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# REVIEW OF WEARABLE ELECTROENCEPHALOGRAM SYSTEMS

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**INTRODUCTION:** The electroencephalogram (EEG) is a non-invasive measurement of electric potentials created by brain activity. The application of EEG using large numbers of wet electrodes is limited to laboratory settings due to its obtrusiveness, lack of portability and usability. Thus, efforts have been made to develop wearable EEG devices that promise high reliability and usability. However, developing a wearable EEG system is still a challenge. This is due to the trade-off between high signal quality against the disposition of electrodes (design) and easy preparation of the system (type of electrodes) [1].

We performed a systematic search of existing wearable EEG devices and prototypes to identify the ideal approaches to develop EEG device designs.

**METHODS:** We systematically investigated the designs and electrodes used in wearable EEG. Twelve different search criteria or keywords (C1 - C12) were systematically stacked for search engines, where each criteria is an ensemble of representative keyword and their synonyms or closely related keywords. Then, we searched for articles, patents, and official web sites on search engines such as, Google (News, Scholar and Patents), and PubMed Central (PMC). In order to identify the most recent approaches, selection of results were limited to publication dates between 01.01.2018 and 28.01.2019.

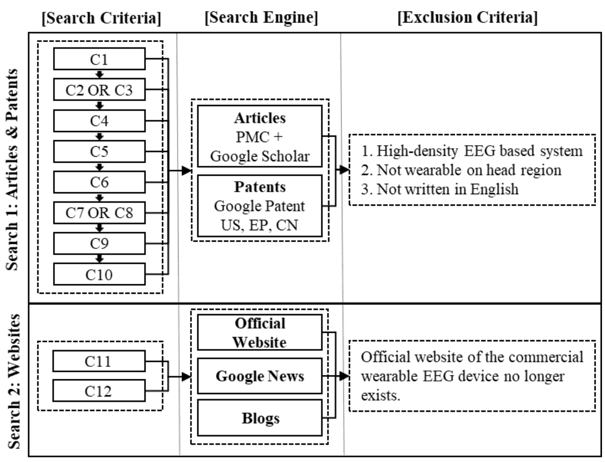


*Figure 1: Systematic search method to identify wearable EEG design and electrodes.*

Finally, we excluded results based on defined exclusion criteria (Figure 1). Multiple use of same device in different studies was included. From the obtained results, the designs and types of electrodes sorted into classes and quantified in percentages.

**RESULTS:** The most popular design for wearable EEG devices were headbands (16, 39.0%), then followed by a headset design (11, 26.8%) (Table 1). Dry electrodes were by far the most prevalent (26, 63.4%) (Table 2).

*Table 1. Different types of wearable EEG designs.*

| Wearable EEG design | Number of results (%) |
|---|---|
| **Headband** | 16 (39.0 %) |
| **Headphones** | 2 (4.9 %) |
| **Headset** | 11 (26.8 %) |
| **Ear EEG** | 7 (17.1 %) |
| **Eyewear** | 5 (12.2 %) |
| **Total** | 41 |

*Table 2. Different types of electrodes used in wearable EEG devices.*

| Electrode types | Number of results (%) |
|---|---|
| **Dry** | 26 (63.4 %) |
| **Wet** | 8 (19.5 %) |
| **Both** | 5 (12.2 %) |
| **Not Identified** | 2 (4.9 %) |
| **Total** | 41 |

**DISCUSSION & CONCLUSIONS:** We have reviewed different approaches to develop wearable EEG systems that eases usability while minimizing obtrusiveness of electrodes. Our analysis showed that more studies develop wearable EEG by using a headband design with dry electrodes.

However, the challenges to design a wearable EEG systems still remain due to dry electrodes's trade-off between the comfort level and performance. Therefore, we have focused in past wearable designs on wet electrode designs [2]. Further research must be conducted in order to obtain better designs for easy to use, wearable EEG systems.

**REFERENCES:** [1] A. Casson (2018) *Biomed Eng Lett* **9**:2. [2] M. Ferster, C. Lustenberger and W. Karlen (2019) *IEEE Sens Lett* **3**:5.