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# VISUAL ADAPTATION TO A NEGATIVE, BRIGHTNESS-REVERSED WORLD: SOME PRELIMINARY OBSERVATIONS

**Stuart Anstis, Dept of Psychology, UC San Diego, La Jolla CA 92093**

## Abstract

There have been many studies of visual adaptation to spatial rearrangements, starting with Stratton's (1897) classic studies on adaptation to an upside-down world. These have been reviewed by Rock (1966) and Howard (1982). Luminance information is crucial to such visual tasks as extracting shape from shading and recognising faces. If a picture of bumps and hollows is turned upside down, or reversed in brightness, the perceived depth reverses (Ramachandran 1988). Cavanagh and Leclerc (1989) have shown that shadows are treated as such only if they are darker than unshadowed regions. Extraction of depth by shape from shading seems to be an early process which precedes perceptual grouping (Ramachandran 1988a, b) and pop-out in visual search tasks (Enns 1990). Is shape from shading affected by perceptual experience? Hershenberg (1971*?) showed that chicks reared with grains lit from below preferred to peck at photographs of grains lit from below versus lit from above. If humans adapt to reversed luminance, will they "unlearn" that light comes from above, or that light is brighter than darkness?

In recognising faces, why is it so hard to recognise photographic negatives of famous faces? The Fourier power spectra are identical to those of positives, and the phase spectra nearly so. The difficulty arises only with 3-D lith (black/white) or half tone (gray scale) portraits, not with outline drawings. Probably, luminance reversal disrupts shape from shading which is a crucial step in recognising the 3-D shape of faces. In order to learn whether humans could perform these tasks when normal brightness relations were disturbed, we have studied visual adaptation to a world that was reversed not in position but in brightness.

*Adaptation procedure*. We examined the effects of long exposure to a visual world in which brightnesses were *reversed* by means of a closed circuit video link. During passive adaptation the observer watched TV in negative. During active adaptation he walked about, or sat and viewed his own hands, conversed and interacted with others, while viewing a negative monitor fed from a TV camera. Perceptual phenomena studied before, during and after this adaptation included the perception of highlights and shadows and perception of depth in convex and concave face masks which were lit from above or from below. The observer was also confronted with negative TV images and asked to extract 3-D shape from shading, to recognise facial emotions such as anger, surprise or happiness, and to identify celebrities from their negative faces. It was observed that....*

## Introduction

The most important property of the visual world is luminance. We usually distinguish an object from its background because the object and background have different luminances. There are other cues we can use -- we can distinguish an object from its background even if the two have the same luminance provided that it differs in colour, or in texture, or in motion (Refs?). However, perception is greatly impoverished in an equiluminous coloured world and there is a considerable loss of visual depth, motion and form perception (Livingstone and Hubel 1988). *IRRELEVANT?

"Cavanagh (19**) has shown that faces can be interpreted using shape from shading information, provided only that the shadowed regions are made darker than the non-shadowed regions. He presented a photograph of a face that had been thresholded so that it contained only two levels of lightness. If the uniform grey areas that corresponded to the lighter areas were replaced by random dots, or moving random dots, or even moving random dots in a separate depth plane, then the percept of a face was maintained, provided only that the lightness information was retained by controlling the intensity of the random dots. If the portions of the face that corresponded to the darker area were also replaced by dots, even dots moving in the opposite direction from those in the lighter area, the perception of a face continued. However, as soon as the lightness information was removed, the percept of a face vanishes. This was true despite the fact that any of the other cues such as motion and depth are perfectly capable of eliciting the outlines of the various facial features. They are just not automatically combined to form a face by our visual system. The implication is that lightness information is uniquely important in the recognition of real-world objects." (Quoted from Savoy 1987).

Add: Shadows (Cavanagh and Leclerc 1989). Shape from shading. Face and emotion recognition (Phillips 1972: Bruce 1988*).

## Method

The main device used was a Hitachi VM-5350A VHS colour video camera. This camera has a switch that converts the camera output, and also the view through the viewfinder, from positive to negative. To view the world in negative while walking around, the observer simply held the camera up to his eye and looked through the viewfinder all the time with the other eye patched. The weight of the camera (2.55 kg) was supported on a TriStar Camporter shoulder brace.
Direct viewing through the viewfinder was versatile, since any desired scene could be inspected, and the observer's movements gave good motion parallax cues. A disadvantage was that the view through the finder subtended only *° x *°, and like all TV cameras gave only a monochrome (black/ grey/ white) view.
The camera zoom was pre-set to give a life sized image, and the camera's focus, iris and white-balance controls were set on automatic.

A more comfortable arrangement was used when the observer was seated. Images of the visual world, including the observer's own hands, were inverted in brightness and colour by the camera and displayed on a TV screen. The negative visual image was optically superimposed on the actual position of the object by means of a double sided mirror (Fig. *, after Howard 1982, Fig 12.13, page 519). The observer could reach under the mirror and watch his own hands as he manipulated various objects, and he practised visuomotor coordination by assembling jigsaw puzzles, sculpting modelling clay, playing solitaire with marbles and so on. He also conversed with friends, seeing their faces in negative, and played two-player hand games with them such as shaking hands and thumb wrestling. The TV screen was viewed binocularly.

For more passive visual experience, the subject wore view-restricting goggles and watched TV in negative.

Several tests were run from time to time, before during and after exposure to the negative world, in order to gauge the progress of visual adaptation. These included:

1. *A diary* of informal observations.

2. *Two white hollow plastic face masks* illuminated from above were viewed in negative, with either the hollow or the convex side facing toward the observer. The observer reported on their appearance -- whether they looked convex or concave, and what the perceived direction of illumination was.

3. *3-D shape from shading:* five grey disks, arranged like the five-spot on a die, were flashed up on a computer screen. Each disk was shaded, either pale at the top shading down to dark at the bottom or vice versa. Normally these shadings look like a bulging egg or a hollow saucer respectively. A randomly chosen subset of disks, between 0 and 4, were shaded with pale at the top, and the remainder were shaded with dark at the top. The observer's task was to judge how many disks looked "convex", protruding toward him in depth, and hit a corresponding key labelled from 0 to 4 on a keyboard as quickly and accurately as possible. His responses and his reaction times were recorded. Before any training the observer's scores approached 100%, since after all the task is not a difficult one. Mean reaction times were about 0.8 s. Our interest lay in seeing whether the observer learned to reinterpret the shading cues as a result of his exposure to a negative world, in which shading with pale at the top corresponded to a concave, not a convex surface.

4. *Judging facial expressions of emotion:* thirty drama students were asked to pose the seven following emotions: anger, disgust/contempt, fear, happiness, interest, sadness and surprise. Each black and white portrait was digitized and stored on the computer. To make the subsequent recognition task easier for the observer, the students were asked to overact and to be blatant, not subtle. Thirty files were compiled, each containing the seven emotions expressed by a single actor. The faces in a file were flashed up in random order, and the computer randomly made

each face either positive or negative. The observer's task was to name each emotion as quickly as possible, pressing a key as soon as he made the identification. His response and reaction time was recorded.

5. *Recognising famous faces:* the faces of seventy celebrities were captured and stored on the computer. The faces were culled from news publications, magazines, and books of photographs, and they included well known actors, politicians and public figures. Ten files were compiled, each containing the faces of seven celebrities. The faces in a file were flashed up in random order, and the computer randomly made each face either positive or negative. The observer's task was to name each celebrity as quickly as possible, pressing a key as soon as he made the identification. His response and reaction time was recorded.

One unwanted source of variance in judging facial expressions and recognising famous faces came from individual differences between faces. Some actors are better at expressing emotions than others, and some celebrities are more famous than others. These fortunate few will elicit shorter reaction times than those less talented or less famous. To reduce these effects of this stimulus variability and leave the way clear to assessing response variability, we used the responses to positive photographs as our baseline and took a *ratio*, namely response times to negatives divided by response times to positives. If this ratio changed during the exposure period it would indicate a selective change in perceiving material presented in negative.

*Diary*

When I first sat in the apparatus I felt claustrophobic. The narrow space between the mirror and TV screen hem one in, reducing one's freedom and mobility. I am obliged to sit in a small space on a not too comfortable chair, seeing the world only on a TV screen a couple of feet from my nose. At first the negative picture is confusing and unpleasant. The pictures look like uninterpretable nonsense, and it feels like landing in a foreign country where one speaks not a word of the language. After a little, however, one begins to recognise that one is seeing familiar objects such as chairs, pairs of legs walking about and so on, albeit in disguise, and it feels as though it will become possible to make sense of this new world.

I hold my hands up in front of me and wiggle them. They look familiar, except that they are dark blue, and they definitely feel a part of me. The only odd feature is the black dots on my finger nails, which seem to float a bit loose as I wave my hands about, like flecks of soot which are not securely anchored in place. I suppose they must be highlights reflecting off my nails, although they certainly do not look as if they are. I hold my hands near my chest, and notice that the underside of my hands seem to give off a glow which illuminates my chest. Each hand is like a weak lantern that can illuminate nearby objects, as though my palms were painted with luminous paint. It takes a while to realise that this glow is really the shadow of my hand produced by the diffuse overhead lighting.

As Patricia walks across the room toward me, I notice that her feet are reflected in the polished marble floor. Then I remember that the floor of the laboratory is carpeted, and I realise that these bright "reflections" are really shadows of her feet, seen in negative.

Patricia comes and sits opposite me and I watch her negative face on the TV as we talk. She has dark blue skin and white hair. When she smiles she has "fine black teeth" like Queen Elizabeth I; this is disconcerting, and so is that fact that when she opens her mouth it looks white inside as though she has a lamp inside her mouth. She has white irises in her eyes as though she is wearing silvered contact lenses. When she smiles and frowns I can read her expression quite easily; yet it is hard to recognise that she is Patricia, not Donna or Louise. It seems that in this new negative world emotions are easier to recognise than personal identity.

Patricia goes off to lunch and I play solitaire. Marbles sit in an array of saucer-shaped depressions on a board and I must jump one marble over another, removing from the board each jumped-over marble. My aim is to clear the board leaving only one solitary marble. The idea is that playing with spheres and hollows will provide good visuomotor training that will rapidly recalibrate the contribution of the luminance input into 3-D shape from shading. I am a little clumsy in manipulating the pieces; perhaps the TV image is inadvertently shifted slightly sideways from where it should be, and slightly larger than life size. I never intended to adapt to changes in size or position, but in the real world nothing is quite perfect. I lose at solitaire, ending up with an irreducible five marbles on the board.

The marbles are made of shiny white plastic. On the TV screen each one seems to have a dark nipple painted on it, which remains in the same position even when I rotate the marble with a fingertip. Or perhaps it looks more like an eyeball on which the dark iris remains facing up even when the marble is rotated. The nipple or iris is actually a highlight from the overhead lights. This is intriguing; I look around the room for other shiny and polished objects made of metal or glossy plastic. I hold a piece of polaroid over my eye and rotate it in its own plane to see what happens to the reflections. This has no effect on the TV image! Guiltily I look around to make sure nobody saw me, then I reach out and hold the polaroid over the lens of the camera where it should be. I am not being very intelligent today. I turn the polaroid round and watch the reflections change....

Patricia brings me a sandwich for lunch, but she will not tell me what it is. I am not allowed to look directly at the (positive) sandwich for fear of losing my adaptation, so I have to eat it with my eyes shut. I cannot recognise the taste at first....

I'm out of doors taking a walk, and I can see a black smudge which I assume is a lamp, and rays of darkness are coming out of it as though it is spraying black paint everywhere. The whole scene looks as if Toronto were in a snowstorm-- the dark patches on the pavement look like ice or melting snow, although I know that they

are really patches of light cast on the ground by the street lamps. Now when I first came out I thought it was still daylight, and I saw intensely black spots which I thought were reflections of the sun that might burn the camera tube. I did not realise it was dark outside (it was about 7 pm) and that the black spots were street lamps. So the scene looks like a daylit snowscape to me. Re: this smudge -- as he leant over I saw his hair, which was made dark by the smudge source (in positive: illuminated by the light source). I saw bright shadows stream away from his feet, rather like rays of light emanating from him. I'm looking into the tree and walking back and forth -- I get very nice parallax. There seems to be white stuff among the branches of the tree, like clouds of interstellar gas, although I suppose there are really shadows. They look like white stuff in my way. Motion parallax gives me very nice 3-D as I move back and forth. I was walking up to the staircase and then suddenly thought: Who is that in front of me, getting in my way? I took another look and saw that it was my own shadow falling on the balustrade. This was very sharp-edged, and colored white not black, and of course moved in a very lifelike way (it moved in just the same way as I did). It looked exactly like a person. In the same way when Frank was in front of me he looked like a white silhouette -- I've never seen a white silhouette before.

When I was watching TV I was struck by how beautifully crisp all the moving shapes are, and somehow the movements seemed to enhance that. And I watched a man dancing on the screen, and I could see every movement he made -- his gait was very clear and all his clothes swung around him, and I could see that he was tap dancing to woo a woman. All this was very clear -- he was wearing a straw hat and striped blazer. What was not clear to me was the man's identity. Someone told me that it was Bob Hope, whose face I know very well. I had completely failed to recognise him in negative. So gait and bodily movements seem to read very well in negative, facial identity not well at all. As I watched an actress, I felt that I could read her expressions very well-- smiling, looking away, downcast eyes and so on -- but then when I later saw her in positive I could see many more graduations of color in her face, which gave good 3-D moulding, than in negative. In positive I could see the shadows on her face, and the little red patches of rouge on her cheeks which I could not see in negative. Colors seem much more washed out and desaturated in negative. I don't know if this is a true visual effect, perhaps based on the fact that we are very good at discriminating flesh tones but are perhaps not so good at the opposite regions of the color circle, or whether there is something uninteresting about the TV set so that it does not show up the colors too well. But I think the latter, because I had some differently colored felt pens, which were brilliantly colored in real life, pretty highly colored in positive on TV, but washed out and desaturated in negative, even when we turned up the color controls. I did notice that when I saw this actress' face in positive I could see a lot more gradations in color and I could read much more subtle changes in emotional expression that had been possible in negative. I could recognise her identity -- it was Kate Jackson in the program "Scarecrow and Mrs. King", and I recognised the face of the principal male actor in the same series, although I never knew his name. Again, I immediately recognised Cassius Clay in negative, admittedly in a commercial for

Sports Illustrated which gave a strong context effect. So some identities do shine forth in negative.

I am wearing the blindfold at night. Being blind is not fun. From now on I am going to be very nice to blind people. Have you ever taken a shower in complete darkness? And walking into the bathroom and hanging the towels tidily on the rail, which is trivial for a sighted person, is quite an undertaking when you are blind. How does a blind person deal with a plate of meat and potatoes when he cannot see what he is cutting up? He does not know whether he has gristle or what, on the end of his fork. I soon found myself eating only foods that were easy to handle. Even cereal seems to fall off the spoon more easily when you cannot see it, so I soon found myself falling back on cookies, fish sticks and ice cream bars -- unhealthy junk food, but easy to eat because I can put it straight in my mouth without having to use a knife and fork.

When I watch a face in negative on TV I tend to take the visual message at "face value" -- I tend to perceive the face as wearing dark blue make up, lit from below. So I am not really seeing it as a negative, but as an unfamiliar negative. As for eyes, I notice that the pupil is a white disk (dark in positive) and the bright highlight or corneal reflex is a tiny black dot in negative, which I often misperceive as if it were a small, beady, malevolent pupil. So I am misinterpreting the whole face, and I have to make a conscious effort to perceive this black spot as a highlight and to recognise the white disk as the pupil that it is. When I do try to see things in negative, I am translating deliberately from darks into lights, rather as when first learning French one mentally translates phrases from French into English. What I hope to achieve later is to start to think in the French language, so that I will perceive things correctly from the negative picture without having to translate. Around lunch time -- I'm looking at a Mooney picture, which Harvey presented to me upside down. I immediately knew it was upside down, but I am reading the white parts as though they really are white, -- I am dealing with the negative as though it is a positive.

Saturday afternoon -- Harvey took me out for a walk to look at the traffic. The cars look like Dinky toys -- they lack reality. Each car travels along on a little white platform [which is really its shadow] but somehow being in negative they look like paper cutouts which are harmless. However, they are accompanied by a real man-sized roar of noise which seems much too real to go with the visuals. The sound track is much more real and compelling than the visuals. For example I would not be frightened to cross the road visually, but I would be frightened by the sound, which is just as well because it will keep me safely on the pavement. I then ask Harvey to talk to me, and I found something similar -- his voice was too real to go with his negative picture. This is odd because when I watched negative TV all day, with voices attached to negative faces, I did not notice this phenomenon. On TV it seemed OK because, I think, the faces were manipulated electronically but so were the voices, so they both suffered a concomitant loss in presence and reality. So the voices sounded just as artificial as the pictures looked, and everything matched.

I visited the laundry room and I was really struck by the smell and feel of the hot, scented blast of air that came out as I opened the door. Again, the realities did not seem to match. The negative TV pictures of the machines that I saw through the viewfinder seemed rather detached from reality and the smells seemed too real to belong. So this reality mismatch applied between smell and vision, as well as between hearing and vision.

When I watched people swimming in the pool I noticed that when swimmers kicked up foam, the water appeared to turn black as though ink was momentarily mixed into it, but disappeared when the disturbance subsided and the water fell back into the pool. In real life, of course, foam looks white when bubbles of air mix into the water, and I suppose we must have learned that this happens, so we learn to ignore this that the change is a temporary physical one, not an addition of white pigment to the water. In negative I lost this perceptual constancy and did not make this perceptual connection.

When watching distant tennis players through a nearby wire mesh fence, the mesh looked extremely obtrusive, much more than in real life. Harvey suggested that maybe the camera was focussing on the wire, which it probably was, and he told me of a visual effect named after an ophthalmologist, in which the eye at rest will focus on the nearest object.

When I walk along I find the smallest slope disturbing -- I like my head to know about them ahead of time and not just encounter them with my feet as I go along. When viewing in these restricted conditions I hate surprises. When a branch brushed across my face I froze and found it rather upsetting. It was even worse when my hip bumped into a wall. So I did not like at all when somebody said Go on, march forward, rather as thought they were making fun of my cowardice, because only I know what the hazards are from my point of view. I find that the loss of peripheral vision is even more of a handicap than the video inversion of brightness. This is not a big problem if you are merely trying to avoid bumping into obstacles. You can still see the obstacles perfectly well in negative. Identifying the details within the obstacle is another story. But looking through a tube is a real problem -- maybe this is what retinitis pigmentosa feels like [in which peripheral vision is lost but foveal vision is spared]. There is also some loss of perspective because of the restricted view, and also because of fish-eye distortion from the wide angle TV lens that I am using in an attempt to compensate for the restricted field of view. A good control would be to walk around looking through a camera with a positive viewfinder and see how I get on.

Monday 1.20 pm: Coming out from the adaptation. Negative, in station, looking at Patricia. Flip to positive. Ah, there she is! Here eyes seem to flip across as her pupils change suddenly from light to dark. She looks much far brilliantly colored & saturated. Her hair looks back to normal [from white in the negative picture to its real-life black]. Everything looks more solid & real, more meaty. The toucan has changed into colors that I don't like so much -- its green body in the negative has

changed to a dull pink. The toucan looks less real than in negative, but everything else looks more real. [Bear in mind that I had hitherto seen the toucan only in negative, never before in positive]. I barely recognise... Patricia looks much more real; her face looks much more molded in 3-D and highly rounded, and I can read her facial expressions much more clearly now. My own hand looks much pinker. I can make sense without any trouble of reflections on the glass crystal of my watch as I tilt it back and forth, it has lost the sense of paradox that it had [in negative] when the reflections looked black. Shadows, both cast & attached, on the wooden building blocks give good relief and I see the blocks standing up off the table with a nice 3-D look. Objects look nicer, good enough to eat, candy colored, more plastic, a pleasure to see them back. Everything looks impossibly real, like technicolor film after watching black and white films for a long time, although that's not an exact description of what happened. Now I'm looking at positive TV to record my impressions. Not a cartoon, I want to see real people please. Cartoons are pos neg neutral. Looking now: brisk colors. Face, wow. Flesh-like flesh. Faces look ordinary but more so. Facial expressions look much more vivid than before, I can recognise people easily, there is Madonna. smiles. Change channels. Candy bright, saturated colors, ordinary faces instead of puzzles. Don't have to reason any more, they are just people. No need to study & figure out, just people, Fred & George there. Here is somebody who looks like Jimmy Carter but I know at once that it is not Carter himself; I immediately recognise that I've never seen that person before, I don't have to puzzle over it, life is just *there*.

Hood off, I'm looking at Patricia wow, looking extremely sunburned, with a big smile, more 3D, so rounded & real, she looks much more real and solid. I feel a little dizzy and the world moves slightly when I turn my head, but I don't know whether that is a result of the experiment or just from lack of sleep. More solid, more of her, like real object. Walking around, feel dizzy, but I can't tell you how solid and real the world looks. The room looks messy but it feels so good to be out of prison.

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