrate on a noise I can pick it out and it gets louder" (P4). Participants who described their focus of attention often alternated between somatic monitoring of their internal experiences and their external perceptions. This shifting focus was associated with more frequent reports of perceptions. An ANOVA was conducted to assess whether these exploratory behaviours, body repositioning (present or absent) and somatic monitoring (present or absent), had an effect on the number of distinct perceptions reported during perceptual deprivation. There was a significant main effect of somatic monitoring [$F(1, 27)=10.89$, $p=0.003$], a main effect of movement [$F(1, 27)=4.65$, $p=0.04$], and an interaction between monitoring and movement [$F(1, 27)=5.50$, $p=0.027$]. Further analysis of this interaction showed that those participants who did not somatically monitor but who moved more during the procedure reported significantly more perceptions than those who remained still, $t(12)=-4.74$, $p<0.001$. Similarly, those who did not reposition their bodies, but showed somatic monitoring reported significantly more perceptions than those who did not somatically monitor, $t(6.643)=3.76$, $p=0.008$. The results suggest that the number of perceptions reported was significantly higher for participants who either moved or reported somatic experiences than for participants who remained still or did not monitor their somatic perceptions.

Discussion

The results replicate earlier observations that, despite the invariant context, participants report distinct perceptions across a range of sensory modalities. In contrast to previous studies, however, reports of auditory perceptions were far greater than reports of visual perceptions. This could be because participants were told to focus on the white noise during the procedure and therefore most visual perceptions were reported in conjunction with semantically-related auditory perceptions and as such were considered to be multisensory experiences. Consistent with previous studies, there was variation within and between participants' accounts, such that some reports, especially those reported after 20 min of deprivation, could be recognised as more 'meaningful' or complex than others ('Type B' sensations; Zuckerman and Cohen 1964). The most basic reports described noticed variation within the audiovisual stimulus and the most complex or meaningful reports described physical aspects of perceptual phenomena such as its cause, location, direction of movement and effects of the environment. Thematic analysis of the data revealed there was a progression of spatiality in the phenomena reported during perceptual deprivation from noticing simple abstract variations in the stimulus array to fully immersive perceptions of complex multisensory events in the environment. This spatial continuum was preferred to discrete categories because there were many borderline cases that did not fit exclusively into one category or another. For example, some participants reported hearing a specific action (like "spinning"), even though they could not exactly identify what was making the sound. This is meaningful in the sense that it conveys a specific action, yet it is not as meaningful as other reports that also describe the cause, for example, "a skateboard rolling across the floor". In this sense, the descriptions were very different from other non-veridical perceptions which are always perceived in the same way such as illusions, or that fluctuate over an extended period of time such as drug-induced hallucinations. The reports obtained during deprivation are more closely associated with everyday misperceptions which are discounted following further exploration. In this respect, they share some of the same characteristics reported by people with Parkinson's Disease and Charles Bonnet Syndrome in that they are fleeting and do not persist following exploration (Barnes and David 2001; Ffytche and Howard 1999).

The second major theme to emerge from the analysis was the prominence of exploratory behaviour, through which the participants reported having an indirect effect on their perceptions. There were no instances where participants described creating or altering their perceptual experience in a deliberate way and reports that could indicate the use of mental imagery were very rare. The participants interacted with their perceptions through their degree of attention or focus, with many describing the surprising clarity of their perceptions as dependent on their perceptual abilities. Our results therefore seem to concur with Sartre's assertions that imaginings are distinct from perceptions because imagined images are not located in space nor can they be explored for new qualities: "To see an object is to localise it in space, between this table and that carpet, at a certain height, on my right or on my left. However, my mental images do not mix with the objects that surround me" ('The Imaginary'; 2004, pg. 52). The very fact that they can interrogate their perceptions argues against the idea that these are purely imaginary phenomena. In the phenomenological literature, it has been noted by the likes of Husserl ('Phantasy, Image Consciousness and Memory' 2005) and Sartre that perception and imagination are 'qualitatively different'. Perception affords an infinite amount of inspection of an object whereas imagination is impoverished or limited by the input. There is nothing in it apart from what the imaginer puts in; therefore, they can never be surprised by its nature and never learn anything from it. However, our participants were surprised by the phenomena they experienced and so we would argue that they *perceived* rather than *imagined* these events.

Body movements can also be regarded as exploratory activity because changes in body position produced associated changes in perceptual experience. The participants described their body movements as relevant to their experience because their movements prevented them from going to sleep and kept them alert. The participants who demonstrated these exploratory aspects reported significantly more perceptions than those who did not. Previous studies have highlighted the possibility that movement may influence deprivation experience, either by eliciting or dampening it, but the results have been inconsistent (Zuckerman 1964). Our findings indicate that it is only movement for a purpose, namely to engage or explore, that is relevant for deprivation experience. The spatial qualities of perceptions confer the possibility of exploration because they indicate what sensory feedback to expect from physical interaction. The spatial continuum reflects the type of exploratory behaviour that a percept could initiate: noticed variation and perceptions that are not attributed to a cause or location require very general exploratory behaviours such as focussing attention, whereas exploration of the cause of a perception in a specific place would require more specific physical activities such as moving in that direction. The analysis suggests two possible roles for the participants' exploratory activity. It may allow meaning to be imposed onto the invariant context but it may also prevent the perceptions from continuing once disproved which triggers further exploratory activity.

Questionnaire measures such as the RHS and the Launay–Slade Hallucination Scale on which it is based (Bentall and Slade 1985; Launay and Slade 1981), consistently reveal that approximately 10% of healthy participants have experienced auditory and visual hallucinations at some point during their lifetime. In addition, we have confirmed that under conditions of perceptual deprivation, some individuals are even more prone to experience illusory phenomena, and there is a strong association between self-report scores of the propensity to hallucinate and the number of reported perceptual experiences (see also Feelgood and Rantzen 1994; Jakes and Helmsleys 1986). Detailed analysis of the qualitative data revealed that such individuals were more likely to report internal bodily sensations, move more during the experimental procedure and score higher on the RHS compared with those who reported fewer illusory phenomena. They may be more likely to shift attention between somatic monitoring of their own body and the audiovisual stimuli and thereby contribute actively to the experience of illusory sensory phenomena. Our results show that participants are not simply passive recipients of sensory information during the perceptual deprivation procedure. If they were, they would simply report the presence of white noise and a blank white visual field. Instead, they experience a wide variety of complex percepts. The question therefore becomes, "if the sensory environment is not driving these percepts, what is and how is it doing it?" We briefly propose here two theories which might explain how the brain generates illusory phenomena under conditions of perceptual deprivation.

'Top-down' processing by the higher centres of the brain can facilitate perception and there are now numerous examples showing that it exerts its strongest influence when the bottom-up input is impoverished or ambiguous (for a review, see Bar et al. 2006). The cortex produces expectations about the most likely interpretation of the input image, thereby limiting the number of object representations to be considered and hastening (or even creating) object recognition (Elbers et al. 2007). For example, commonly reported sensory phenomena, such as hearing voices on electronic recordings (Electronic Voice Phenomena; Banks 2001), seeing faces in pieces of toast, seeing shapes in clouds and many other cases of pareidolia (Zusne and Jones 1989) can, according to Banks, be explained using the idea of 'projection', where the missing sense is provided (by higher brain centres) based on what the stimulus is most likely to be. It is therefore unsurprising that faces are among the most commonly reported percepts as the brain is hard-wired to recognise faces, which are important for human survival. Similarly, it is unsurprising that voices are most commonly heard in noisy stimuli, particularly when that stimulus is white noise, which covers the whole range of the frequency spectrum. In this way, the brain creates consistency in the world by reality testing and structuring the environment into previously existing schemata. It is this process (of changing non-order into order) which may account for the sensory aberrations seen here.

A second possibility is that perceptual deprivation results in 'disinhibition' or a functional denervation in which a reduction in the range of sensory input 'releases' activity within cortical brain regions and/or lowers the threshold for subsequently presented stimuli (Merabet et al. 2005; Shultz 1965). Research in this area has largely focused on visual hallucinations, whereby reduced sensory input leads to periods of excitation, particularly within the extrastriate region of the visual cortex. When the participant is in an unpatterned sensory environment, they may search for both interoceptive and exteroceptive stimulation. The increased somatic monitoring and movement reported by some of our participants could be due to increased sensitisation to interoceptive and somesthetic sensations because of an absence of competing stimulation from other exteroceptors (i.e. vision and sound), which normally dominate. In support of this hypothesis, there is some preliminary evidence to suggest that hallucinations are more common in conditions characterised by a reduction in the normal level of sensory stimulation, such as in the blind or blindfolded (Merabet et al. 2004) or the deaf (Atkinson 2006).

If perceptual deprivation can, in some individuals, cause them to seek out sensory stimulation, either through increased somatic monitoring and/or lowering of sensory thresholds then this could explain why an unchanging sensory environment can have medical consequences. Studies have shown that patients confined to bed for long periods of time have increased levels of anxiety, delusions and hallucinations (ICU syndrome/psychosis; Dyson 1999). Traditional therapies do not work but light, radio and TV can alleviate the symptoms. Similarly, somatic delusions can be brought on by lying still (the arms and legs can feel numb, or the bed can disappear as if the person were floating in the air; Bexton et al. 1954; Freedman et al. 1961). The body schema breaks down because the link between perception and action is disrupted and the normal relationships between the body and space no longer exist. A review by Allen et al. (2008) proposes a putative neuroanatomical model to account for clinical hallucinations whereby bottom-up sensory regions generate perceptions in the absence of sensory stimuli because of weakened top-down control from the anterior cingulate cortex. Although purely hypothetical at this stage, there may be a continuous interchange between sensory and integrative/association areas of the brain involved in the generation of illusory percepts under conditions of uncertain/ambiguous stimulation. Parietal regions acting as change detectors for visual (parieto-occipital), auditory (temporo-occipital) and tactile (parietal operculum) stimuli have extensive connections with prefrontal cortex (PFC; Downar et al. 2000). If some parietal regions are engaged with invariant auditory and visual stimuli, then PFC may lower the threshold for activation in parietal regions subserving tactile inputs, which may increase the reports of anomalous bodily experience, as seen in some of our participants. The relative contribution of parietal regions and the activation levels of PFC during perceptual deprivation warrant further investigation to support this hypothesis.

Conclusions

To investigate and understand the neural signature corresponding to altered states of consciousness, we must provide 'basic conceptual categories for talking about the true nature of the mental' (Marbach 1993; pg. 9). Our results demonstrate how descriptions of conscious representation can be made more precise by methodologically controlled reflective introspection. We acknowledge that this method of data collection may interfere with the experimental condition by providing stimulation. Such spontaneous verbalisation (continuous report instructions) may produce a 'reward for report' in stimulus hungry individuals and affect the reliability of the reports. There is an indication that participants who talk the most under continuous report instructions also report the greatest amount of deleterious effects (e.g. somatic complaints; Zuckerman 1964). However, we have shown that both qualitative (interpretative phenomenological analysis) and quantitative measures (number of reported experiences and questionnaires) of sensory phenomena can be used to give clear conceptual dimensions by which to develop future theories to test empirically the effects of perceptual deprivation. This could further be combined with cognitive neuroscience methodologies to provide a neurophenomenological account of these effects. For example, recent electroencephalogram (EEG) studies by Pütz et al. (2006) and Wackermann et al. (2008) have shown changes in the alpha rhythm after 45 min of exposure to a multimodal Ganzfeld (homogeneous visual and acoustic field). These and other authors (e.g. Hayashi and Hiroshima 1992) suggest that accelerated alpha activity is associated with an active inhibition of cortical areas processing sensory input, which allows for internally directed attention to dominate (which we would suggest is mediated by PFC). Acceleration of the alpha rhythm was also seen in response to Ganzfeld-induced altered states of consciousness in an earlier study by Wackermann et al. (2002). The Ganzfeld-induced EEG trace was similar (but not identical to) the EEG spectrum of the waking (hypnapompic) state but not sleep onset (hypnagogic state) despite the fact that the subjective experience of visual phenomena was similar. Our findings would suggest that multimodal Ganzfeld and hypnapompic phenomena share an underlying mechanism as both constitute an alteration of attention (see also Sartre, pp. 37–49).

As well as providing testable theories and models of the explanatory mechanisms underlying illusory phenomena and altered states of consciousness, this work could have important real-world applications (Zubek 1969): in understanding performance decrements in individuals performing low-variability tasks for long periods of time (e.g. radar operators, truck drivers; Fiske 1961); getting along in isolated groups (i.e. nuclear submarines and polar station personnel) and clinical sensory deprivation (e.g. eye disorders, orthopaedic wards with bed rest, movement restriction, infection isolation and neurological paralysis; Jackson et al. 1962). In all such situations, individuals report illusory percepts similar to those seen during conditions of perceptual deprivation.

Acknowledgements The authors wish to thank Samantha Rowbotham for help with data collection and Martin Farrell for comments on an earlier draft of the manuscript.

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