TOWARD A PORTABLE, SELF-ADMINISTERED CRITICAL FLICKER FREQUENCY TEST

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HEPATIC ENCEPHALOPATHY (H.E.)

Occurs in people with end-stage liver disease

Normal function of liver impaired
Toxins build up in the blood (e.g., ammonia)
Increased concentration of toxins affects cognitive abilities
# WEST HAVEN CRITERIA FOR HEPATIC ENCEPHALOPATHY

<table>
<thead>
<tr>
<th>Stage</th>
<th>Level of Consciousness</th>
<th>Intellect &amp; Behavior</th>
<th>Neurological Findings</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Normal</td>
<td>Normal</td>
<td>Normal examination; if impaired psychomotor testing, then MHE</td>
</tr>
<tr>
<td>1</td>
<td>Mild Lack of Awareness</td>
<td>Shortened attention span; impaired addition or subtraction</td>
<td>Possible mild asterixis or tremor</td>
</tr>
<tr>
<td>2</td>
<td>Lethargic</td>
<td>Disoriented; inappropriate</td>
<td>Obvious asterixis; slurred speech</td>
</tr>
<tr>
<td>3</td>
<td>Somnolent but arousable</td>
<td>Gross disorientation; bizarre behavior</td>
<td>Muscular rigidity &amp; clonus; hyper-reflexia</td>
</tr>
<tr>
<td>4</td>
<td>Coma</td>
<td>Coma</td>
<td>Decerebrate posturing</td>
</tr>
</tbody>
</table>
IMPACT OF LATE DETECTION OF H.E.

Reduced quality of life and affects everyday tasks
Increased risk of road traffic incidents
Increased hospitalizations
Increased mortality
COST OF LATE DETECTION

If detected early, easily treatable (Stage 0-1)
   Affordable, effective home medications to clear toxins

If detected late, not easily treatable (Stage 2)
   Requires hospitalization for intravenous and enema medications

If detected really late, can be life-threatening (Stage 3-4)
   Requires intensive care unit with airway protection (e.g., intubation)
PROGRESSION OF H.E.

Worsening liver disease

First sign of an underlying infection, gastrointestinal bleeding, dehydration, etc.
CURRENT EARLY DIAGNOSTIC PRACTICES

Figure 1. The five paper and pencil tests that make up the Psychometric Hepatic Encephalopathy Score (PHES), which assesses attention, visual perception, and visuo-constructional abilities [6,19]. Number Connection Tests A and B: subjects are asked to join the numbers or numbers and letters in sequence as quickly as possible. The time taken to complete the task is recorded. Digit Symbol Test (C): subjects are asked to insert symbols in the blank squares below the numbers using the key provided. The exercise is timed and the number correctly completed in 60 s recorded. Serial Dotting (D): subjects are asked to place a dot in the center of each circle as quickly as possible. The time taken to complete the task is recorded. Line Tracing (E): subjects are asked to trace a line between the two guidelines as quickly and accurately as possible without moving the paper. The time taken to complete the task and the number of errors made are recorded.
PROBLEM SPACE

Early detection
Looking for small effects
Missing baseline measurement
Needs more frequent monitoring
We want to reframe as self-tracking instead of a clinical test
Treatment effective but can be objectionable
CRITICAL FLICKER FREQUENCY

Neuro-physiological phenomena

Measures the ability of the central nervous system to detect flickering light

Is directly influenced by cortical activity
CRITICAL FLICKER FREQUENCY

20 Hz

~40 Hz
Healthy adults

60 Hz
CFF AS AN EARLY INDICATOR

Moderate sensitivity (correctly identify those with the disease) of 61%
Good specificity (correctly identify those without the disease) of 79%
Effective in discriminating patients with MHE from those without MHE (screening).
**DESIGN GOALS**

Make the device portable
Reduce device cost / Enable easy replication
Enable self-administration
Improve threshold detection algorithm
APP ONLY DESIGN

Limited by API access and hardware capabilities

LED flash as the light source
Phone display as the light source
PERIPHERAL BASED DESIGN

First step, get the hardware working
VIEWING BOX DESIGN
PERIPHERAL BASED DESIGN

First step, get the hardware working
Next step, miniaturize the set up
NEXT STEPS

Step 1: Device Performance and Accuracy Testing
  - Comparison to the reference device
  - Impact of different test conditions (hopefully relaxing the test constraints)

Step 2: Usability Testing
  - Understandability of the device operation
  - Ability to self-administer the test by users

Step 3: Feasibility of Lifestyle Integration
  - Understanding everyday challenges in applying the test
OTHER APPLICATIONS FOR CFF

Detect a broad spectrum of neuro-psychological abnormalities:
- visual signal processing (retinal gliopathy)
- cognitive functions

Applied to the study of several neurological disorders:
- multiple sclerosis
- Alzheimer’s disease

CFF is particularly apt for the study of alterations in visual signal processing, and is also suitable for the detection of arousal or attention abnormalities.
DISCUSSION

Design priorities
  viewing conditions
  reaction time
  motor impairment
  identifying distractions

Designing for long-term self-monitoring
  frequency of measures
DISCUSSION

Communicating results and ethical issues therein
patients disbelieve or lie about results
show / hide results from patients
provide instructions based on result
communicate uncertainty
share with provider
Discussion:
Design priorities
Designing for long-term self-monitoring
Communicating results and ethical issues therein

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