Migraine factors as reported by smartphone users

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***Abstract*— In this paper, we describe how we used a smartphone app to collect migraine data. The users log their migraine details in the app with the purpose of discovering their migraine triggers. We analyze details of over half a million migraines and we report some novel findings that traditional studies missed because of their rigid clinical setting. We report the most common triggers, symptoms, relief methods, onset locations and drug combination outcomes.**

Keywords—health; Android; migraine; iOS; demographics; case cross-over.

I. Introduction

Migraine is a neurological disorder that can cause severe disabling pain. It is estimated that 4.7% of the population in USA qualify as migraine sufferers and that of those 26% do not realize that they suffer migraines [1]. If migraine is combined with severe headache, then 16% of adults are affected [2]. Depending on the study, every year a migraine patient generates on average direct medical costs of between $100 and $200 while 60% of those costs are related to visits to the doctor. In addition, the indirect costs of migraine due to lost workdays and lost productivity are three to six times that of the direct costs [1-3].

A. Triggers

Despite its relatively high prevalence, the mechanism behind a migraine, the so called triggers, are not yet well understood. Each person seems to have a particular trigger or combination of triggers. It is known that some triggers are related to certain types of foods and beverages such as alcohol, coffee, chocolate or aged cheese [4-8]; There are as well non-food related triggers: physical activity, changes in barometric pressure, menstruation and stress have been related to migraine episodes, too. However, no studies exist that clarify and rank the prevalence of triggers. The situation is similar with symptoms. In addition, there is confusion between trigger and an aggravating factor. For example, some recent studies have challenged the cause-effect relationship of previously thought well-established triggers such as, for example, *sensitivity to light* which has been challenged in 2013 by the experimental results of [9]. This study demonstrated that light was in fact not a trigger of migraine even though patients had believed so. (Patients just suffered sensitivity to light during migraines).

B. Pathogenesis

However, triggers are just one of the many unknowns that surround migraine. A second unknown is the physiological mechanism. In the last decade medical research has advanced the understanding of the migraine mechanism although a complete physiological explanation has not yet been found. For example, thanks to magnetic resonance angiography techniques we now know that migraine is not always related to inflammation of the vascular system in the brain (as was previously commonly believed) [9]. Thanks to this new understanding, during the last decade drug research has been directed away from finding vasoconstrictor drugs and redirected towards other areas [10].

C. Sample size & bias

A third unknown is related to the lack of statistics with sample sizes sufficiently large. In the past, the majority of migraine related surveys and studies have been based on sample sizes of about 30 to 50 patients. A review of studies was conducted by [5]. The three largest clinical studies existing until year 2,000 monitored 490 patients in 1984 [6] and 490 patients in 1995 [7], (both with a focus of finding food triggers). A third study from 2004 monitored 532 chronic migraine patients during one year with the purpose of studying the progressiveness of the disease [11]. More recently case cross-over studies with N>1,000 have been published but they are based on migraine sufferers that visited an Emergency Room (ER) of a hospital at least once. [12, 13]. However, since the only population considered is the one that visited a hospital at least once, this approach might lead to a selection bias known as *ER-visited* bias. Unfortunately, even with N>1,000, studies show conflicting results. For example, [12] reported correlation of migraine probability with apparent temperature in Boston while [13] could not find a conclusive relationship in Ottawa.

Other contradictions have been pointed out by [5] where it mentions two studies that have opposed views on whether chocolate is a trigger or not.

D. Treatments

1) Drug satisfaction

A fourth unknown, (particularly in chronic patients dependent on medication), is drug satisfaction. In this area sample sizes are of the order of N~500. Phone surveys are typically used to collect user feedback. An example is [14], a phone based survey of N=688 that reported that only 29% of migraine sufferers were fully satisfied with their current treatment.

2) Drug overuse

As we mentioned, 26% of migraine chronic patients do not know of their condition and think they just have recurrent headaches leading to under-medication. On the other hand, we have over-medication. Depending on the study, it is estimated that between 0.7% to up to 4% of all headaches and migraines combined are actually "rebound" episodes triggered by the overuse of certain medications. These are usually triptan-based drugs and analgesics such as Advil [15,

*Research supported by the Office of the Deputy Vice Chancellor for Research and Graduate Studies, UAEU.

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16]. However, due to the limited sample sizes the studies could not explore the effects of combining drugs.

E. Advantages of using an app to log data

1) Computer-mediated vs. Face-to-Face feedback

Using an app to let users annotate and log migraine details might not offer the same data quality assurance that a clinical setting offers. If data is collected via an app then the experimental conditions cannot be controlled in the same accurate way that they are in a clinical setting. Errors might arise. However, we can apply the law of large numbers and assume that inaccuracies resulting from not controlling the experimental setting will cancel out. Additionally, a benefit of using an app to collect data (particularly feedback on treatments) is that for the patient, it is not only more convenient, but when it comes to negative feedback using an app as writing medium is easier than a face-to-face mediated communication (typical in a clinical setting) [17]. In addition, some studies indicate that computer-mediated communication results in more accurate (honest) evaluations than face-to-face based ones [18].

2) Direct data vs. processed data

In the previous section we mentioned that using an app instead of a clinical setting might impair the quality of data. However, in a clinical setting the data is typically collected by a nurse, then it travels from the nurse to the doctor's desk where it is reviewed and then it is compiled into a statistic. And opposing view states that the app data is more accurate than in a clinical setting because it is transformed by the user one time, where as in a clinical setting it undergoes more transformation steps.

II. METHODS

An app called *Migraine Buddy* was used to log and collect data. The app is free and at the moment it is available in five languages for both Android and iOS mobile operating systems. The users use the app as a migraine diary to log details on their migraine episodes.

A. Sample Size & demographics

The app has been downloaded over 200,000 times and the current active user-base (defined as the users using the app at least once during the last 30 days) is 83,000. The number of migraine episodes logged is 809,000. Only data from users that volunteered to share the data was used in this study. 87.856% of users are female. Fig. 1 shows an age histogram to visualize the age. In the tables and unless otherwise stated, the sample size is N>20k migraine episodes per language locale (column).

B. Graphical User Input

Data input is touch-based to reduce cognitive load to the user. Icons rather than text are favored. For example, in order for the user to indicate the onset location of a migraine, a touch sensitive head picture is shown. See Fig. 2.

C. Factors

In the following section we report findings regarding: (i) triggers, (ii) symptoms, (iii) relief methods, (iv) onset locations, (v) drug combination effectiveness.

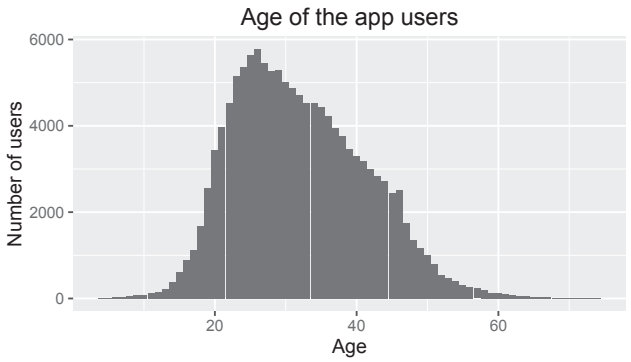

Figure 1. Count of users by reported age in the app. 87% are female. The most common age is 26 years old. The distribution follows a normal curve centered at 35 years, decimated from age 26 to 45.

Figure 2. Four screenshots of the iOS version of the app.

III. RESULTS

A. Triggers

Self-reported triggers are collected when the app user answers the question, "What do you think triggered the migraine?", a screen with a list of icons is presented to her, multiple choice is allowed. The user can specify its own particular trigger. Table 1 compiles the most commonly reported triggers for seven languages locales. The top three triggers (stress, anxiety, and lack of sleep) are common across locales. Fig. 2 visualizes aspects table 1. In Fig. 3 we can see that triggers such as to "skip a meal" are infrequent in romance related locales even if the users live in a country where it is a common trigger. Such is the case if we compare es_US (migraines of Spanish speakers in USA) and en_US (migraines English speakers in USA).

B. Symptoms, relief methods & onset locations

Table 2 shows the top symptoms by rank in three locales. Table 3 shows the top relief methods (remedies that the users rated as effective other than drugs). Some methods such as "Peppermint Oil" have been added by users. Table 4 shows the percentages of the most common onset locations. Multiple onset locations are allowed per migraine.

C. Outcomes of drug combinations

Table 5 shows how effectively was a drug rated (patient reported outcome) when taken alone or in combination with another drug for USA users (N=66,075). 67 drug combinations (combos) are considered. The table shows that combining two drugs only improves the outcome in 19 out of

67 combination cases (28%). Taking a drug alone beats other combinations in 41/67 cases (60%).

TABLE I. PERCENTAGES OF THE MOST COMMON SELF-REPORTED TRIGGERS IN A MIGRAINE EPISODE FOR SEVEN APP LANGUAGE LOCALES

Trigger	en_CA	en_GB	en_US	es_ES	es_US	fr_FR	ja_JP
Stress	20.28	22.84	23.07	23.43	23.26	20.13	22.26
Lack of sleep	18.33	21.78	18.10	18.22	18.31	28.93	18.43
Anxiety	11.93	14.39	13.96	13.62	13.21	15.12	9.72
Skipped a meal	8.19	7.69	7.94	0.00	6.69	4.36	3.04
Weather	8.84	2.32	6.79	4.24	3.54	0.00	6.15
Physical exercise	4.13	5.60	5.07	4.71	5.32	4.48	2.96
Neck pain	4.45	3.05	3.91	7.03	6.00	4.14	9.69
Caffeine	4.08	3.74	3.96	2.32	1.85	1.83	2.26
Irregular sleep	4.20	3.64	3.03	7.53	6.93	4.61	3.82
Dehydration	4.29	4.46	3.41	1.86	2.27	0.00	1.60
Alcohol	2.83	3.56	2.58	3.39	2.74	4.66	3.15
Processed food	3.42	2.41	3.13	2.38	3.13	1.94	0.00
Sinus	2.15	1.74	2.32	0.00	0.00	1.74	0.00
Rebound	1.51	1.34	1.37	3.64	3.09	1.67	1.66
Bright light/Sun	1.37	1.43	1.36	2.88	3.63	1.93	0.00
Fatigue	0.00	0.00	0.00	0.00	0.00	2.20	10.39
Menstruation	0.00	0.00	0.00	0.00	0.00	0.00	2.50
Salty food	0.00	0.00	0.00	4.75	0.00	0.00	0.00
Low pressure	0.00	0.00	0.00	0.00	0.00	0.00	2.38
Heat	0.00	0.00	0.00	0.00	0.00	2.28	0.00

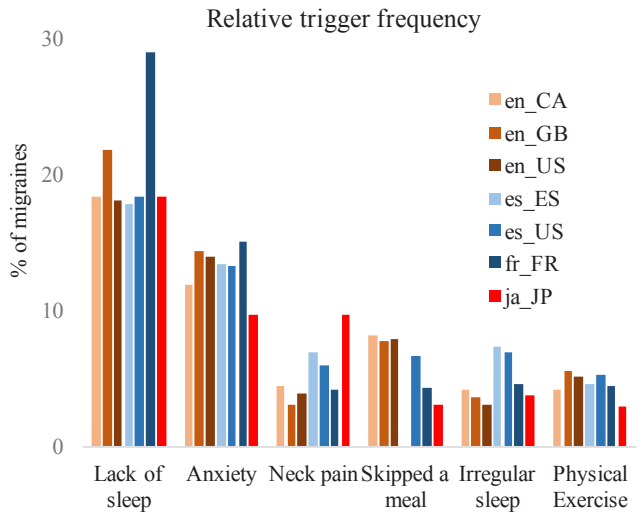

Figure 3. Comparison of the top six triggers for seven app locales. Y-axis is percentage of migraine frequency of a trigger given a locale. The locale format is the two letter ISO code for language in small caps followed by the two letter ISO country code capitalized. X-axis is trigger name. Color codes: Red indicates a Japanese locale. Blue tone indicates that the locale's language belongs to a romance-language family (Spanish, French). Brown tone indicates that the locale's language belongs to the Anglo-Saxon family. Cultural differences seem to influence the prevalence of triggers. (Sample size N >20k migraines/locale.)

TABLE II. RANKING OF TOP SELF-REPORTED SYMTOMS BY APP LANGUAGE LOCALE IN USA, CANADA AND JAPAN

Symptom	en_US	en_CA	ja_JP
Sensitivity to light	1	1	2
Neck pain	2	2	1
Sensitivity to noise	3	3	5
Nausea	4	4	3
Nasal congestion	5	5	7
Sensitivity to smell	6	7	9
Depressed mood	7	6	4
Anxiety	8	8	8
Insomnia	9	9	11
Fatigue / Tiredness	10	10	10
Vomiting	11	15	13
Giddiness	12	13	-
Confusion/Light headed	13	11	-
Blurred vision	14	14	14
Moody	15	15	-
Shoulder pain	-	-	12

TABLE III. RANKING OF TOP SELF-REPORTED RELIEF METHODS BY APP LANGUAGE LOCALE IN USA, CANADA, JAPAN

Relief method	en_US	en_CA	ja_JP
Sleep	1	1	1
Dark room rest	2	2	3
Stay indoor	3	3	2
Drink water	4	4	7
Ice pack	5	5	5
Caffeine	6	7	9
Eat	7	6	6
Hot shower	8	8	8[a]
Yoga/Meditation	9	9	12
Heat pad	10	10	14
Massage	11	12	11
Coffee	12	11	9
Rest	13	13	-
Cold shower	14	-	14
Peppermint oil [a]	-	14	-
Lie down	-	-	4

a. User addition.

TABLE IV. PERCENTAGES OF THE MOST COMMON SELF-REPORTED ONSET LOCATIONS FOR SIX APP LANGUAGE LOCALES

Trigger	en_CA	en_GB	en_US	es_ES	es_US	fr_FR	ja_JP
Right Head	12.58	15.22	12.99	15.99	15.48	16.21	12.20
Left Head	11.95	14.49	12.40	14.80	14.55	15.19	12.52
Right Eye	9.94	10.38	9.46	10.15	9.36	9.68	8.60
Left Eye	9.86	10.03	9.06	8.99	8.86	9.17	8.83
Top Right B. H.[a]	5.71	6.44	6.39	6.42	7.01	6.22	5.49
Right Back Head	6.10	5.16	6.68	5.87	6.00	5.00	6.51
Right Neck	6.13	5.33	6.35	4.78	4.97	5.84	5.90
Left Back Head	5.80	4.86	6.19	5.04	5.53	4.64	6.61
Top Left. H.	5.41	5.96	5.87	5.51	6.60	5.74	5.86
Right Temple	6.35	5.14	5.85	6.47	6.07	5.76	9.11
Left Neck	5.55	5.00	5.97	4.26	4.61	5.32	5.95
Left Temple	6.10	5.00	5.56	6.07	5.75	5.85	9.39
Between Eyes	4.44	4.01	4.02	3.79	3.43	3.12	2.20
Left Cheek	2.14	1.52	1.62	0.88	0.96	1.20	0.44
Right Cheek	1.93	1.45	1.60	0.99	0.85	1.07	0.37

Right all[b]	48.75	49.12	49.31	50.67	49.73	49.79	48.19
Left all	46.82	46.87	46.67	45.55	46.84	47.09	49.61
Center	4.44	4.01	4.02	3.79	3.43	3.12	2.20

a. B. H. = Back Head.

b. Sum of all locations (not migraines) pertaining to the right side.

TABLE V. REPORTED OUTCOME OF A DRUG WHEN COMBINED WITH SECOND DRUG

2nd drug \ Main drug	Zomig	Relpax	Sumatriptan	Maxalt	Advil	Excedrin	Ibuprofen	Tylenol	Propranolol	Topiramate
Paracetamol	**76**	73	65				37		16	
Aleve	60	**74**	62	65		35		35		
Advil	74	66	63	58		38		34		
Ibuprofen	73	66	64	67	30	40		32	17	13
Naproxen	69	72	70	64				28		
No drug	**70**	**70**	**67**	**64**	**42**	**46**	**37**	**30**	**17**	**15**
Topiramate	68	62	56	56	32	39	30	24	07	
Propranolol	65	66	57	57	31	43	36			**08**
Excedrin	62	63	64	57	**22**		26	15	10	12
Tylenol	**48**	56	62	62	39	38	34			15
Zomig					**50**	34	36	**10**	14	16
Rizatriptan					45		**44**		**24**	15
Relpax					41	30	24	25	16	13
Maxalt					35	**26**	38	27	20	17

DISCUSSION

We have demonstrated a smartphone based **alternative** to emergency-room-visit-based case cross-over studies. Based on the collected data we compiled a list of the top triggers, symptoms, reliefs and onset locations for various language locales. The top three triggers across locales by order are stress, lack of sleep, and anxiety. The top three symptoms are sensitivity to light, noise, and neck pain. The top three reliefs (other than drugs) are sleep, dark room rest, and stay indoors.

In general, factors are common across locales with a few exceptions attributed to cultural and translation factors. Example of cultural factor: Spanish speakers in the USA (es_US) skip more meals than Spanish speakers in Spain (es_ES). Example of translation factor: Japanese users report neck pain more often that other users. This can be explained by the fact that the translation of "neck pain" to Japanese has a wider meaning (used more often) in Japanese than in other languages.

Regarding onset locations, there is inter-hemispheric **asymmetry**. On average, for every one onset location attributed to any location on the left side of the head 1.056 migraine onset locations were attributed to the right side of the head.

Regarding the effectiveness of taking two drugs at the same time as compared to taking a drug alone, users report a decrease in effectiveness in about $3/5^{ths}$ of the combinations.

IV. ACKNOWLEDGMENT

Our thanks to Healint staff, Ali El Gamal and Nicolas Paris for helping compile the data.

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