Technical Review

Visual Stimuli, Light and Lighting are Common Triggers of Migraine and Headache

Alex J. SHEPHERD

Faculty of Architecture, Design and Planning, University of Sydney, Australia

Received November 24, 2009, Accepted February 18, 2010
This paper was presented at the 6th Lux Pacifica, Bankok, Thailand, April, 2009

ABSTRACT
This study investigated the associations between various factors anecdotally reported to trigger headache and migraine. Headache symptoms and headache triggers were assessed using a questionnaire given to 180 volunteers. Two groups were identified, those who fulfilled the International Headache Society’s criteria for migraine, and those who did not. Associations between reported headache triggers were explored using a principal components analysis, which grouped common headache triggers into four components: visual stimuli, food, alcohol, and stress/tiredness. The visual stimuli cited as triggers included flickering light, repetitive patterns (stripes), sunshine, patterns of light and shade, glare, bright reflections, computers, TV and the cinema. A separate analysis on the data from the migraine group produced the same four components together with a fifth, interpreted as a non-visual sensory trigger (noise and smell). The results demonstrate that visual stimuli are commonly reported as headache triggers. Those involved in the design of the visual environment could improve the quality of life of many by avoiding environmental factors, particularly visual factors, which can trigger headache and migraine.

KEYWORDS: headache, migraine, visual triggers, flicker, stripes, visual discomfort.

1. Introduction
There has been relatively little research on factors that can provoke headache and migraine, despite numerous anecdotal reports that various environmental stimuli can be a reliable trigger. Most people will have experienced headaches where they can identify the cause, such as headaches resulting from stress, tiredness, dehydration or, in women, hormonal factors. For many, these headaches are easily resolved with rest, sleep, or over the counter medication. There are, however, many less commonly known factors that can act either in isolation, or in association with other triggers, to induce headache.

Environmental triggers of migraine and headache include visual stimuli, some of which are similar to those that can induce seizures in photosensitive epilepsy. There are guidelines to avoid visual triggers of photosensitive epilepsy (although they are not always followed, as demonstrated by reports of seizures triggered while watching flickering images on television) as recently as 2007. What is surprising is the lack of research on factors that can provoke headache and migraine, despite much higher prevalence rates. The lack of awareness of headache triggers in the environment is surprising since, if reliable triggers can be identified, some attacks could be prevented. This study explores the associations between various factors anecdotally reported to provoke migraine and headache.

The number of people affected by migraine and headache is substantial. Prevalence rates are inevitably estimates, as many do not seek medical advice, particularly when there is a family history of headache and migraine. Consequently, the World Health Organisation’s (WHO) report that migraine affects one in nine is likely to underestimate the actual prevalence rates (11% overall, 6-8% males, 15-18% females, estimates based on European and American epidemiological studies in 2004). Tension-type headache is more common than migraine, affecting 67% of the world’s male population and 80% of females at some stage in their lives and affecting 42% at any one current period of time.

The cost of migraine and headache is substantial due to their high prevalence. Cost estimates take into account the individual’s loss of quality of life and the impact it has on employment and productivity at work. Quality of life factors include both the time lost due to disability during the attack (on average,
24 hours) and, in between attacks, the anxiety that can be experienced about the onset of the next attack. Some people experience migraine or headache only a few times a year, so it has minimal impact on their daily lives. Others can experience it once or twice a week, which severely interferes with their quality of life and ability to work.

As mentioned, the average attack is over within 24 hours, but people can still feel affected and sluggish the next day. The International Headache Society’s classification criteria distinguishes migraine with and without aura. In migraine with aura, transient neurological symptoms (commonly visual, sometimes somatosensory, sometimes involving speech) usually precede the headache by up to 60 minutes and the sensory ones typically move or spread during that time.

Aura symptoms vary in severity. The visual symptoms usually involve a partial loss of vision, often in one quadrant or hemifield, which is preceded by positive symptoms superimposed on whatever the person is looking at. The positive symptoms include the classic fortification spectra, which is a jagged or zig-zag collection of lines that starts centrally and grows, shimmering, over time (so called as it resembles fortifications around a castle, if viewed from above). Others report simpler stars and phosphenes that may twinkle, or they have the impression of looking at the world through running water. People also report double vision, or tunnel vision, or simply a loss of vision.

More elaborate distortions can also be experienced: people can experience a distortion in the relative size of parts of images (or of the person’s own body image), so some elements expand and others shrink, called the ‘Alice in Wonderland’ syndrome. Indeed, Lewis Carroll’s inspiration for Alice in Wonderland has been credited to the visual auras that he experienced. There are numerous paintings that depict the variety of visual disturbances that can be experienced, created by artists inspired by their particular visual auras.

Somatosensory aura symptoms typically involve pins and needles, tingling or numbness on one side of the face or body, but can extend to hemiplegia. The reported language difficulties are reminiscent of either of the aphasias described by Broca (difficulty finding appropriate words), or Wernicke (fluent output but little content). Evidently, people who experience these symptoms will have a loss of productivity at home, work or in education and a reduction in their quality of life beyond that which results from a severe headache.

The WHO has a metric, the number of years lost to disability (YLD), which attempts to estimate the years of life lived in less than full health. In 2000, migraine was the 20th leading cause of YLD at a global level. As migraine is more common in women, it was the 9th leading cause of disability in women. Stovner et al. combined the prevalence rates for migraine, tension-type headache and chronic daily headache and concluded that headache disorders, in general, fall within the top ten most disabling global health problems overall, based on a YLD measure, and within the top five for women.

In the UK, it is estimated that 90,000 people cannot attend work or education each day because of headaches, amounting to 25 million workdays or schooldays lost every year. The Migraine Action Association estimated the cost of this in the United Kingdom as more than a billion pounds each year. Furthermore, more than 50% of the people surveyed by the Migraine Action Association felt that migraine had adversely affected their careers, whilst a third kept the fact that they had migraine a secret fearing discrimination at work. So the cost of migraine for those affected, and for work and daily life, is high.

Clearly, any measures that can be introduced to minimise exposure to headache triggers would benefit both individuals and employment. As mentioned, stress, tiredness and dehydration are well-known triggers, but environmental factors can also play a significant role. A review of the literature relating to light and visual stimuli as migraine trigger factors suggested that they are of similar importance to triggers such as stress and hormonal factors. In that review, it was noted that in a sample of 344 migraine patients, 62% had “glare” as a precipitating factor, 53% had “flicker” as a precipitating factor and 1% had “colour” as a precipitating factor. Simple striped patterns have also been implicated as stimuli that can trigger migraine.

There are relatively few studies, however, that have examined associations between various migraine triggers or that have compared triggers for headaches other than migraine. In the research presented here, the links between various anecdotally reported headache triggers were investigated using questionnaire data collected from 180 volunteers. The aim of the research was to identify common environmental headache triggers experienced by people with migraine and by people with more general headaches. Ultimately, the aim is to produce guidelines for the design of the visual
environment to reduce the occurrence of headache and so improve the quality of life of those affected.

2. Methods
2.1 Participants and Procedure
The participants were 180 volunteers for 4 separate experiments on visual processing in migraine (the experimental data are not presented here). Their ages ranged between 18 and 63 years (average 33 years ± 9 years, 132 female, 48 male). Each participant was interviewed individually in the migraine and perception laboratory in the Department of Psychological Sciences at Birkbeck College, University of London. All self-reported being fit and healthy and none were taking any daily medication. Participants with any neurological condition other than migraine were excluded. Informed written consent was obtained in accordance with the Declaration of Helsinki and the studies were approved by the ethics committee of the Department of Psychological Sciences.

2.2 Questionnaire
All participants completed a detailed questionnaire about their headaches, which included details on the nature, frequency, and severity of headaches experienced, and included a list of potential headache triggers. Two groups were subsequently identified: those who fulfilled the International Headache Society’s (IHS) criteria for migraine\(^\circ\), and those who did not (Table 1). There were 132 participants in the migraine group (98 female) and 48 in the control group (34 female). In the part of the questionnaire that listed potential triggers (Table 2), participants were asked to record if each trigger commonly, occasionally, or never triggered a headache. Potential triggers were given a score of 2 if the factor precipitated headaches “commonly”, 1 for “occasionally” and zero for “never”. The relationships between headache triggers were explored using a principal component analysis to determine general clusterings between the variables.

Table 1 IHS criteria for migraine\(^\circ\). Migraine without aura presents as a headache fulfilling each of the criteria A–D. Patients must have experienced at least five attacks that fulfill these criteria. In migraine with aura, transient neurological symptoms (commonly visual, sometimes somatosensory, sometimes involving speech) usually precede the headache by up to 60 minutes, although they can last longer.

A. The headache must last longer than 4 hours (typically 4-72 hours).
B. The headache must have at least 2 of the 4 following characteristics:
   i. Throbbing or stabbing pain
   ii. Pain that is exacerbated by routine physical activity
   iii. Pain that is sufficiently intense to interfere with daily activities
   iv. Pain that is experienced on one side of the head
C. Either (or both) of the following must also be experienced:
   i. Phonophobia and photophobia
   ii. Nausea
D. There must be no other obvious causes of the headache.

3. Results
3.1 Headache Triggers: Overview
Overall, the most frequent item reported to commonly trigger headache was stress, which was endorsed by 39% of the participants. This figure rose to 86% if the data from common and occasional triggers were combined. The next most frequent triggers were hormonal factors (women only, common trigger: 27%, common or occasional trigger: 62%), tiredness (common trigger: 19%, common or occasional trigger: 57%) and flickering light (common trigger: 16%, common or occasional trigger: 34%). Fifty-three per cent cited at least one visual item as a common or occasional trigger.

The trigger data revealed characteristic differences between the migraine and control groups. For example, 105 (80%) of the migraine group reported at least one of the items as commonly triggering headache, compared to 20 (42%) of the control group. This association between group and having at least one common headache trigger was statistically significant ($\chi^2(1) = 23.8, p<0.001$). Participants in the migraine group also reported that significantly more items commonly triggered their headaches (selecting up to 9 items, median 2) than participants in the control group (selecting up to 4 items, median 0, Mann-Whitney $Z = 5.3, p<0.001$).

Rank ordering the commonly reported items for each group revealed the most common headache trigger to be stress (migraine: 46%, control: 21%, $\chi^2(1) = 9.5, p<0.005$), followed by hormonal factors in the migraine group (migraine: 34%, control: 9%, $\chi^2(1) = 7.9, p<0.005$) but tiredness in the control group (migraine: 21%, control 15%, $\chi^2(1) = 0.9, NS$). The next most commonly cited trigger in the migraine group was flickering light (22%), whereas no-one in
the control group cited flicker as a common headache trigger ($\chi^2_{(1)} = 12.6$, $p<0.001$). Including items cited as occasional triggers produced stress again as the most common trigger in each group (migraine: 89%, control: 77%, $\chi^2_{(1)} = 4.5$, $p<0.05$), followed by tiredness (migraine: 58%, control: 56% $\chi^2_{(1)} = 0.02$, NS). Flickering light was reported as a common or occasional trigger in 45% of the migraine group, and in 6% of the control group ($\chi^2_{(1)} = 23.0$, $p<0.001$). Overall, at least one of the visual items was reported as a trigger in 60% of the migraine group, and in 15% of the control group ($\chi^2_{(1)} = 27.5$, $p<0.001$).

When completing the questionnaire, participants were also given the option of listing other headache triggers. From the 61 people who responded to this question, 11 additional triggers were specified. Seven of these referred to visual stimulation. In rank order these were: computer screens, bright sunshine or bright light, glare and abrupt transitions from light to dark (leaving a dark cinema, driving at night with oncoming car headlights, bright reflections of chrome or water, glare from windows), reading or viewing patterns of stripes, television and cinema, bright colours, optic flow. Non-visual triggers included hunger, dehydration, irregular sleep and sinus congestion.

3.2 Headache triggers: principal components analyses

To explore the relationships between the headache trigger data, an exploratory principal components analysis was conducted using SPSS version 16. Although the trigger data were coded with limited scales, principal components or factor analysis can be performed to determine general clusterings between variables. The 'hormonal' trigger was omitted so that the data from the male participants could be included.

Four components were extracted with eigenvalues greater than 1, which accounted for 60% of the variance in the original variables. The rotated solution (varimax rotation) lead to an interpretation of these components as (1) visual triggers; (2) general food; (3) alcohol; (4) stress and tiredness (Table 2). These components are listed in order: the amount of variance that was explained by each component was 18%, 18%, 12% and 11%, respectively. A cut-off correlation of each variable with each component was selected (0.5) that resulted in each variable loading on only one component, apart from 'noise', which did not load on any component. The correlations between each variable and the component to which it contributes are shown in Table 2.

As the migraine group reported more triggers than the control group, a second analysis was performed on the data from the migraine group alone. Five components were extracted with eigenvalues greater than 1, which accounted for 69% of the variance in the original variables. The rotated solution (varimax rotation) lead to an interpretation of four of these components as above (visual triggers, general food, alcohol, stress and tiredness), together with a fifth component interpreted as a non-visual sensory trigger (noise and smell). The amount of variance that was explained by each component was 18%, 16%, 12%, 11% and 11%, respectively.

A third analysis was performed on the data from the female participants, so that 'hormonal factors' could be included in the list of headache triggers. Five components were again extracted, which accounted for 65% of the variance. The first three components were the same as above (visual triggers, general food, alcohol). Hormonal factors, stress and smell contributed to the fourth component, while stress and tiredness comprised the fifth. The amount of variance explained by each component was 17%, 15%, 12%, 11% and 10%, respectively.

4. Discussion

The questionnaire data revealed visual stimuli to be relevant as triggers for migraine and headache. Sixty per cent of the migraine group, and 15% of the control group, cited visual patterns as identifiable headache triggers. Moreover, visual triggers emerged as the first factor in the principal components analysis, accounting for the largest amount of variance in the data set.

Anecdotal reports from the volunteers revealed that even very brief exposure to certain visual triggers was sufficient to induce their headache. These patterns included flickering light, high contrast repetitive patterns (e.g. stripes or checkerboards), bright sunshine and bright light, glare, and high contrast reflections (e.g. sunlight off chrome or water).

Many of these stimuli are ubiquitous in the environment. People can be exposed to flicker from sunlight through trees or gratings, from badly maintained lighting, by working in environments that are lit with older 60Hz fluorescent light ballasts, or by using LCD screens with a flickering back-light or CRT screens that have refresh rates less than 100Hz. Flicker appears in images on TV and in the cinema and, more recently, in the images displayed on projection screens at subway/train stations and in pubs and bars. Stripes appear on clothing, escalator treads, gratings and some art designed for public


Table 1  The list of possible headache triggers and results from the principal components analysis

<table>
<thead>
<tr>
<th>Triggers</th>
<th>Visual Triggers</th>
<th>General Food</th>
<th>Alcohol</th>
<th>Stress and Tiredness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flickering lights</td>
<td>0.83</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Striped patterns</td>
<td>0.78</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other visual stimuli</td>
<td>0.86</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chocolate</td>
<td></td>
<td>0.85</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cheese</td>
<td></td>
<td>0.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other food</td>
<td></td>
<td>0.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Smell</td>
<td></td>
<td>0.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red wine</td>
<td></td>
<td></td>
<td>0.79</td>
<td></td>
</tr>
<tr>
<td>Other alcohol</td>
<td></td>
<td></td>
<td></td>
<td>0.80</td>
</tr>
<tr>
<td>Stress</td>
<td></td>
<td></td>
<td></td>
<td>0.79</td>
</tr>
<tr>
<td>Tiredness</td>
<td></td>
<td></td>
<td></td>
<td>0.71</td>
</tr>
<tr>
<td>Noise</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hormonal factors</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

spaces. Glare can result from windows, from halogen spotlights, and from other overhead lighting that is visible in the peripheral field of view.

The other headache trigger factors that emerged from the principal components analysis could be anticipated (food, alcohol, stress and tiredness), and sceptics may suggest that the analysis merely shows predictable associations between words in the English language. Two facts argue against this suggestion. First, the order of the components was not anticipated – if the data reflected frequent word associations, stress and tiredness would emerge as the first component rather than visual stimuli.

Second, in separate experiments it has been found that performance on various visual tasks differs when people who are affected by visual triggers are compared to those who are not. For example, many people see distortions and illusions when viewing striped patterns (termed pattern glare, pattern sensitivity, or visual discomfort)\(^{10}\). People can report seeing flashes of colours, shadowy shapes or lattices behind the stripes, or the stripes may appear to bend, fragment or move (these effects contribute to the appeal of art such as Bridget Riley’s, at least for people who are not prone to visually triggered headache or photosensitive epilepsy). People with visual headache triggers are more likely to see illusions in striped patterns, they tend to see more vivid illusions and they find the images painful to view\(^ {14151819}\). In addition to distortion and discomfort, people can experience nausea, dizziness, confusion or disorientation, a lack of co-ordination and, exceptionally, seizures.

There are many other aspects of visual processing that have been shown to differ in migraine and in those with visual headache triggers when they are compared to people who are not so affected. For example, colour perception is impaired\(^ {20}\) as is performance on visual search tasks\(^ {21}\). Visual after-effects are illusions seen after prolonged viewing of visual displays, such as viewing motion in one direction (the motion after-effect, when the real motion stops, stationary patterns appear to move in the opposite direction) or oriented gratings (the tilt after-effect, when oriented gratings are replaced by vertical gratings, they appear tilted in the opposite direction). Visual after-effects are enhanced in migraine and are particularly enhanced for people with visual triggers\(^ {2223}\). The association between people prone to visually triggered headache and performance on visual tasks also suggests that the principal components analysis reveals more than common associations between words.

There are presently no guidelines to avoid visual discomfort or visually triggered headaches. There are, however, strong similarities between the visual stimuli that induce headache and those that can trigger seizures in photosensitive epilepsy\(^ {146}\). For striped patterns, there are some individual differences in the likelihood that distortions will be perceived but, for the majority, high contrast mid-spatial frequencies (2-8 cycles per degree, cpd) will generate the most illusions and be the most unpleasant to view\(^ {146}\). Any high contrast repetitive pattern (e.g. stripes, checkerboards, spotty images) can elicit illusions, aversion and headache, but the probability of eliciting them increases as the pattern elements are elongated i.e. as the pattern becomes more stripe-like. Mid-spatial frequencies with 50 % duty cycle (equal width light and dark components)

---

The Illuminating Engineering Institute of Japan
and high contrasts are most likely to generate illusions and headache, and the likelihood also increases with size. The likelihood is also greater with binocular rather than monocular viewing, and when the patterns are viewed foveally rather than in the periphery. More recent work suggests that any complex pattern can generate aversion if it has significant contrast energy near 3 cpd, regardless of any other spatial frequencies that are also in the image.20

There is less research on the temporal frequencies associated with visually induced headache. Martin25 assessed temporal frequencies below 10 Hz and reported 5 Hz to be aversive and to produce the most visual disturbance. Flicker between 15 and 25 Hz is the optimum range to trigger seizures, although there are individual differences and some are sensitive to lower or higher flicker rates (range 1-65 Hz29). Anecdotal reports and a case report suggest headache from computer screens is associated with screen refresh rates of 60 Hz27, but again there are likely to be individual differences in sensitivity to particular flicker rates. Long wavelength flicker is more aversive than short wavelength or broadband light28.

In the absence of guidelines for the general environment, the recommendations currently in place for television images may make a suitable substitute.26 These cover acceptable spatial and temporal frequencies, the content of moving images, and the duration of any successive sequences to minimise cumulative effects.

Increased awareness of the type of visual stimuli that can trigger headache is important because they are relatively easy to alleviate. The quality of life and productivity of those affected by visual triggers could be easily improved if those involved in the lighting, appearance and decoration of the visual environment actively avoided them in their designs.

Acknowledgements

Thanks are due to Mr Richard Peatfield at Charing Cross Hospital and the General Medical Practitioners who helped recruit patients for these studies. This paper was presented at the 2009 Lux Pacifica conference in Bangkok. The Royal Society in the UK provided funding for Dr Shepherd to take up a visiting fellowship at Griffith University, Brisbane, Australia, which enabled attendance at that conference.

References

http://www.who.int/mental_health/neurology/neurogy_atlas_review_references.pdf


