Institution: University of Glasgow

Unit of Assessment: Unit 4; Psychology, Psychiatry and Neuroscience

Title of case study: Playing with perception using optical illusions from hybrid image technology

1. Summary of the impact

Research carried out at the University of Glasgow has led directly to the development of hybrid image technology, allowing the creation of optical illusions that have been internationally disseminated in popular culture, architecture, advertising and science education, reflecting their use commercially and non-commercially worldwide. The Marilyn Einstein image, created with University of Glasgow technology, has experienced global popularity and has been included in textbooks and permanent exhibitions in Glasgow and San Francisco. Having featured in educational and entertainment media (including a high-profile 2010 Mercedes-Benz advert) and inspired Michel Mossessian's iconic design of the 5 Merchant Square building in London, hybrid images play on our processes of perception, and have delivered tangible insight into how we observe and understand the world around us.

2. Underpinning research

Visual perceptual processing is the way in which the brain handles external visual information and interprets meaning from what is seen. For example a face can be identified as a male in his mid-30s, often smiling, sometimes sad, etc. This process involves a series of steps. First, the retina (the visual sensor in the eye) captures external visual information. This information is composed of a series of different spatial frequency (SF) bands. Second, the information from the retina has to be transmitted to the brain, where the various SF bands are merged to generate awareness and meaning. However, the visual information received by the retina is constantly changing as individuals interact with their environment (for example, people may bring a book closer to their eyes to resolve its text but step back from a painting or a visual scene to gain an impression of it as a whole). The brain's visual system is therefore confronted with ever-changing information that needs to be processed and interpreted using a bank of SF bands. Hence, characterisation of the critical SF band(s) that enable multiple perceptions of a single piece of visual information is important for our understanding of the link between vision and perception.

In 1994, research at the University of Glasgow led by Professor Philippe Schyns resulted in the development of the 'hybrid image' — a unique visual stimulus that combines two different faces, objects or scenes (or any combination of these categories) across two distinct SF bands[1,2]. In a hybrid image (see Fig. 1), features with high SFs appear as sharp lines whilst features with low SFs appear blurred. When displayed for a brief duration (about 30 milliseconds), hybrid images become bi-stable — that is, both low and high SFs can be perceived. For longer durations, however, the brain preferentially perceives the sharp (high SF) detailed features over the blurred ones (low SF). In the researchers' experimental designs, responses of the observers were recorded so that the SF band used to identify each hybrid image could be measured.

Research stemming from the development and use of hybrid images led to notable discoveries that are now considered to be classic results in the field of perception and demonstrated the flexibility of coding in the visual system:

1. The visual system can be sensitised to one SF band versus the other (e.g. high versus low or vice versa), and thus to the perception of only one of the images comprising the hybrid stimulus[2, 4].

2. Perception of high and low SF information is associated with beta and theta oscillatory activity in the brain, respectively[5], which can be detected by measuring the electrical activity in the brain This suggests that, like a radio tuner, the brain relies on different oscillatory frequencies to interpret different types of information (high SF details or low SF coarse features). The coding of multiple data sources (i.e. across spatial frequency bands) in the brain optimises its coding capacity[7].

3. Mutually exclusive perceptions of the same hybrid image can be flexibly determined depending on the information required by the visual system to categorise the stimulus. For example, in conditions of brief presentation (a few tens of milliseconds), observers would perceive the face in Fig. 1C as that of an angry female on the basis of both high (angry male face) and low SF (neutral female face) information.

Together, these results demonstrated the flexibility of coding of the visual system and have helped

to unravel the interaction between visual information from the outside world and its perception by the brain[6].

The research was predominantly carried out at the University of Glasgow between 1994 and 2013 by Philippe Schyns (PI, Professor of Cognitive Neuroscience, University of Glasgow, 1994–present), Aude Oliva (Post-doctoral fellow, 1995–1997, University of Glasgow, now Associate Research Professor at MIT, USA, where she heads the Computer Science & Artificial Intelligence Lab, which includes a Hybrid Image Gallery built entirely from the research at the University of Glasgow), Roberto Caldara (Post-doctoral fellow, 2004–2007, University of Glasgow, now Professor at University of Fribourg, Switzerland) and Sebastien Miellet (Post-doctoral researcher, 2009–2011, now Lecturer at University of Fribourg, Switzerland).

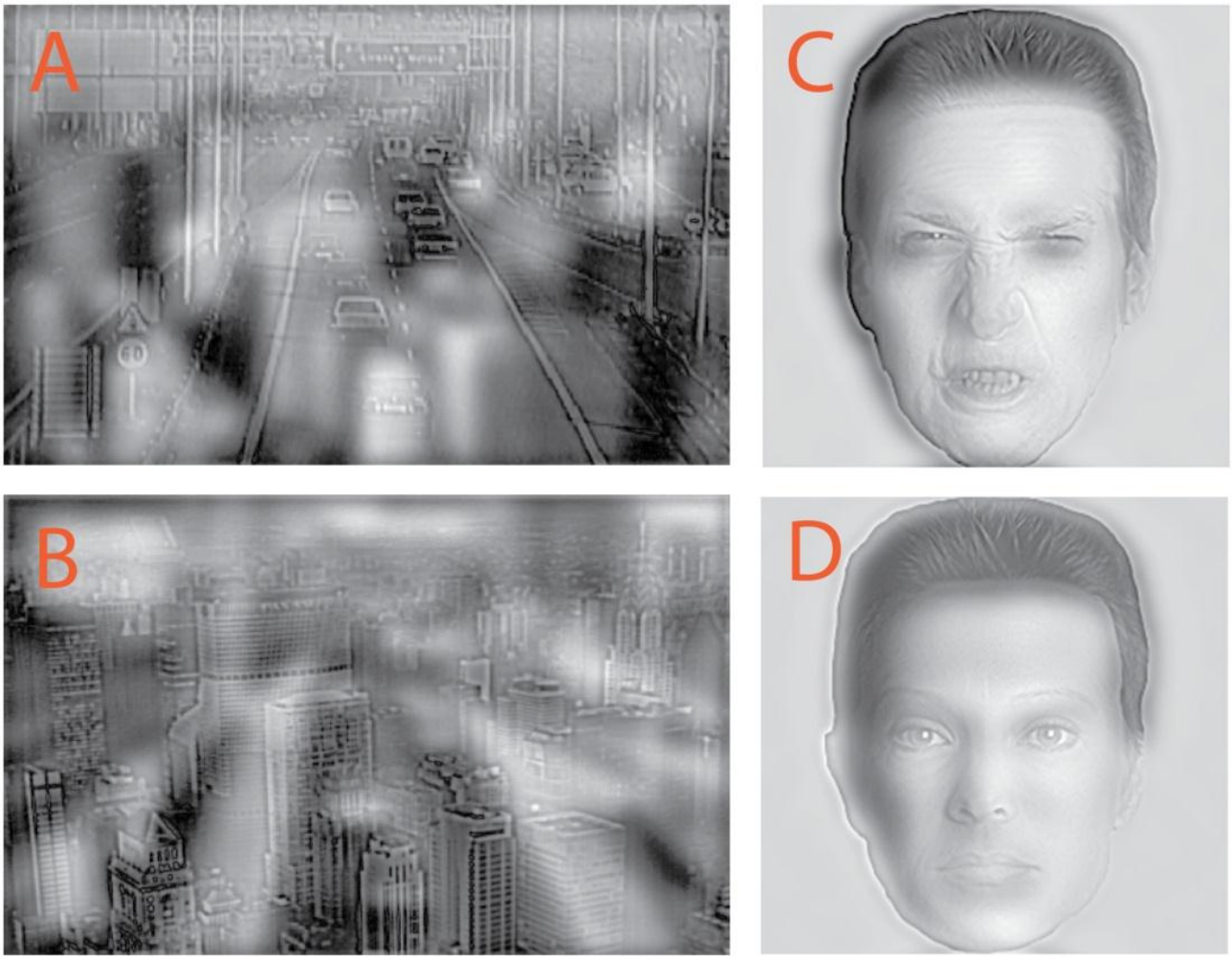


Fig. 1 Hybrid images. Panels A and B show a motorway in high (low) SFs and a city in low (high) SFs. At first glance, the scene in panel A appears as a motorway. However, increasing the viewing distance by a few feet or squinting brings about the perception of a city. The opposite occurs for panel B. Similarly, in panels C and D a male's angry face and a neutral female face are merged at different SFs. Panels A and B reproduced from refs. 1,3; panels C and D reproduced from ref. 3.

3. References to the research

1. Schyns, P. G. & Oliva, A. From blobs to boundary edges: Evidence for time and scale dependent scene recognition. *Psychol. Sci.* 1994; 5, 195–200. doi: 10.1111/j.1467-9280.1994.tb00500.x
2. Oliva, A. & Schyns, P.G. Coarse blobs, or fine scale edges? Evidence that information diagnosticity changes the perception of complex visual stimuli. *Cogn. Psychol.* 1997; 34, 72–107. doi: 10.1006/cogp.1997.0667
3. Schyns, P. G. & Oliva, A. Dr. Angry and Mr. Smile: When categorization flexibly modifies the perception of faces in rapid visual presentations. *Cognition* 1999; 69, 243–265. doi: 10.1016/S0010-0277(98)00069-9

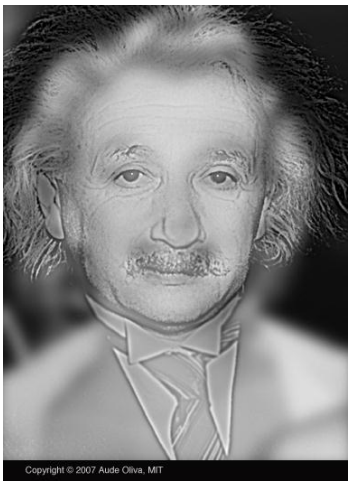
4. Smith, M.L., Gosselin, F. & Schyns, P. G. Perceptual moments of conscious visual experience inferred from oscillatory brain activity. *Proc. Natl Acad. Sci. USA* 2006; 103, 5626–5631. doi: 10.1073/pnas.0508972103
5. Oliva, A., Torralba, A., Schyns P. G. Hybrid images. *ACM Trans. Graphics*, 2006; 25, 527–532. doi: 10.1145/1141911.1141919
6. Miellet, S., Caldara, R. & Schyns, P. G. Local Jekyll and global Hyde: The dual identity of face identification. *Psychol. Sci.* 2011; 22, 1518–1526. doi: 10.1177/0956797611424290
7. Schyns P. G., Thut G., Gross J. Cracking the code of oscillatory activity. *PLoS Biol.* 2011 9: e1001064. doi: 10.1371/journal.pbio.1001064

4. Details of the impact:

The brain interprets complex visual stimuli extremely rapidly; viewers usually interpret a scene within 1/20th of a second, but have little knowledge of the process that leads to their understanding of what they are seeing. By separating information into distinct SF bandwidths, the hybrid image instantly challenges and broadens a viewer's understanding of what they see and how they interpret it. Hybrid image technology[1], developed exclusively by University of Glasgow researchers allows the creation of 'optical illusions' that illustrate the interaction between visual information we receive from the outside world and the brain's perception of that information, which dictates our reaction to what we see. The hybrid image technology allows a multi-layered, complex process to be demonstrated quickly and easily, lending itself to 'popular science' media such as museums, magazines and the internet.

Hybrid image technology has been widely used in commercial, cultural and educational contexts; representative examples are given below to demonstrate the ubiquity of the image.

Marilyn Einstein and Ghostly Gaze: creative impact



Optical illusions produced through hybrid image technology have been disseminated worldwide. The most widely recognised example is the Marilyn Einstein optical illusion[a] (created by Aude Oliva at MIT using the University of Glasgow technology; shown on the left). At different distances, a viewer will perceive either Marilyn Monroe or Albert Einstein. For example, when viewing the image close up (as in the left hand image) a viewer will see Albert Einstein whilst viewing the same image from a distance a viewer will see Marilyn Monroe (as in the right hand image). In July 2013, a search for 'Marilyn Einstein' using Google returned over 6 million entries. The popular Ghostly Gaze hybrid image

(created by University of Glasgow researcher Rob Jenkins) won second prize in the 2008 Visual Illusion of the Year Awards[b] (Vision Sciences, Naples, Florida).

In 2010, media coverage of these two optical illusions inspired the architect Michel Mossessian to design the exterior of his iconic building, 5 Merchant Square, in Paddington, London.[c] In an article in The Independent[d], Mossessian was described as '*tak[ing] architectural perception into entirely new zones'*. Mossessian used an adaptation of the hybrid image technology to achieve his design. From a distance, the building presents an image of cloud formations; up close, it appears shielded from external eyes by drawn curtains. Mossessian called it 'pure perception – a new architectural canvas' and says, '*I wondered how you could give interesting depth to a flat glass façade, a perception that suggested distance, and focus, but with a seamless transition between what you saw from a distance, or from closer*.'[j]

'Far away, a beauty': commercial impact

Hybrid image technology has been widely used for commercial purposes by multinational and UK companies, and is freely available via the University of Glasgow Easy-Access IP scheme. Ads designed by Saatchi & Saatchi for Mercedes-Benz used the Marilyn Einstein hybrid image to help sell the Viano car model in 2010 with the tag line '*Far away, a beauty. Close up, sheer intelligence*.'[e]

The hybrid image is also used by online IT forums and opticians (GlassesDirect.co.uk,

HomeOpticians.co.uk and JustEyewear.com[f,g]) as an initial eye test because the separation of SF bands is an easy indicator of possible vision problems. Software manufacturer Adobe refers customers to an online training library of courses for sale, including one on the creation of dual-image optical illusions (which features Marilyn Einstein).[h] Current industrial interest involves the application of the hybrid image technology in the development of innovative large-scale display technologies that will form large viewing environments for use in open public spaces such as airports.[i]

Textbooks and Exhibitions: educational impact

Hybrid image optical illusions have been the basis for numerous science and popular exhibitions on vision and perception. Marilyn Einstein has been included in the permanent exhibits of the San Francisco Exploratorium since 2003 (550,000 annual visitors)[j] and in the Glasgow Science Centre since 2006 (since April 2011 as part of its Mindworks exhibit; 513,000 annual visitors).[k] The image has also been used at the Exploratorium to explain the process behind vision and perception of images through a series of annual Continuous Professional Development workshops for secondary school science teachers in California (the Exploratorium Teacher Institute's High School Science Summer Institute[l]), and in an online resource for science teachers alongside the original hybrid images shown in Fig. 1C,D. Hybrid images have also been featured on educational and entertainment television programs, such as The One Show (BBC1, October 2009).[m]

Within the formal education sector, hybrid images have been featured in numerous textbooks in the USA and UK,[n] including the 2010 textbook, *Face Processing: Psychological, Neuropsychological, and Applied Perspectives*, published by Oxford University Press and authored by Graham Hole and Victoria Bourne (University of Sussex). In the USA, hybrid images and the relevant research findings are carried in the most recent edition of Sensation and Perception (*Goldstein*, 9th edition, 2013). The hybrid image has also been featured on the covers of *Scientific American* (in 2010 and 2011), and in the *Scientific American Mind* anthology of the best visual illusions (13 September 2011).[o]

5. Sources to corroborate the impact

Creative impact

a. Marilyn Einstein image: Hybrid image gallery, Computational Visual Cognition Laboratory, MIT
b. Ghostly Gaze: 9th Annual Best Illusion of the Year 2008
c. On Office: Workplace, Design, Architecture, Mossessian & Partners in Paddington Basin, 20 January 2011 (Mossessian's use of hybrid image technology) in 5 Merchant Square, Paddington.
d. Article, 'Paddington's Merchant Square building is a bit of a mind-bender', The Independent, 26 November 2010 (influence of research on architect).

Commercial impact

e. Use in Mercedes Benz advertising
f. Glasses Direct
g. Life Hacker Eye Test
h. Use in Photoshop training video
i. Hybrid Image visualization for large viewing environments

Educational impact

j. Exploratorium: Art and Human Perception, San Francisco (permanent exhibit), 2003–present. Facts & Figures showing annual visitor numbers
k. Glasgow Science Centre (permanent exhibit as part of 'Mindworks'), 2006–present. Information obtained from Director of Science at Glasgow Science Centre (available on request)
l. The Exploratorium Teacher Institute's High School Science Summer Institute, 2012 [see: Facial Blur 3 and Facial Blur 5]
m. TV. The One Show, BBC1, 13 October 2009
n. Textbooks featuring hybrid image technology: *Face Processing: Psychological, Neuropsychological, and Applied Perspectives* (2010, ISBN-13: 978-0199235704); *Sensation and Perception* (Goldstein, 9th edition, Feb 2013, ISBN-13: 978-1133958499)
o. Magazines featuring hybrid image technology: *Scientific American Mind*, Foundations of Misperception, May 2010, 20, p26; PDF copy available on request; Scientific American Mind, The Eyes Have It, August 2011, 22, p18–20