REVIEW

Symptoms related to the visual system in migraine [version 1; peer review: 2 approved]

Robin M. van Dongen ¹, Joost Haan^{1,2}

¹Department of Neurology, Leiden University Medical Centre, Albinusdreef 2, 2333 ZA, Leiden, The Netherlands

²Department of Neurology, Alrijne Ziekenhuis, Simon Smitweg 1, 2353 GA, Leiderdorp, The Netherlands

V1 First published: 30 Jul 2019, 8(F1000 Faculty Rev):1219
<https://doi.org/10.12688/f1000research.18768.1>

Latest published: 30 Jul 2019, 8(F1000 Faculty Rev):1219
<https://doi.org/10.12688/f1000research.18768.1>

Abstract

Migraine is a common headache disorder characterized by often-severe headaches that may be preceded or accompanied by a variety of visual symptoms. Although a typical migraine aura is not difficult to diagnose, patients with migraine may report several other visual symptoms, such as prolonged or otherwise atypical auras, “visual blurring”, “retinal migraine”, “ophthalmoplegic migraine”, photophobia, palinopsia, and “visual snow”. Here, we provide a short overview of these symptoms and what is known about the relationship with migraine pathophysiology. For some symptoms, the association with migraine is still debated; for other symptoms, recent studies indicate that migraine mechanisms play a role.

Keywords

migraine aura, prolonged aura, persistent aura, retinal migraine, ophthalmoplegic migraine, photophobia, palinopsia, visual snow

Open Peer Review

Approval Status

	1	2
version 1 30 Jul 2019

Faculty Reviews are review articles written by the prestigious Members of **Faculty Opinions**. The articles are commissioned and peer reviewed before publication to ensure that the final, published version is comprehensive and accessible. The reviewers who approved the final version are listed with their names and affiliations.

1. **Christoph J. Schankin**, University of Bern, Bern, Switzerland
2. **Andrew Charles**, David Geffen School of Medicine at the University of California, Los Angeles, USA

Any comments on the article can be found at the end of the article.

Corresponding author: Robin M. van Dongen (r.m.van_dongen@lumc.nl)

Author roles: **van Dongen RM:** Conceptualization, Writing – Original Draft Preparation, Writing – Review & Editing; **Haan J:** Conceptualization, Writing – Review & Editing

Competing interests: No competing interests were disclosed.

Grant information: The author(s) declared that no grants were involved in supporting this work.

Copyright: © 2019 van Dongen RM and Haan J. This is an open access article distributed under the terms of the [Creative Commons Attribution License](#), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

How to cite this article: van Dongen RM and Haan J. **Symptoms related to the visual system in migraine [version 1; peer review: 2 approved]** F1000Research 2019, **8**(F1000 Faculty Rev):1219 <https://doi.org/10.12688/f1000research.18768.1>

First published: 30 Jul 2019, **8**(F1000 Faculty Rev):1219 <https://doi.org/10.12688/f1000research.18768.1>

Introduction

Symptoms related to the visual system are common in migraine, a neurovascular brain disorder characterized by episodes of often-severe headache lasting between 4 hours and 3 days¹. In almost one third of patients with migraine, the headache is preceded by a visual aura² but there are several other visual symptoms related to migraine. The purpose of this narrative review is to provide a brief overview of these visual symptoms. Because migraine prevalence is high—lifetime prevalences are 33% in women and 13% in men²—many physicians, especially general practitioners, neurologists, and ophthalmologists, will see patients with migraine. First, as background, the typical migraine aura is discussed, followed by the differential diagnosis of atypical auras. Next, visual symptoms other than migraine aura are reviewed: photophobia, palinopsia, and visual snow.

Typical visual migraine aura

In its most typical form, a visual aura begins with a “scintillating scotoma”, a small blind spot with a flickering, brightly colored, and typically jagged front—the so-called fortification spectrum—that generally expands in a C-shape to one side of the visual field (Figure 1)^{1,3}. The expansion is gradual and lasts between 5 and 60 minutes¹. These visual symptoms are fully reversible and should not be accounted for by another disorder,

Figure 1. Example of a migraine aura. This picture illustrates the typical gradual expansion of a migraine aura along with the characteristic fortification spectrum.

according to the third edition of the International Classification of Headache Disorders¹. The positive symptoms often take shapes other than a classic fortification spectrum. Patients commonly report that the aura starts with light flashes or balls of light that gradually expand across the visual field^{4,5}. Furthermore, positive symptoms do not have to occur; patients can also report that the scotoma (that is, the blind spot or the hole in the visual field) has no colors or jagged lines. When patients close their eyes, the positive features of an aura remain visible. Besides having visual symptoms, patients may experience sensory symptoms, speech problems, and sometimes motor symptoms during their auras¹. If a person has had two attacks fulfilling criteria for migraine with aura, he or she is classified as a migraine with aura patient¹. If a person has only attacks without aura, he or she is classified as migraine-without-aura. Migraine with aura patients can still have attacks without aura. In a general-population study, median attack frequency was 12 attacks per year and 25% of patients with migraine had at least two attacks per month².

Gradual expansion is considered the most typical feature of a migraine aura¹. This corresponds with the suspected underlying pathophysiological mechanism called “cortical spreading depolarization” (CSD): a wave of intense neuronal and glial depolarization that is followed by neuronal depression. Pre-clinical and clinical studies suggest that the velocity of CSD through the occipital cortex is in line with the velocity of the visual spread observed by patients^{6–8}. Patients can report a classic cascade in aura symptoms: the aura starts with visual symptoms and is followed by sensory symptoms, aphasia, and sometimes motor problems⁹. It is believed that in these cases the CSD expands from the occipital cortex to the motor cortex¹⁰. However, a prospective diary study showed that in 34% of patients the aura symptoms start simultaneously, suggesting that CSD may also start in a non-symptomatic brain area and reach two cortical areas at about the same time^{5,11}. Sometimes patients report complex visual phenomena during their auras, such as distortions of observed body parts (for example, disproportionately large ears, sometimes referred to as the Alice in Wonderland syndrome) or visual splitting (one half of the observed face shifts upwards or downwards)^{3,12,13}. This suggests that more complex processes of visual perception, involving orientation and size, can also be altered during migraine attacks. Additionally, patients often report that during migraine auras their vision is “blurred” or “foggy” or that they see “heat waves”. In the diary study, this was registered in 33% of auras⁵. However, information on gradual expansion was not collected. Furthermore, these symptoms have not been prospectively studied in migraine without aura patients. Therefore, there is still discussion about whether these symptoms are part of the aura spectrum.

In most patients, the aura is followed by a migraine headache. Typically, the headache starts after the aura has ended, although the headache can also start during or—in rare cases—before the aura^{5,9,14}. In a minority of attacks, the aura is not followed by headache^{4,9} and this classically occurs in elderly patients and is often referred to as “late-life migraine accompaniments”¹⁵.

Current acute migraine medication is able to treat the headache only and has no effect on the auras. Preventive drugs such as beta-blockers, candesartan, topiramate, valproate, and amitriptyline and nortriptyline are generally considered when patients have an average of more than two attacks per month. When successful, the auras can also be prevented. For patients with frequent auras, lamotrigine can also be tried¹⁶.

Atypical visual migraine auras

Atypical auras are important to identify because of the differential diagnosis with other diseases. First, migraine auras can mimic stroke because of the homonymous visual field defects or additional focal symptoms¹⁷. However, in migraine aura, symptoms gradually develop whereas in stroke they are often maximal from the start. Furthermore, classic aura features (colors and zig-zag lines) are generally not present in stroke¹⁸. Nonetheless, it can be hard to discriminate between the two diagnoses and other clinical factors such as age and cardiovascular risk factors should be taken into account. When the aforementioned “late-life migraine accompaniments” in an elderly patient are considered, secondary causes such as cerebral amyloid angiopathy should also be excluded. Amyloid spells (that is, transient focal neurological episodes caused by superficial cortical siderosis) can mimic migraine auras¹⁹.

Second, occipital epilepsy can also present with visual symptoms followed by headache but without the characteristic motor seizures. Classically, patients describe these symptoms as colored phosphenes³, although phosphenes can also be reported as aura symptoms by patients with migraine²⁰. However, visual symptoms in epilepsy generally last shorter than 5 minutes and often start in the periphery of one temporal visual field whereas in migraine the auras generally start more to the center and expand to the periphery²⁰. These criteria are not specific and sometimes electro-encephalography recordings could help in diagnosing occipital seizures. The following entities have been described as variants of migraine aura, although the actual relationship with migraine has been criticized for some of them.

Prolonged and persistent aura

In migraine, visual auras can last longer than the classic 60 minutes that is defined by the International Classification of Headache Disorders^{21,22}. In one diary study, 26.4% of patients had a visual aura, a sensory aura, or speech problems that lasted longer than 60 minutes²². This is often referred to as “prolonged aura”. However, visual auras lasting longer than 2 hours are considered rare and require additional investigation since they can be associated with cerebral infarction. If the aura is typical of previous auras (except in its duration) and there are imaging signs of ischemic infarction in the relevant brain area the term “migrainous infarction” is used to classify the infarct, but only if other causes of stroke are ruled out. Most cases of migrainous infarction are of cortical origin, suggesting that CSD could play a role; however, this could be confounding by indication since cortical infarcts are more likely to be classified as migrainous whereas subcortical infarcts may be attributed to a different cause^{23–25}. There is still debate on whether increased

prevalence of patent foramen ovale in patients with migraine could play a role as well^{23,26}.

If infarction and other causes of binocular visual disturbances are excluded and aura symptoms last longer than 1 week, the term “persistent aura without infarction” is used¹. This is very rare. Symptoms can last months to years. Evidence on treatment is limited, lamotrigine is recommended on the basis of case series²⁷, and in one randomized controlled trial intranasal use of ketamine in patients with prolonged auras limited the aura severity but not the duration²⁸.

Migraine aura status

Some patients with migraine with aura may experience a sudden and large increase in the frequency of their auras, typically without headache. If at least three auras occur over a period of 3 days, the term “migraine aura status” is used¹. However, this diagnosis requires that secondary causes, including occipital infarction, arterial dissection, reversible cerebral vasoconstriction syndrome, and posterior reversible encephalopathy syndrome, be excluded^{1,29}. Retrospective studies indicate that a migraine aura status is rare^{30,31}. Aura frequency can spontaneously normalize within a few weeks, but acetazolamide³² or valproate³¹ could aid in this process and prevent new episodes, although evidence is limited to case reports.

Retinal migraine

The relevance of “retinal migraine” is still debated and unfortunately the term has been misused to describe visual auras, although these are binocular and homonymous and therefore of cortical origin. The term “retinal migraine” is reserved for monocular, fully reversible visual symptoms with at least two of the following criteria: the visual symptoms spread gradually during at least 5 minutes, last between 5 and 60 minutes, and are accompanied or followed within 60 minutes by headache¹. Importantly, secondary causes of monocular visual disturbances should be excluded. Critics of retinal migraine argue that symptoms are not monocular in patients with this diagnosis but binocular and that patients were not properly instructed to discriminate between monocular and binocular symptoms³³. Nonetheless, cases have been reported of recurrent, transient monocular visual disturbances followed by migraine headache in patients who were clearly instructed³³. Proponents additionally argue that CSD can occur in the retina, although these studies are still limited to *in vitro* models³⁴.

Ophthalmoplegic migraine

Some patients with migraine—in particular, children with migraine—reported transient double vision after a migraine attack. This ophthalmoplegia involved mostly the third cranial nerve. Therefore, the term “ophthalmoplegic migraine” was introduced. A prerequisite is that the ophthalmoplegia is preceded by a “migraine-like” headache in the prior four days. However, a literature review of published cases showed that one third of cases did not have a headache fulfilling migraine criteria³⁵. Furthermore, the time between the headache and the ophthalmoplegia could be as long as 14 days and there was

often focal enhancement of the third cranial nerve on magnetic resonance imaging. It was therefore re-classified as “recurrent painful ophthalmoplegic neuropathy”, and demyelization was suggested to play a role^{1,35}.

Photophobia

One of the main discriminating symptoms between migraine headache and other headache disorders is photophobia accompanying the headache, often occurring simultaneously with phonophobia¹. Patients often report that the migraine headache is worsened by the presence of light and that they have to lie in the dark.

Therefore, photophobia is classically viewed as an ictal symptom. However, studies focusing on the premonitory phase—most often defined as the 48 hours before the migraine attack starts—found that up to 49% of patients already experienced photophobia before the headache developed^{36,37}. Furthermore, patients report that they have light aversion on days not preceding or following a migraine attack³⁸. There is increasing evidence for this hypersensitivity to light. Interictally, patients with migraine have a lower light discomfort threshold than controls³⁹. Additionally, many of them find patterns with high contrast more discomforting to look at^{38,39}. This is supported by visual hyperexcitability studies using visual adaptation techniques⁴⁰, visual evoked potentials⁴¹, and positron emission tomography (PET) brain imaging⁴² in patients with interictal migraine. Interestingly, migraine with aura patients reported more discomfort than migraine without aura patients, suggesting that visual hyperexcitability could play a more prominent role in the former³⁹. This is in line with the hypothesis that migraine with aura patients have a lower threshold to experience a CSD. Although light stimulates nociceptive trigeminal neurons⁴³, it is thought that central processes involving thalamus and visual cortex have a more important role⁴⁴. There is also recent evidence from longitudinal studies that visual sensitivity already increases in the days preceding a migraine attack^{45,46}. Although these discoveries are promising, they have not led to therapeutic options for photophobia.

Palinopsia

Palinopsia is derived from the Greek words *palin* (again) and *opsis* (vision) and is used to describe perseveration of visual images. This can be experienced as seeing an afterimage of an object (after staring at an object and looking away) or as a series of images when an object is moving (Figure 2)⁴⁷. Especially the former can be a normal physiological phenomenon when the stimulus was bright or there was a high contrast, and it results mostly in a negative afterimage: the afterimage is in complementary color. A positive afterimage, which has colors similar to those of the original image, is generally not considered physiological, although there is no strict cutoff in terms of frequency, duration, or other characteristics⁴⁷. There is evidence that patients with migraine are more prone to palinopsia, although the number of studies is limited and methods differ^{45,48,49}, complicating estimates on the prevalence of this symptom. In palinopsia, as in photophobia, it is thought that a central origin in the lateral geniculate nucleus of the posterior thalamus or visual cortex plays a role. Possibly altered sensory processing

leading to palinopsia occurs primarily in the days preceding a migraine attack⁴⁵.

Visual snow

Visual snow is characterized by the continuous presence of countless small dots in the entire visual field (Figure 3)⁵⁰. Patients often describe it as “TV static from a detuned analogue television” since the dots are flickering on and off⁵⁰. Although the severity of the snow can vary during the day, symptoms are never fully absent. Visual snow was not considered a separate entity until 2014⁵⁰. Earlier reports often referred to the snow as a form of “persistent migraine aura”, possibly because many patients have a history of migraine with aura^{27,51–55}. However, in visual snow, the classic migraine features such as scintillating scotomas and fortification spectra are absent^{1,50,54}. Furthermore, persistent migraine auras often start unilaterally and expand whereas patients with visual snow generally report that it started in the entire visual field and there was no spatial expansion⁵⁰.

Figure 2. Example of palinopsia. An example of a moving object (the hand is moving from left to right) with perseveration of multiple images is shown.

Figure 3. Example of visual snow. Patients with visual snow observe tiny dots in the entire visual field. The dots often resemble the “static” from a detuned analogue television because the dots “flicker on and off”. Classically, the dots are black/gray on a white background and white on a black background, but colors may vary.

Little is known about the epidemiology of visual snow^{50,56}. Age of onset is often in the early twenties. In visual snow, in contrast to migraine, current data do not show an increased prevalence in females. Visual snow seems to be related to migraine: two case series found that between 47 and 59% had a history of migraine and that the prevalence of migraine with aura was relatively high compared with that of migraine without aura^{50,56}. Furthermore, patients with migraine sometimes also report seeing visual snow, albeit transient and not continuous. In a prospective diary study, 8% of patients with migraine reported visual snow during their visual aura but not outside the aura⁵.

A diagnosis of visual snow is made after exclusion of secondary causes of pan-field visual disturbances, such as lesions in the visual pathways and retina. Nevertheless, ophthalmic and neurological examinations in patients with visual snow are generally normal⁵⁰. Most patients report additional visual symptoms: palinopsia, enhanced entoptic phenomena (excessive floaters or blue field entoptic phenomena and spontaneous photopsia), photophobia, and nyctalopia. Therefore, it was proposed that visual snow is part of a clinical syndrome⁵⁰. The syndrome criteria were proposed for research purposes and have no current clinical consequence for diagnosis or prognosis. Visual snow has also been reported as a persistent visual effect after intake of illicit hallucinogenic drugs such as LSD and ecstasy⁵⁷. However, since there are patients with visual snow who never used hallucinogenic drugs⁵⁰ and since visual snow is also reported in children⁵⁸, it seems that hallucinogenic drug use is not the only potential risk factor.

It is hypothesized that cortical hyperexcitability plays a role in visual snow as well. Theoretically, the visual disturbances can also be localized to bilateral retinal pathology; however,

this seems unlikely since ophthalmological examinations and electro-retinograms are generally normal in patients with visual snow⁵⁰. Therefore, visual snow is generally considered a cortical problem. Indeed, there is some evidence that cortical excitability parameters are increased in patients with visual snow and without comorbid migraine. This has been tested by using visual tasks⁵⁹ and visual-evoked potentials⁶⁰, but findings still have to be replicated in larger studies. One study using [¹⁸F]-2-fluoro-2-deoxy-D-glucose PET showed hypermetabolism in the lingual gyrus, an area that modulates visual processing, in visual snow patients compared with healthy controls⁶¹. The same area was shown to be involved in previous migraine studies on photophobia^{42,62}. However, because 14 out of 17 patients with visual snow also had comorbid migraine, it remains unknown whether this hypermetabolism is specific for visual snow⁶¹. Treatment of visual snow is limited to case reports and expert opinion. Lamotrigine may sometimes help^{63,64}.

Conclusions

The visual aura is the most typical form of visual disturbances in migraine but there are several other visual symptoms that people with migraine report. In this review, we have given a short clinical overview of these symptoms and what is known about the relationship with migraine pathophysiology. Although there are currently no specific therapeutic options focusing on visual symptoms, recent studies have begun to unravel some of the mechanisms that are involved.

Grant information

The author(s) declared that no grants were involved in supporting this work.

References

1. Headache Classification Committee of the International Headache Society (IHS) The International Classification of Headache Disorders, 3rd edition. *Cephalalgia*. 2018; 38(1): 1–211.
[PubMed Abstract](#) | [Publisher Full Text](#)
2. Launer LJ, Terwindt GM, Ferrari MD: The prevalence and characteristics of migraine in a population-based cohort: The GEM study. *Neurology*. 1999; 53(3): 537–42.
[PubMed Abstract](#) | [Publisher Full Text](#)
3. Schott GD: Exploring the visual hallucinations of migraine aura: The tacit contribution of illustration. *Brain*. 2007; 130(Pt 6): 1690–703.
[PubMed Abstract](#) | [Publisher Full Text](#)
4. Hansen JM, Goadsby PJ, Charles AC: Variability of clinical features in attacks of migraine with aura. *Cephalalgia*. 2016; 36(3): 216–24.
[PubMed Abstract](#) | [Publisher Full Text](#)
5. Viana M, Sances G, Linde M, et al.: Clinical features of migraine aura: Results from a prospective diary-aided study. *Cephalalgia*. 2017; 37(10): 979–89.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
6. Leão AAP: Spreading depression of activity in the cerebral cortex. *J Neurophysiol*. 1944; 7: 359–90.
[Publisher Full Text](#)
7. Hadjikhani N, Sanchez Del Rio M, Wu O, et al.: Mechanisms of migraine aura revealed by functional MRI in human visual cortex. *Proc Natl Acad Sci U S A*. 2001; 98(8): 4687–92.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
8. Hansen JM, Baca SM, VanValkenburgh P, et al.: Distinctive anatomical and physiological features of migraine aura revealed by 18 years of recording. *Brain*. 2013; 136(Pt 12): 3589–95.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
9. Russell MB, Olesen J: A nosographic analysis of the migraine aura in a general population. *Brain*. 1996; 119(Pt 2): 355–61.
[PubMed Abstract](#) | [Publisher Full Text](#)
10. Ferrari MD, Klever RR, Terwindt GM, et al.: Migraine pathophysiology: lessons from mouse models and human genetics. *Lancet Neurol*. 2015; 14(1): 65–80.
[PubMed Abstract](#) | [Publisher Full Text](#)
11. Viana M, Linde M, Sances G, et al.: Migraine aura symptoms: Duration, succession and temporal relationship to headache. *Cephalalgia*. 2016; 36(5): 413–21.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
12. Kew J, Wright A, Halligan PW: Somesthetic aura: The experience of “Alice in Wonderland”. *The Lancet*. 1998; 351(9120): 1934.
[PubMed Abstract](#) | [Publisher Full Text](#)
13. Jürgens TP, Schulte LH, May A: Migraine trait symptoms in migraine with and

- without aura. *Neurology*. 2014; **82**(16): 1416–24.
[PubMed Abstract](#) | [Publisher Full Text](#)
14. **F** Hansen JM, Lipton RB, Dodick DW, *et al.*: **Migraine headache is present in the aura phase: A prospective study.** *Neurology*. 2012; **79**(20): 2044–9.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 15. **F** Vongvaivanich K, Lertakyanan P, Silberstein SD, *et al.*: **Late-life migraine accompaniments: A narrative review.** *Cephalalgia*. 2014; **35**(10): 894–911.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 16. Lampl C, Katsarava Z, Diener H-C, *et al.*: **Lamotrigine reduces migraine aura and migraine attacks in patients with migraine with aura.** *J Neurol Neurosurg Psychiatr*. 2005; **76**(12): 1730–2.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 17. Nadarajan V, Perry RJ, Johnson J, *et al.*: **Transient ischaemic attacks: Mimics and chameleons.** *Pract Neurol*. 2014; **14**(1): 23–31.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 18. **F** Lavallée PC, Cabrejo L, Labreuche J, *et al.*: **Spectrum of transient visual symptoms in a transient ischemic attack cohort.** *Stroke*. 2013; **44**(12): 3312–7.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 19. Charidimou A, Peeters A, Fox Z, *et al.*: **Spectrum of transient focal neurological episodes in cerebral amyloid angiopathy: Multicentre magnetic resonance imaging cohort study and meta-analysis.** *Stroke*. 2012; **43**(9): 2324–30.
[PubMed Abstract](#) | [Publisher Full Text](#)
 20. **F** Hartl E, Gonzalez-Victores JA, Rémi J, *et al.*: **Visual Auras in Epilepsy and Migraine - An Analysis of Clinical Characteristics.** *Headache*. 2017; **57**(6): 908–16.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 21. Viana M, Sprenger T, Andelova M, *et al.*: **The typical duration of migraine aura: A systematic review.** *Cephalalgia*. 2013; **33**(7): 483–90.
[PubMed Abstract](#) | [Publisher Full Text](#)
 22. **F** Viana M, Sances G, Linde M, *et al.*: **Prolonged migraine aura: New insights from a prospective diary-aided study.** *J Headache Pain*. 2018; **19**(1): 77.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 23. **F** Wolf ME, Szabo K, Griebel M, *et al.*: **Clinical and MRI characteristics of acute migrainous infarction.** *Neurology*. 2011; **76**(22): 1911–7.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 24. Laurell K, Arto V, Bendtsen L, *et al.*: **Migrainous infarction: A Nordic multicenter study.** *Eur J Neurol*. 2011; **18**(10): 1220–6.
[PubMed Abstract](#) | [Publisher Full Text](#)
 25. Lee MJ, Lee C, Chung C-S: **The Migraine-Stroke Connection.** *J Stroke*. 2016; **18**(2): 146–56.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 26. **F** Koppen H, Palm-Meinders IH, Mess WH, *et al.*: **Systemic right-to-left shunts, ischemic brain lesions, and persistent migraine activity.** *Neurology*. 2016; **86**(18): 1668–75.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 27. Thissen S, Vos IG, Schreuder TH, *et al.*: **Persistent Migraine Aura: New Cases, a Literature Review, and Ideas About Pathophysiology.** *Headache*. 2014; **54**(8): 1290–309.
[PubMed Abstract](#) | [Publisher Full Text](#)
 28. Afridi SK, Giffin NJ, Kaube H, *et al.*: **A randomized controlled trial of intranasal ketamine in migraine with prolonged aura.** *Neurology*. 2013; **80**(7): 642–7.
[PubMed Abstract](#) | [Publisher Full Text](#)
 29. **F** Terrin A, Mainardi F, Maggioni F: **The pathological spectrum behind migraine aura status: A case series.** *Neurol Sci*. 2019; **40**(4): 861–4.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 30. Beltramone M, Donnet A: **Status migrainosus and migraine aura status in a French tertiary-care center: An 11-year retrospective analysis.** *Cephalalgia*. 2014; **34**(8): 633–7.
[PubMed Abstract](#) | [Publisher Full Text](#)
 31. João AA, Goucha TB, Martins IP: **Aura status: A not so frequent aura.** *Cephalalgia*. 2014; **34**(14): 1150–62.
[PubMed Abstract](#) | [Publisher Full Text](#)
 32. Haan J, Sluis P, Sluis LH, *et al.*: **Acetazolamide treatment for migraine aura status.** *Neurology*. 2000; **55**(10): 1588–9.
[PubMed Abstract](#) | [Publisher Full Text](#)
 33. Hill DL, Daroff RB, Ducros A, *et al.*: **Most cases labeled as “retinal migraine” are not migraine.** *J Neuroophthalmol*. 2007; **27**(1): 3–8.
[PubMed Abstract](#) | [Publisher Full Text](#)
 34. Wang M, Chazot PL, Ali S, *et al.*: **Effects of NMDA receptor antagonists with different subtype selectivities on retinal spreading depression.** *Br J Pharmacol*. 2012; **165**(1): 235–44.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 35. Gelfand AA, Gelfand JM, Prabhakar P, *et al.*: **Ophthalmoplegic “migraine” or recurrent ophthalmoplegic cranial neuropathy: new cases and a systematic review.** *J Child Neurol*. 2012; **27**(6): 759–66.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 36. Maniyar FH, Sprenger T, Monteith T, *et al.*: **The premonitory phase of migraine—what can we learn from it?** *Headache*. 2015; **55**(5): 609–20.
[PubMed Abstract](#) | [Publisher Full Text](#)
 37. Giffin NJ, Ruggiero L, Lipton RB, *et al.*: **Premonitory symptoms in migraine: an electronic diary study.** *Neurology*. 2003; **60**(6): 935–40.
[PubMed Abstract](#) | [Publisher Full Text](#)
 38. Mulleners WM, Aurora SK, Chronicle EP, *et al.*: **Self-reported photophobic symptoms in migraineurs and controls are reliable and predict diagnostic category accurately.** *Headache*. 2001; **41**(1): 31–9.
[PubMed Abstract](#) | [Publisher Full Text](#)
 39. **F** Perenboom MJL, Zamanipour Najafabadi AH, Zielman R, *et al.*: **Quantifying visual allodynia across migraine subtypes: the Leiden Visual Sensitivity Scale.** *Pain*. 2018; **159**(11): 2375–82.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 40. Shepherd AJ: **Increased visual after-effects following pattern adaptation in migraine: a lack of intracortical excitation?** *Brain*. 2001; **124**(Pt 11): 2310–8.
[PubMed Abstract](#) | [Publisher Full Text](#)
 41. Chen WT, Wang SJ, Fuh JL, *et al.*: **Persistent ictal-like visual cortical excitability in chronic migraine.** *Pain*. 2011; **152**(2): 254–8.
[PubMed Abstract](#) | [Publisher Full Text](#)
 42. Bouloche N, Denuelle M, Payoux P, *et al.*: **Photophobia in migraine: an interictal PET study of cortical hyperexcitability and its modulation by pain.** *J Neurol Neurosurg Psychiatr*. 2010; **81**(9): 978–84.
[PubMed Abstract](#) | [Publisher Full Text](#)
 43. Okamoto K, Tashiro A, Chang Z, *et al.*: **Bright light activates a trigeminal nociceptive pathway.** *Pain*. 2010; **149**(2): 235–42.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#)
 44. **F** Goadsby PJ, Holland PR, Martins-Oliveira M, *et al.*: **Pathophysiology of Migraine: A Disorder of Sensory Processing.** *Physiol Rev*. 2017; **97**(2): 553–622.
[PubMed Abstract](#) | [Publisher Full Text](#) | [Free Full Text](#) | [F1000 Recommendation](#)
 45. **F** Luedtke K, Schulte LH, May A: **Visual processing in migraineurs depends on the migraine cycle.** *Ann Neurol*. 2019; **85**(2): 280–3.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 46. **F** McKendrick AM, Chan YM, Vingrys AJ, *et al.*: **Daily vision testing can expose the prodromal phase of migraine.** *Cephalalgia*. 2018; **38**(9): 1575–84.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 47. **F** Gersztenkorn D, Lee AG: **Palinopsia revamped: a systematic review of the literature.** *Surv Ophthalmol*. 2015; **60**(1): 1–35.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 48. Belcastro V, Cupini LM, Corbelli I, *et al.*: **Palinopsia in patients with migraine: a case-control study.** *Cephalalgia*. 2011; **31**(9): 999–1004.
[PubMed Abstract](#) | [Publisher Full Text](#)
 49. **F** Kalita J, Uniyal R, Bhoi SK: **Is palinopsia in migraineurs an enhanced physiological phenomenon?** *Cephalalgia*. 2016; **36**(13): 1248–56.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 50. Schankin CJ, Maniyar FH, Digre KB, *et al.*: **“Visual snow” - a disorder distinct from persistent migraine aura.** *Brain*. 2014; **137**(Pt 5): 1419–28.
[PubMed Abstract](#) | [Publisher Full Text](#)
 51. Liu GT, Schatz NJ, Galetta SL, *et al.*: **Persistent positive visual phenomena in migraine.** *Neurology*. 1995; **45**(4): 664–8.
[PubMed Abstract](#) | [Publisher Full Text](#)
 52. Rothrock JF: **Successful treatment of persistent migraine aura with divalproex sodium.** *Neurology*. 1997; **48**(1): 261–2.
[PubMed Abstract](#) | [Publisher Full Text](#)
 53. Jäger HR, Giffin NJ, Goadsby PJ: **Diffusion- and perfusion-weighted MR imaging in persistent migrainous visual disturbances.** *Cephalalgia*. 2005; **25**(5): 323–32.
[PubMed Abstract](#) | [Publisher Full Text](#)
 54. Wang YF, Fuh JL, Chen WT, *et al.*: **The visual aura rating scale as an outcome predictor for persistent visual aura without infarction.** *Cephalalgia*. 2008; **28**(12): 1298–304.
[PubMed Abstract](#) | [Publisher Full Text](#)
 55. Chen WT, Lin YY, Fuh JL, *et al.*: **Sustained visual cortex hyperexcitability in migraine with persistent visual aura.** *Brain*. 2011; **134**(Pt 8): 2387–95.
[PubMed Abstract](#) | [Publisher Full Text](#)
 56. **F** Lauschkke JL, Plant GT, Fraser CL: **Visual snow: A thalamocortical dysrhythmia of the visual pathway?** *J Clin Neurosci*. 2016; **28**: 123–7.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 57. Litjens RP, Brunt TM, Alderlieste GJ, *et al.*: **Hallucinogen persisting perception disorder and the serotonergic system: a comprehensive review including new MDMA-related clinical cases.** *Eur Neuropsychopharmacol*. 2014; **24**(8): 1309–23.
[PubMed Abstract](#) | [Publisher Full Text](#)
 58. Simpson JC, Goadsby PJ, Prabhakar P: **Positive persistent visual symptoms (visual snow) presenting as a migraine variant in a 12-year-old girl.** *Pediatr Neurol*. 2013; **49**(5): 361–3.
[PubMed Abstract](#) | [Publisher Full Text](#)
 59. **F** McKendrick AM, Chan YM, Tien M, *et al.*: **Behavioral measures of cortical hyperexcitability assessed in people who experience visual snow.** *Neurology*. 2017; **88**(13): 1243–9.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 60. **F** Eren O, Rauschel V, Ruscheweyh R, *et al.*: **Evidence of dysfunction in the visual association cortex in visual snow syndrome.** *Ann Neurol*. 2018; **84**(6): 946–9.
[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)
 61. Schankin CJ, Maniyar FH, Sprenger T, *et al.*: **The relation between migraine,**

typical migraine aura and “visual snow”. *Headache*. 2014; **54**(6): 957–66.

[PubMed Abstract](#) | [Publisher Full Text](#)

62. Denuelle M, Bouilloche N, Payoux P, *et al.*: **A PET study of photophobia during spontaneous migraine attacks**. *Neurology*. 2011; **76**(3): 213–8.

[PubMed Abstract](#) | [Publisher Full Text](#)

63. Unal-Cevik I, Yildiz FG: **Visual Snow in Migraine With Aura: Further**

Characterization by Brain Imaging, Electrophysiology, and Treatment—Case Report. *Headache*. 2015; **55**(10): 1436–41.

[PubMed Abstract](#) | [Publisher Full Text](#) | [F1000 Recommendation](#)

64. White OB, Clough M, McKendrick AM, *et al.*: **Visual Snow: Visual Misperception**. *J Neuroophthalmol*. 2018; **38**(4): 514–21.

[PubMed Abstract](#) | [F1000 Recommendation](#)

Open Peer Review

Current Peer Review Status:

Editorial Note on the Review Process

Faculty Reviews are review articles written by the prestigious Members of **Faculty Opinions**. The articles are commissioned and peer reviewed before publication to ensure that the final, published version is comprehensive and accessible. The reviewers who approved the final version are listed with their names and affiliations.

The reviewers who approved this article are:

Version 1

1. **Andrew Charles**

UCLA Goldberg Migraine Program, David Geffen School of Medicine at the University of California, Los Angeles, USA

Competing Interests: No competing interests were disclosed.

2. **Christoph J. Schankin**

Department of Neurology, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

Competing Interests: No competing interests were disclosed.

The benefits of publishing with F1000Research:

- Your article is published within days, with no editorial bias
- You can publish traditional articles, null/negative results, case reports, data notes and more
- The peer review process is transparent and collaborative
- Your article is indexed in PubMed after passing peer review
- Dedicated customer support at every stage

For pre-submission enquiries, contact research@f1000.com

F1000Research