Synaesthetic hallucinations induced by psychedelic drugs in a congenitally blind man

Sara Dell'Erba, David J. Brown & Michael J. Proulx*

Crossmodal Cognition Lab
Department of Psychology
University of Bath
Bath BA2 7AY
UK

In Press: *Consciousness and Cognition*

*Correspondence to: m.j.proulx@bath.ac.uk

Abstract

This case report offers rare insights into crossmodal response to psychedelic drug use in a congenitally blind (CB) individual as a form of synthetic synaesthesia. BP's personal experience provides us with a unique report on the psychological and sensory alterations induced by hallucinogenic drugs, including an account of the absence of visual hallucinations, and a compelling look at the relationship between LSD induced synaesthesia and crossmodal correspondences. The hallucinatory experiences reported by BP are of particular interest in light of the observation that rates of psychosis within the CB population are extremely low. The phenomenology of the induced hallucinations suggests that experience acquired through other means, might not give rise to "visual" experience in the phenomenological sense, but instead gives rise to novel experiences in the other functioning senses.

Keywords: synaesthesia, congenital blindness, LSD, psychosis, hallucination

Background

Hallucinations induced by psychedelic drugs often cause synaesthesia-like experiences (Luke & Terhune, 2013), in which a sensorial stimulus in one modality will consistently and involuntarily produce a second concurrent experience in a different one (Ward, 2013). Acquired synaesthesia (Proulx, 2010; Proulx & Stoerig, 2006) or that attributed to drug ingestion, convolve sensory experience from multiple modalities and elicit phenomenon that are not experienced solely in the 'mind's eye', but instead are projected onto a person's reality in real time (Sinke et al., 2012). For example, hearing sounds may trigger a "visual" perception of gustatory flavours (Beeli et al, 2005) or colours (Marks & Mulvenna, 2013). LSD has been shown to robustly induce a form of audio-visual synesthesia in a placebo-controlled study in healthy subjects (Terhune et al., 2016) and similar experiences of in other studies that did not evaluate the induction of the experiences in a synesthetic framework (Schmid et al., 2015; Carhart-Harris et al., 2016; Liechti et al., 2017). Note that these studies, and the current investigation, are not examining developmental synaesthesia, where a person has the condition and a number of its accepted characteristics, such as consistency of the evoked experiences. However, are all characteristics of developmental synaesthesia necessary for the labels of synthetic or temporary-acquire synaesthesia (Proulx & Stoerig, 2006)? A number of researchers have argued that consistency might not be a necessary "gold standard" for the reality of a synesthetic experience, as having a plastic evoked response to an inducer does not necessarily negate its existence (Ward & Mattingley, 2006; Simner, 2012). Therefore even though Terhune and colleagues (2016) might not have found that the LSD-induced experiences were consistent, this does not necessarily suggest that it differs from all forms of developmental synaesthesia. LSD-evoked synthetic synesthetic experiences include marked increases in self-rated visual scale items such as: "sounds seemed to influence what I saw"; "the shapes of things seemed to be changed by sounds and noises"; and "the colors of things seemed to be changed by sounds" (Liechti et al., 2017). Although most studies have focused on developmental synaesthesia, which is posited to arise from existing cross-modal connectivity in the brain (Roux et al, 2011), research on acquired synaesthesia also highlights interesting results. As the plasticity of the nervous system allows the recognition and translation of auditory or tactile patterns into visual images, acquired synaesthesia can be triggered not only through psychedelic drugs, as covered in this report, but also through assistive technology such as sensory substitution devices which convert one type of sensory signal to an alternate one. This non-invasive assistive technology triggers experiences in one modality by converting one type of sensory signal into a different one (Bach-y-Rita, 1967, Proulx, 2010; Ward & Meijer, 2010). Drug induced synaesthesia is both common (Griffiths et al, 2006; 2008; Schmid et al., 2015; Carhart-Harris et al., 2016; Preller et al., 2016; Liechti et al., 2017), and implicated in the production of visual inducers from auditory stimulation (Luke and Terhune, 2013). The most common hallucinogenic substances reported to evoke synaesthesia-like experiences are mescaline (Marks, 1975), LSD (McKenna, 1982; Hofmann, 1983), cannabis (Marks, 1975), and ayahuasca (Shanon, 2003; Fotiou, 2012). Proulx and Stoerig (2006) noted that these sorts of synaesthetic experiences can have very different origins, yet all might have an interesting application in helping to create sensory substitution devices that could evoke the missing sensory modality (e.g., vision) through stimulation of an intact senses (e.g., audition).

Synesthetic phenomena may also be promoted by neurological disorders, including thalamic lesions and sensory deprivation (e.g., blindness). For example, in late blind populations, sound has been shown to elicit ‘visual’ perceptions such as coloured photisms (Niccolai V. et al., 2012; Armel K. et al., 1999 ; Jacobs L. et al., 1981). In a review on colour synaesthesia Safran and Sanda (2015) described an individual blinded by bilateral arteritic anterior ischemic optic neuropathy, who perceived coloured photisms when brushing his teeth or hearing the sound of a handclap. In a second unusual case a late blind individual suffering from retinitis pigmentosa consistently reported seeing his limbs when they were in motion, with cross-modal activation between the visual cortex and proprioceptive inputs posited as an explanation (Safran & Sanda, 2015).

It has been observed that synaesthesia-like events recounted by late blind individuals occur due to activation of the deafferented cortex (Merbet & Pascual-Leone, 2010). While the visual cortex is recruited by other modalities to process sensory information in a functionally relevant manner, very little is known about how visual experience, or crucially the lack of it, impacts the phenomenology of synesthetic hallucinations induced by psychoactive substances. In visual deprivation, auditory to visual synaesthesia is most common (Afra, Funke & Matsuo, 2009) implying that there might be an inordinate likelihood for cross-wiring between these senses in late blind populations. Of course, such “visual” experiences are not found in CB individuals who not only have been deprived of any previous visual experience but also lack the semantic framework to describe phenomena associated with sight.

In this paper, we provide a detailed insight into synesthetic hallucinations as a response to psychedelic drug use in a CB ex-rock music singer (or “rock star” by his own account), identified by the pseudonym Mr Blue Pentagon (BP). BP's personal experience provides us with a unique report on the psychological and sensorial alterations induced by hallucinogenic drugs, including an account of the absence of visual hallucinations, and a compelling look at the relationship between LSD induced synaesthesia and cross-modal correspondences.

Case Report

BP gave informed, oral and written consent for the interview and publication of the results, with the research approved by the departmental ethics committee for the study of multisensory cognition in the visually impaired. BP was born in 1948, two months premature. Due to an over-saturation of oxygen at birth, he suffered from premature retinopathy causing him permanent, congenital blindness. From a young age, he listened to popular composers of the time and attempted to imitate their melodies on his piano at home, although he never received any formal lessons. His passion was kindled and he taught himself how to play the piano. By the age of 16, he was already performing solo in local bars and clubs. Though he worked in a bank for many years, his passion was always playing his own music for an audience and upon moving from his hometown and meeting two other blind musicians, he formed a rock music group. In 1971, after recording a song, the band relocated abroad for six months to work on a new album and by 1984, at the age of 36, BP was a professional keyboard player, singer and entertainer. After several years, his wild and extravagant lifestyle caught up with him (along with multiple incidences of equipment theft) and he decided to return to his day job in a bank, part time.

In the 1970's BP would regularly take a type of LSD called *'Blue Pentagon'*, named after its distinct shape and colour. Additionally, he smoked large amounts of marijuana into his 40s, and experimented with other psychedelics such as mescaline and psilocybin (magic mushrooms).

When asked about his history with taking psychedelic drugs, BP described his experience as follows:

> *"I started taking drugs at a very young age, but the one I felt the most connected with, apart from cannabis, was called 'Blue Pentagon', basically LSD! Every time I did acid, I experienced something new and spectacular. Obviously through the senses which are available to me! I never had any visual images come to me. I can't see or imagine what light or dark might look like. With LSD and cannabis though, I experienced so much through my hearing, touch and emotions that it was already enough for me to take!"*

When under the effect of psychedelic drugs, sensory awareness and connection to emotion is commonly described as being significantly heightened. Magnified emotional experiences take on a profound meaning in the mind of the user, who becomes extremely receptive and susceptible to sounds, facial expressions, gestures, and minor changes within their immediate environment (Grinspoon & Bakalar, 1983, Kaelen et al., 2015). BP noted that during his psychedelic experiences, he felt drawn towards playing with his own voice, often calling out-loud with strange voices and personas:

> *"There was a marked difference between hallucinations and dreaming. On acid, I definitely knew that I was awake, although on unfamiliar territory: not like dreaming. During my psychedelic experiences, whenever I listened to music, I felt as if I was immersed in the most beautiful waterfall ever. The episode of the waterfall was the nearest I ever came to experiencing anything like synaesthesia. The music of Bach's third Brandenburg concerto brought on the waterfall effect. I could hear violins playing in my soul and found myself having a one hour long monologue using different tones of voices. I remember they sounded extremely unique! LSD gave everything 'height'. The sounds coming from songs I would normally listen to became three dimensional, deep and delayed. It seemed that music began coming apart and unravelling. My favourite track began to echo in my mind, as if my brain would hear the music played in the present, but while still hanging on to what I had heard a second before. It was like a tape loop that kept on echoing. This led me to look within and I became more aware of myself and the understanding of life, of people, and the music I was listening to. I felt like my brain was overloaded with information and I could not take all of it in at once! On one of my trips, I remember finding myself touching a tree, on the way to my friend's house. This felt amazing! Just like a tree from the forest, or the jungle. Walking that day felt almost as if I wasn't heavy on land and I was racing at such a tremendous speed that it felt like I was actually flying."*

The interaction of LSD and music in the creation of visual imagery has previously been demonstrated in sighted participants with increased connectivity between the parahippocampal cortex (PHC) and visual cortex posited as a neural substrate (Kaelen et al, 2016). Considering the PHC has been implicated in music-evoked emotion, the action of psychedelics, and mental imagery, it is possible that the 'waterfall effect' arises from links in this brain area through increased connectivity to nonvisual areas as a potential driver of this nonvisual imagery. The original description by BP suggested that the experience was tactile in nature, with somatosensory sensations arising from the auditory experience of the music. We asked him to clarify this experience:

> *"The waterfall experience was limited to one specific piece of music: Bach's Brandenburg concerto number 3. It was almost tactile, but it was so outside my normal parameters of experience that it was the only way I could express it."*

The qualia, or phenomenal experience (Proulx & Stoerig, 2006), evoked by the music was expressed in tactile terms, but his explanation notes that it had other qualities beyond his usual experience of touch. This bears an interesting parallel to how users of sensory substitution devices describe the qualitative experience of "seeing with sound." Auvray, Hanneton and O'Regan (2007) asked participants who learned to use The vOICe to describe which sensory modality most resembled their use of the device. They found that the qualia were at once both task specific (localisation was more like seeing, and object recognition was more like hearing), idiosyncratic (a couple of participants thought of it as being like touch, which was not stimulated at all), and something beyond their normal experience. Yet one aspect of the phenomenal experience that was shared was the feeling of extending their bodies through a tool in a way that created a new sense. They did not have a vocabulary to describe what a new sensory modality would be, and so could only describe it in terms of what it was like through their existing senses (Auvray & Myin, 2009). BP similarly could only make reference to the non-auditory aspect of the musical experience by describing it in tactile terms, though it is possible he was experiencing a new sense just as the users of a sensory substitution device.

When BP listened to human voices under the influence of LSD, he sometimes perceived them being distorted and found it difficult to make sense of the words being spoken. He felt like he had lost his ability to comprehend and formulate language, experiencing a temporary episode of sensory aphasia.

> *"Because I have no visual mental imagery through which I can speak, I perceive things in the senses I possess. In 1971, at a party I remember being able to hear every individual word of what people were saying, but not understanding their meanings. This was quite a frightening experience as I could recognise language and therefore know that they were speaking in English, but it did not make any sense to me. Almost as if I unconsciously forgot it."*

This aphasia described by BP is not uncommon in psychedelic drug use but is normally associated with visual stimulation (Hoffer & Osmond, 1967). For example, when under the influence of psychedelic drugs individuals often struggle to recall the name or function of specific objects but are still able to make effective use of them. While dissociative drugs are most commonly considered to temporarily alter the functioning of speech articulation and language recognition, high doses of psychedelics may also impact many of the same cognitive and perceptual processes (Giannini, 2000).

BP continued to articulate the tactile sensations he experienced:

> *"I felt like I was in a fairyland, in a surreal reality where everything I touched was extremely velvety, almost as if it had a very soft patina on top. Sometimes I could not clench my hands as tight as I wanted to, or maybe I did and did not realise. Once I took acid and marijuana at the same time and I wanted to feel everyone faces so that I could tell each person what I thought of them just by touching their faces. It was a very strange experience as their skin felt so soft, but their eyes, noses and mouths were in some way distorted."*

Research has demonstrated that enhanced overstimulation of sensory apparatus manifests in optical, acoustic and tactile hallucinations (Leuner, 1968). In drug-induced synaesthesia, all kinds of sensory stimulation (bar ordinal sequences) can lead to visual experiences (Shanon, 2003). Sounds are most often reported as inducers, but also haptic, gustatory, olfactory, pain, or emotional stimuli can be translated, mainly to the visual domain (Leuner, 1962). Synesthetic effects are likely the result of how a message is assessed emotionally rather than what the content is (Delay et al., 1951; Mayer-Gross, 1931). BP further describes how the perception of time was altered whilst he was under the influence of psychedelic drugs:

> *"I often felt it took me so long to do certain things, it was like LSD also made time last longer. I know it is not scientifically possible to stretch time, but that's what it felt like. Once I was with an ex-girlfriend of mine and just after taking LSD, the time we spent together absolutely never ended!"*

However, BP also shares his thoughts on how this long-term usage of LSD affected him:

> *"I realised that the drug often altered the way I thought about things, as I had much deeper thoughts. My dreams have always been very vivid in the past, but when I was under the*

influence of LSD, I would occasionally find myself dreaming in prose. I 'm unable to use my visual imagination and therefore whenever I dream of something, places are not important and I rarely know where I am. The only things I remember are the sounds and the events happening in the dream. When I took LSD, I couldn't always sleep, but if I did my dreams would be extremely detailed, sometimes even in very wordy Shakespearian language, often lasting longer than my normal dreams.

Absence of visual hallucinations among congenitally blind were further explored by Ring and Cooper, (2008) who documented accounts of blind interviewees having near-death experiences and reporting what they regard as visual percepts. Visual experiences were reported by some two-thirds of the 14 congenitally blind participants in their study, offering interesting cues on the question of whether one sees with the eyes or with the eyes of the mind. To finish, BP expressed that when 'tripping' with two other common psychedelic drugs: psilocybin mushrooms and mescaline, the experience felt a lot more personal, introspective, and revelatory rather than engaging and recreational.

"When I tried mushrooms my experience was not as rich as I was used to. I just went to sleep and they didn't do much to me. Whereas when I had mescaline I felt a lot more contemplative and I was more aware of my thoughts, in such a way that made me very conscious that the substance was altering my mind in some way. Having mushrooms and mescaline was a very different trip from the experiences LSD gave me, as they just took over my thoughts."

BP emphasises that whenever he used psychedelic drugs, he felt a more harmonious connection to sound, touch and smell as conjoined magisterial, although sound had always been the component that most captivated his attention:

"*Sound, touch and smell were experienced at the same time, whenever I took any drug, but it was always the sounds that played a big, big part. Probably the most important part during all of my trip experiences. I guess my auditory experiences just did it for me!*"

In 1975, BP decided to stop using hallucinogens as he reflects:

> *"I think that at some point I had enough, not of the experiences itself, because, believe me, they were just so incredible, but I felt I was starting to go into myself too much... becoming quite antisocial and a bit paranoid with people. Therefore, I began thinking that people were saying nasty things about me, probably because of the huge amounts of dope I was constantly eating... So I stopped taking drugs as I got quite worried. I was in denial about the paranoia which gradually overcame me for years. I knew it was happening, and after smoking cannabis I was a little low for a while, but marijuana was such a part of my lifestyle that I couldn't give it up until 1993, when I started playing competitive chess."*

Discussion

This case study is, to our knowledge, the first qualitative account of the phenomenological experience of LSD use in a CB subject, and implies that psychedelic drugs may induce temporary acquired-synaesthesia, sensory aphasia and distortion of time perception in this population. BP's personal experience allows us to comment on three main points. Firstly, the absence of visual hallucinations; second, the quality and intensity of the experience, and finally, the relationship between LSD induced synaesthesia and cross-modal correspondences.

This case study corroborates Krill et al's (1963) observation that visual hallucinations are absent in CB individuals, creating a fascinating crucible to look at the interesting question of whether peripheral and central visual pathways are fundamental for the cross-modal cortical development associated with visual hallucinations. The effects of visual deprivation during the critical period in the development of vision are well documented in studies on kittens (Wiesel & Hubel, 1965), non-human primates (Hubel et al, 1977) and humans. In the latter, regions of the brain normally associated with processing visual information have been shown to undergo remarkable dynamic changes in response to blindness, with implications for both the processing carried out by the remaining senses (Proulx et al, 2014) and enhancement of higher cognitive functions such as language and memory (Amedi A. et al., 2005; Pasqualotto, Lam & Proulx, 2013).

Drug-induced synaesthesia occurs primarily as a result of auditory, kinesthesic, and olfactory cross-modal perceptions, raising questions of how increased connectivity between the occipital lobe and temporal and prefrontal regions in early blind individuals (e.g. Noppeney et al., 2003; Leclerc et al., 2005) can result in a more effective and efficient networking and processing. BP reflected on not having a visual “mind's eye” as a strength, believing that the heightened feelings of pleasure and intimate emotional connectivity associated with tactile and auditory hallucinations as being the greater gift. Such emotional connectivity and ego dissolution is commonly described in users of psychedelics with LSD posited to increase both neural global connectivity and the subsequent perceptual boundaries between ‘self’ and the environment (Tagliazucchi et al, 2016). On one occasion BP described what appears to be an episode of reversible sensory aphasia where he could recognise spoken words but not understand the meaning or syntax. While this, anecdotally, is a commonality in LSD use in sighted populations Wright et al (1972) found no difference between LSD users and controls on aphasia tests. BP also experienced a perception of time distortion, a common effect induced by psychedelic drugs (Grinspoon & Bakalar, 1983). After a few years of use, BP found himself becoming introverted and paranoid, with his experiences often resembling those of psychotic patients. This is possibly the only case of apparent drug-induced psychosis in a CB subject described in literature.

In regard to LSD induced synaesthesia, previous investigations utilising mild doses of LSD found that auditory tones elicited visual disturbances, such as increased luminance, geometric shapes and chromatic photisms, in less than 50% of participants (Hartman & Hollister, 1963). While largely absent from congenital synaesthetes, the described experience of multiple sensory synaesthesia is reported as far back as the 1920s by Heinrich Klüver with his experiments with mescaline. Furthermore, Luke and Terhune (2013) noted additional informal experiments, case studies and surveys that support the notion of induced audio-visual synaesthesia and more spontaneous synaesthesia-like experiences under LSD (Terhune et al, 2016). However, the lack of direct experiments makes comment on the qualitative attributes of these hallucinations indeterminate.

While this study offers valuable insight, several limitations provide scope for future research. Firstly, independent evidence confirming the occurrence of the experiences, of genuine behavioural synaesthesia, and of the respondent’s status as being ‘congenitally’ rather than ‘early’ blind is lacking, and secondly, as this paper explores events which happened over 40 years ago, the reliance on self-report is another limitation to consider. However, since LSD appears to have wide reaching effects and induces qualitative changes in audio-visual perception, its use within carefully controlled research settings may shed light on whether the mechanisms that give rise to audio-visual correspondences (Spence, 2011) remain intact during the psychedelic experience, and influence the nature of the disturbances. Naturally, this raises an interesting question - how does the total deprivation of sight, the primary sensory experience, impact the experience of hallucinogenic substances.

In conclusion, this case study offers rare insight into the phenomenon of synaesthesia induced by hallucinogens in a CB individual, supporting prior research on cross-modal sensory experience through visual qualia and sensory substitution (Proulx & Stoerig, 2006), as well as providing important information on the phenomenology of visual hallucinations and synaesthesia in this population.

Acknowledgements

This work was funded in part by an EPSRC grant (EP/J017205/1) to MJP. We thank members of the Crossmodal Cognition Lab for conversations about this case study.

References

Amedi, A., Merabet, L., Bermpohl, F., & Pascual-Leone, A. (2005). The occipital cortex in the blind: lessons about plasticity and vision. *Current Directions in Psychological Science, 14,* 306–311.

Armel, K. C., & Ramachandran, V. S. (1999). Acquired synesthesia in retinitis pigmentosa. *Neurocase*, 5, 293–296.

Afra, P., Funke, M. & Matsuo, F. (2009). Acquired auditory-visual synesthesia: A window to early cross-modal sensory interactions. *Psychology Research Behavioral Management, 2,* 31–37.

Auvray, M., Hanneton, S., & O'Regan, J. K. (2007). Learning to perceive with a visuo-auditory substitution system: Localization and object recognition with The Voice. *Perception, 36,* 416–430

Auvray, M., & Myin, E. (2009). Perception with compensatory devices: from sensory substitution to sensorimotor extension. *Cognitive Science, 33*(6), 1036-1058.

Beeli, G., Esslen, M., & Jäncke, L. (2005). Synaesthesia: when coloured sounds taste sweet. *Nature, 434,* 38.

Carhart-Harris RL, Kaelen M, Bolstridge M, Williams TM, Williams LT, Underwood R, et al. (2016). The paradoxical psychological effects of lysergic acid diethylamide (LSD). *Psychological Medicine,* 46: 1379-1390

Delay, J., Gérad, H. P., & Racamier, P. C. (1951). Les synesthésies dans l'intoxication Mescalinique. *L'Encephale, 40*, 1–10

Erowid, LSD (Acid) Vaults : LSD Tablet and Blotter Contents, 1968-1974, accessed https://www.erowid.org/chemicals/lsd/lsd_history1.shtml

Fotiou, E. (2012). Working with “la medicina”: Elements of healing in contemporary ayahuasca rituals. *Anthropology of Consciousness, 23*, 6–27.

Giannini, J. M. D. (2000). Chemical Abuse Centers, Inc.,Austintown, Canton and Columbus, Ohio. *American Family Physician, 61*(9), 2763-2774.

Griffiths, R., Richards, W., Johnson, M., McCann, U., & Jesse, R. (2008). Mystical-type experiences occasioned by psilocybin mediate the attribution of personal meaning and spiritual significance 14 months later. *Journal of Psychopharmacology*, *22*, 621-32.

Griffiths. R., Richards, W., McCann, U., & Jesse, R. (2006). Psilocybin can occasion mystical-type experiences having substantial and sustained personal meaning and spiritual significance. *Psychopharmacology*, *187*, 268-83.

Grinspoon, L., & Bakalar, J. B. (1983). *Psychedelic reflections*. New York: Human Sciences Press.

Grob, C. S., McKenna, D. J., Callaway, J. C., Brito, G. S., Neves, E. S., Oberlender, G., Saide, O. L., Labigalini, E., Tacla, C., Miranda, C. T., Strassman, R. J., & Boone, K. B. (1996). Human psychopharmacology of Hoasca, a plant hallucinogen used in ritual context in Brasil. *Journal of Nervous & Mental Disorders, 184,* 86-94.

Hartman A. M., Hollister L. E. (1963). Effect of mescaline, lysergic acid diethylamide and psilocybin on color perception. *Psychopharmacologia, 4,* 441–451.

Hoffer, A., & Osmond, H. (1967). *The Hallucinogens.* New York: London Academic Press.

Hoffman, A. (1983). *LSD: My Problem Child*. New York: J. P. Tarcher.

Hubel, D. H., Wiesel, T. N., & LeVay, S. (1977). Plasticity of ocular dominance columns in monkey striate cortex: a discussion on structural and functional aspects of plasticity in the nervous system. *Philosophical Transactions of the Royal Society of London. Series B,* *Biological Sciences*, *278*, 377-409.

Jacobs, L., Karpik, A., Bozian, D., & Gøthgen, S. (1981). Auditory–visual synesthesia: Sound-induced photisms. *Archives in Neurology*, *38*, 211–216.

Kaelen, M., Barrett, F. S., Roseman, L., Lorenz, R., Family, N., Bolstridge, M., & Carhart-Harris, R. L. (2015). LSD enhances the emotional response to music. *Psychopharmacology*, *232*, 3607-3614. doi: 10.1007/s00213-015-4014-y

Kaelen, M., Roseman, L., Kahan, J., Santos-Ribeiro, A., Orban, C., Lorenz, R., Barrett, F.S., Bolstridge, M., Williams, T., Williams, L., Wall, M.B., Feilding, A., Muthukumaraswamy, S., Nutt, D.J., & Carhart-Harris, R. (2016). LSD modulates music-induced imagery via changes in parahippocampal connectivity. *European Psychopharmacology*, *26*, (7), 1099-1109.

Klüver, H. (1966). *Mescal and mechanisms of hallucinations*. Chicago, IL: University of Chicago Press.

Krill, A. E., Alpert, H. J., & Ostfeld, A. M. (1963). Effects of a hallucinogenic agent in totally blind subjects. *Archives of Ophthalmology*, *69*, 180-185.

Leclerc, C., Segalowitz, S. J., Desjardins, J., Lassonde, M., & Lepore, F. (2005). EEG coherence in early-blind humans during sound localization. *Neuroscience Letters, 376*, 154–159.

Leuner, H. (1962). *Die experimentelle Psychose.* Berlin: Springer.

Leuner, H. (1968). In J. M. Shlien (Ed.), *Basic functions involved in the psychotherapeutic effect of psychomimetics.* Washington, DC: American Psychological Association, Inc.

Liechti, M.E., Dolder, P.C., Schmid, Y. (2017). Alterations in consciousness and mystical-type experiences after acute LSD in humans. *Psychopharmacology* (Berl), 234: 1499-1510.

Luke, D. P., & Terhune, D.B. (2013). The induction of synaesthesia with chemical agents: a systematic review. *Frontiers in Psychology*, *4*, 753.

Manford, M., & Andermann, F. (1998). Complex visual hallucination: clinical and neurobiological insights. *Brain*, *121*, 1819-1840.

Merabet, L. B., & Pascual-Leone, A. (2010). Neural reorganization following sensory loss: The opportunity for change. *Nature Reviews Neuroscience, 11,* 44 –52

Marks, L. E. (1975). On coloured-hearing synaesthesia: cross-modal translations of sensory dimensions. *Psychological Bulletin, 82*, 303–331

Marks, L. E., & Mulvenna, C.M. (2013). Synesthesia on our mind. *Theoria et Historia Scientiarum*, *10*, 13-35.

Mayer-Gross, W. (1931). Über synästhesien im meskalinrausch. In G. Anschütz (Ed.), *Farbe-Ton-Forschungen Bd. III* (pp. 266–277). Hamburg: Psychologisch- ästhetische Forschungsgesellschaft.

McKenna, T. (1982). *Food of the Gods.* London: Bantam.

Merabet, L. B., Maguire, D., Warde, A., Alterescu, K., Stickgold, R., & Pascual-Leone, A. (2004). Visual hallucinations during prolonged blindfolding in sighted subjects. *Journal of NeuroOphthalmology*, *24*, 109-13.

Merabet, L. B., Pascual-Leone, A. (2010). Neural reorganization following sensory loss: the opportunity of change. *Nature Reviews Neuroscience, 11*, 44–52.

Niccolai, V., Van Leeuwen, T. M., Blakemore, C., & Stoerig, P. (2012). Synaesthetic perception of colour and visual space in a blind subject: an fMRI case study. *Consciousness & Cognition, 21*, 889–899.

Nichols, C. D., & Sanders-Bush, E. (2001). Serotonin receptor signaling and hallucinogenic drug action. *Heffter Review of Psychedelic Research, 2*, 73-79.

Noppeney, U., Friston, K. J., & Price, C. J. (2003). Effects of visual deprivation on the organization of the semantic system. *Brain, 126*, 1620–1627.

Petri, G., Expert, P., Turkheimer, F., Carhart-Harris, R., Nutt, D. J., Hellyer, P., & Vaccarino, F. (2014). Homological scaffolds of brain functional networks. *Journal of the Royal Society, Interface / the Royal Society, 11*, 20140873.

Pasqualotto, A., Lam, J. S., & Proulx, M. J. (2013). Congenital blindness improves semantic and episodic memory. *Behavioural Brain Research*, *244*, 162-165. doi: 10.1016/j.bbr.2013.02.005

Preller, K. H, Vollenweider FX (2016). Phenomenology, structure, and dynamic of psychedelic states. *Current Topics in Behavioral Neuroscience,* 10.1007/7854_2016_459.

Proulx, M. J. (2010). Synthetic synaesthesia and sensory substitution. *Consciousness & Cognition, 19*, 501-503. doi: 10.1016/j.concog.2009.12.005

Proulx, M. J., & Stoerig, P. (2006). Seeing sounds and tingling tongues: Qualia in synaesthesia and sensory substitution. *Anthropology & Philosophy, 7*, 135-151.

Proulx, M.J., Brown, D.J., Pasqualotto, A., & Meijer, P. (2014). Multisensory perceptual learning and sensory substitution. *Neuroscience & Biobehavioral Reviews*, *41*, 16-25. doi: 10.1016/j.neubiorev.2012.11.017

Ring, K., & Cooper, S. (2008). *Mindsight: Near-death and out-of-body experiences in the blind* (2nd ed.). New York: iUniverse.

Roux, R., Scholte, H. S., & Colizoli, O. (2011). Brain areas involved in synaesthesia: a review. *Journal of Neuropsychology, 5*, 214-42.

Safran, A. B., & Sanda, N. (2015). Color synesthesia. Insight into perception, emotion, and consciousness. *Current Opinion in Neurology, 28*, 36.

Shanon, B. (2003). Three stories concerning synaesthesia: a commentary on Ramachandran and Hubbard. *Journal of Consciousness Studies, 10*, 69–74.

Schmid Y, Enzler F, Gasser P, Grouzmann E, Preller KH, Vollenweider FX, et al. (2015). Acute effects of lysergic acid diethylamide in healthy subjects. *Biological Psychiatry* 78: 544-553.

Simner, J. (2012). Defining synaesthesia. *British Journal of Psychology*, *103*(1), 1-15.

Sinke, C., Neufeld, J., Zedler, M., Emrich, H. E., Bleich, S., Münte, T. M., & Szycik, G. R. (2012). Reduced audiovisual integration in synesthesia – evidence from bimodal speech perception. *Journal of Neuropsychology*. 8, 94–106.

Spence, C. (2011). Cross-modal correspondences: a tutorial review. *Attention, Perception, & Psychophysics, 73,* 971-95.

Tagliazucchi, E., Roseman, L., Kaelen, M., Orban, C., Muthukumaraswarmy, S.D., Murphy, K., Laufs, M., Leech, R., McGonigle, J., Crossley, N., Bullmore, E., Williams, T., Bolstridge, M., Feilding, A., Nutt, D.J., & Carhart-Harris, R. (2016). Increased global functional connectivity correlates with LSD-induced ego dissolution. *Current Biology*, 26, (8), 1043-1050.

Terhune, D. B., Luke, D. P., Kaelen, M., Bolstridge, M., Feilding, A., Nutt, D., Carhart-Harris, R., Ward, J. (2016). A placebo-controlled investigation of synaesthesia-like experiences under LSD. *Neuropsychologia, 88,* 28-34.

Ward, J. (2013). Synesthesia. *Annual Review of Psychology*, *64*, 49–75.

Ward, J., & Mattingley, J. B. (2006). Synaesthesia, An overview of contemporary findings and controversies. *Cortex, 42*, 129-36.

Wiesel, T. N., & Hubel, D. H. (I965). Comparison of the effects of unilateral and bilateral eye closure on cortical unit responses in kittens. *Journal of. Neurophysiology*, 2l (8), 1029-1040.

Wright, M., & Hogan, T. P. (1972). Repeated LSD ingestion and performance on neuropsychological tests. *The Journal of Nervous and Mental Disease, 154*(6), 432-438. doi:10.1097/00005053-197206000-00005