Phosphene data pre-processing

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To be used in Vladas Valiulis's MSc thesis and Niina Salminen-Vaparanta's PhD thesis

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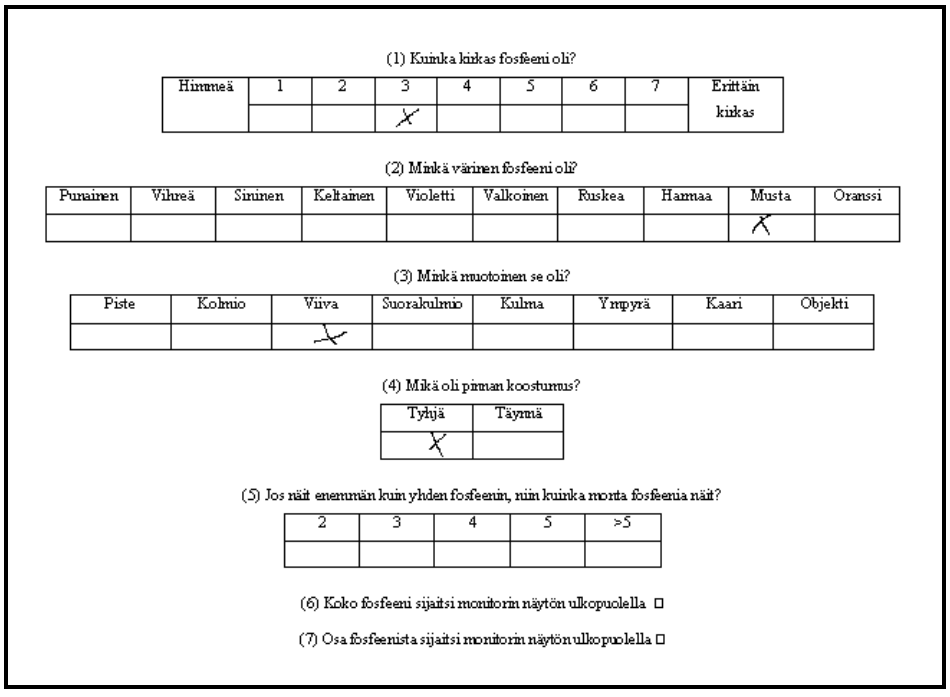
In a series of experiments, four subjects were stimulated on their visual V1 and V2 cortical areas by single-pulse TMS. The subjects were carefully selected by exclusion rules, and pre-tested for being able to perceive phosphenes upon cortical stimulation. Each stimulation session lasted about 2 hours and consisted of 100 stimuli per session. As stimuli were given to different areas of the visual cortex, each subject had a different "expected region" where the phosphenes ought to appear. After receiving a TMS stimulus, the subject was asked to mark the perceived characteristics of her visual experience (such as brightness, color and shape of the phosphene) on a 7-question form (see Figure 1) by using a tablet pen. In addition, the subject was asked to produce a freehand drawing of the perceived phosphene, showing its more precise shape and location within the visual field (see Figure 2).



(1) Kuinka kirkas fosfeeni oli?

Himmeä	1	2	3	4	5	6	7	Erittäin kirkas
			X					

(2) Minkä värinen fosfeeni oli?

Punainen	Vihreä	Sininen	Keltainen	Violetti	Valkoinen	Ruskea	Harmaa	Musta	Oranssi
								X	

(3) Minkä muotoinen se oli?

Piste	Kolmio	Viiva	Suorakulmio	Kulma	Ympyrä	Kaari	Objekti
		X					

(4) Mikä oli pirnan koosturmus?

Tyhjä	Täynnä
X	

(5) Jos näit enemmän kuin yhden fosfeenin, niin kuinka monta fosfeenia näit?

2	3	4	5	>5

(6) Koko fosfeeni sijaitsi monitorin näytön ulkopuolella ☐

(7) Osa fosfeenista sijaitsi monitorin näytön ulkopuolella ☐

Figure 1: An answered questionnaire form example.

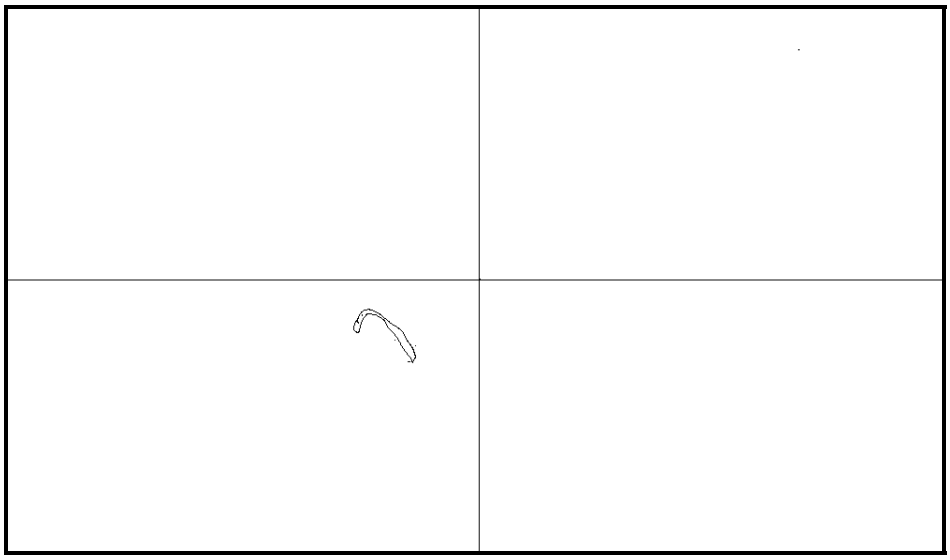


Figure 2: A phosphene drawing example.

A total of 800 questionnaire forms and 800 phosphene drawings were collected from the subjects and stored as image files in Paint Shop Pro (PSP) file format. This huge amount of image data would have required an extensive amount of monotonous, mechanical and error-prone human labour to preprocess into computer-readable format. Thus, our research team concluded to utilise custom-made programming solutions for automatised data processing of the images. The required programming was implemented in PERL language scripts (www.perl.org) in a Debian Linux environment (www.debian.org) using GraphicsMagick image processing utilities (www.graphicsmagick.org).

For converting the hand-marked questionnaire forms into numerical data, an optical symbol recognition system was developed. The process started by converting the PSP files into Portable BitMap (PBM) format, so that the question texts of the form were merged into the background, leaving only the answer marks visible. Then for each question, all of its answer options were automatically checked for any marks in the corresponding rectangular-shaped answer boxes (that were defined by upper left corner X and Y coordinates, width, and height). If any pixels were detected within that location, a positive answer option was written into a text data file in a comma-separated values (CSV) format, with a header line (see Table 1).

Subj,Area,Sess,Num,1-1,1-2,1-3,1-4,1-5,1-6,1-7,2-pun,2-vih,2-sin,2-kel,2-vio,2-val,2-rus,2-har,2-mus,2-ora,3-pis,3-kol,3-vii,3-suo,3-kul,3-ymp,3-kaa,3-obj,4-tyh,4-tay,5-2,5-3,5-4,5-5,5-5plus,6-koko,7-osa

HL,v1,01,01,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,
HL,v1,01,02,0,1,0,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,0,0,0,0,1,0,1,0,0,0,0,0,0,0,0,
HL,v1,01,03,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,1,0,1,0,1,0,0,0,0,0,0,
HL,v1,01,04,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,1,0,1,1,1,0,0,0,0,0,0,
HL,v1,01,05,0,0,0,1,0,0,0,0,0,0,0,0,0,1,0,0,0,0,0,0,1,0,0,0,0,0,1,0,0,0,0,0,0,0,0,
...

Table 1: Questionnaire form answer data, in CSV format.

In order to find out more details about the perceived visual effects, the phosphene drawings were processed by two further methods. First, the precise location and extent of the phosphene in the subject's visual field was computed. The subject's actual visual field size was calculated (by using the distance from the display and the width of the display) both in degrees and in screen pixels. The drawings were checked against a visual mask consisting of an inner disc with a diameter corresponding to a 1° foveal area of the visual field, and three concentric rings at 4°, 8°, and 12° of the visual field. These three rings were divided into eight 45° sectors, from which four were divided further into 22.5° subsectors by the horizontal and vertical axes. Thus, the masking procedure defined a total of 24 sectors and 12 subsectors, as well as 12 corresponding areas outside the largest ring (see Figure 3).

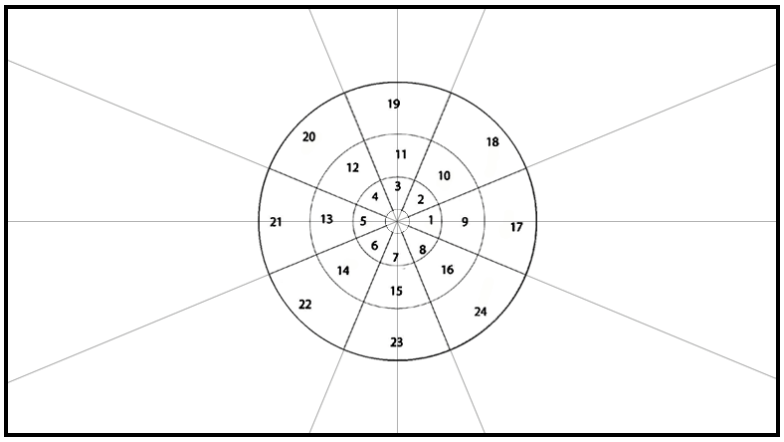


Figure 3: Sector mask layout.

In an automatised process, each phosphene drawing was checked against each sector, and the number of pixels found inside that sector was written into a text data file in CSV format (see Table 2). For each subject, the expected regions were calculated by adding up the individual sectors (see Figure 4).

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Subj,Area,Trial,Drawing,00,01.1,01.2,01,02,03.1,03.2,03,04,05.1,05.2,05,06,07.1,07.2,07,08,09.1,09.2,09,10,11.1,
11.2,11,12,13.1,13.2,13,14,15.1,15.2,15,16,17.1,17.2,17,18,19.1,19.2,19,20,21.1,21.2,21,22,23.1,23.2,23,24
HL,v1,01,01PH,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,4,44,46,48,0,0,0,0,0,0,0,0,0,0,0,0,57,0,57,50,0,0,0,0,
HL,v1,01,02PH,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,32,32,54,0,0,0,0,0,0,0,0,0,0,0,0,0,17,17,6,0,0,0,0,
HL,v1,01,03PH,0,16,3,18,0,0,0,0,0,0,0,0,0,8,12,20,22,0,21,21,0,0,0,0,0,0,8,10,92,27,0,27,0,0,0,0,0,0,0,0,0,0,0,0,99,0,0,0,0,
HL,v1,01,04PH,0,7,13,19,11,0,0,0,0,0,0,0,8,18,6,24,10,0,0,0,34,0,0,0,0,0,0,0,38,0,0,0,0,0,0,0,8,0,0,0,0,0,0,0,121,0,0,0,0,
HL,v1,01,05PH,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,0,24,54,76,68,0,0,0,0,
...
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Table 2: Detected pixel-count data for the 24 sectors, in CSV format.

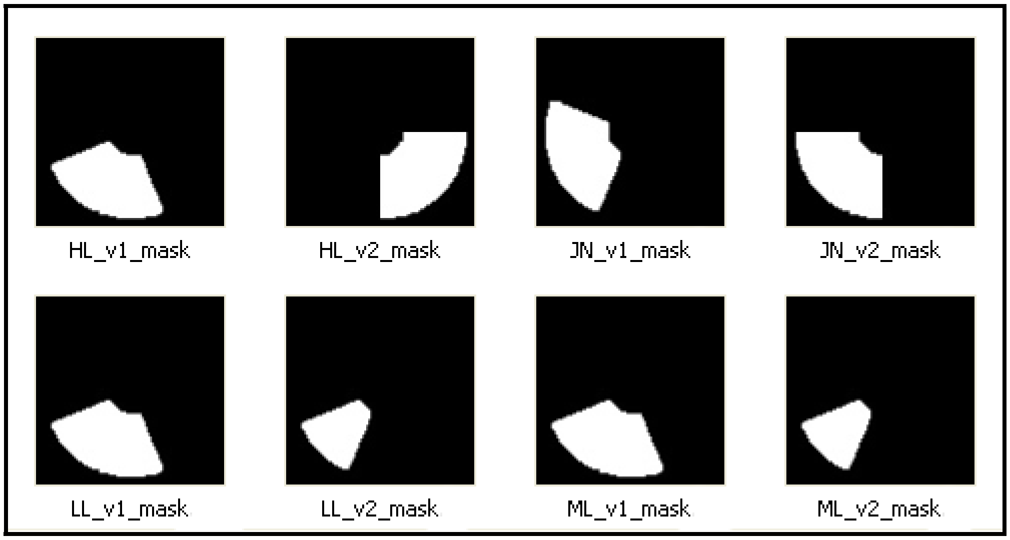

Figure 4: V1 and V2 expected regions for the four subjects.

The generated CSV data files were converted into Microsoft Excel sheet (XLS) file format, from which the data could be imported into the SPSS software for statistical analysis. In addition, some illustrative visualisation of the data was made by overlaying the phosphene drawings on top of each other, showing their actual areas of appearance in each subject's visual field (see Figure 5).

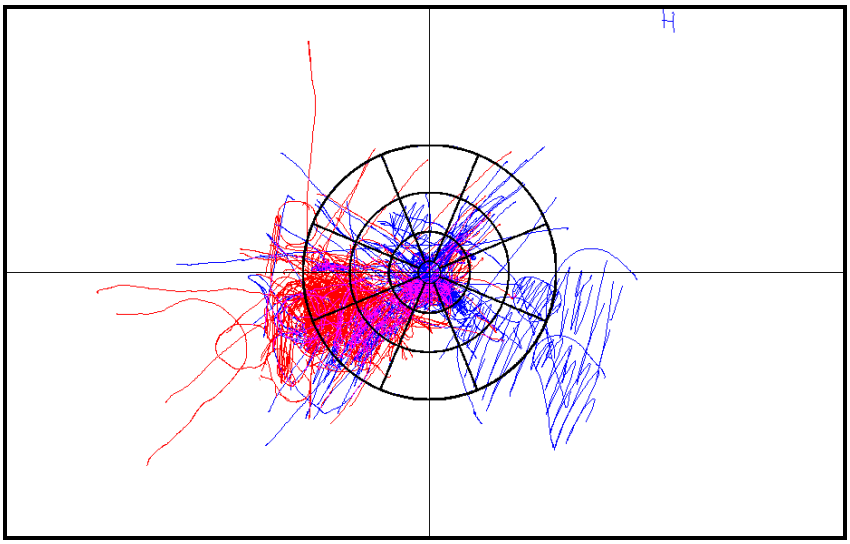

Figure 5: V1 and V2 phosphenes overlayed, visualised in red and blue.

To find out the size and orientation of the phosphene drawing, another computational method was developed. Each phosphene drawing was rotated by 1°, 2°, 3° etc. degrees, up to 90°. After each rotation, the phosphene drawing was cropped by a bounding box that included only a rectangular non-empty area. During the rotation process, one size dimension (width or height) is always increasing up to a certain angle, while the other size dimension (height or width) is respectively decreasing. At the angle where the height gets its maximal value and the width gets its minimal value, the phosphene drawing is in its most vertical position (pointing to 90°), thus its original orientation can be computed by adding this angle to 90°. Respectively, at the angle where the height gets its minimal value and the width gets its maximal value, the phosphene drawing is in its most horizontal position (pointing to 0°), thus its original orientation corresponds to the angle of rotation (see Figure 6).

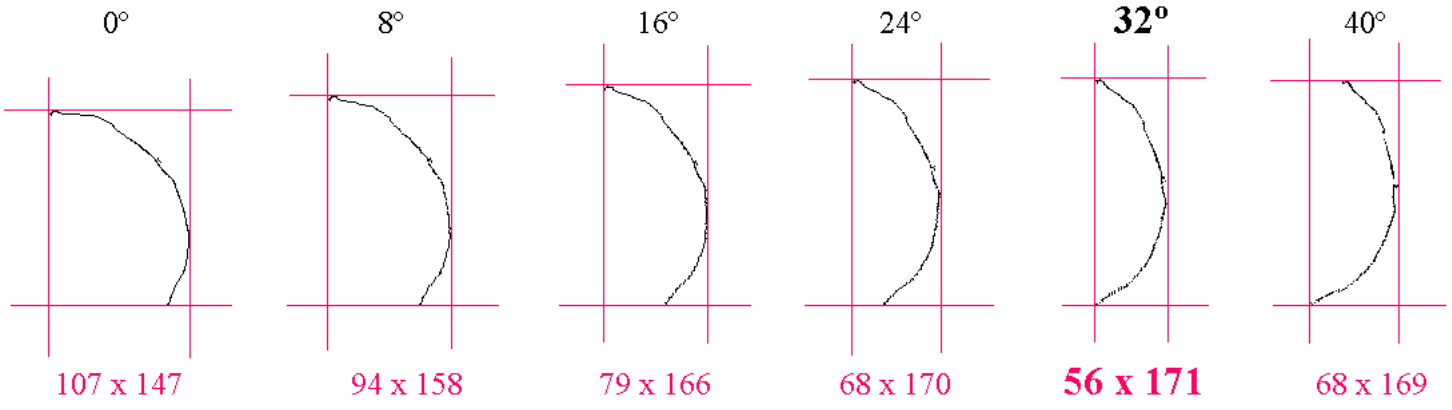

Figure 6: Finding out a phosphene drawing's size and orientation. After 32° rotation, the phosphene drawing gets its minimal width and maximal height, pointing vertically up to 90°. Thus, its original orientation was 122°.