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Smart Gel-Enabled EEG Systems for Brain-Computer Interfaces in Children with Profound Motor Impairments

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Introduction:

Millions of children worldwide are cognitively capable but unable to move or speak, leaving families seeking solutions to support their right to play, communicate, and interact. Brain-computer interfaces (BCIs) offer a groundbreaking opportunity for these children to engage with their environment [1]. However, children remain significantly underserved in BCI research, with less than 2% of studies focusing on this population [2]. Addressing this gap is critical to enabling these children to express themselves and benefit from assistive technologies. Current EEG headsets used in BCI systems face significant challenges in daily use. For all-day measurement, the current EEG technology requires manual injection of conductive hydrogel into each electrode. The gel is commercially available and has toothpaste-like consistency. After applying it for a day, the gel dries up, gets jammed to hair, and is laborious to wash off. In addition, the current headsets require restrictive chin straps and transverse tightening to ensure for high-quality signals obtained using the conductive gel. For children with smaller head shapes and repetitive movements, overtightened caps cause discomfort, particularly for those with hypersensitivity. These barriers often force children to rely on less effective headsets, limiting their ability to benefit from BCI advancements and the life-changing potential of this technology [3].

Material, Methods and Results:

To improve on the current EEG headset design, a smart gel-enabled EEG system is under developing for practical daily EEG use. A polyampholyte sticky conductive gel is designed to transition from a solid-like consistency with firm adhesion to a water-like flow on demand. The precursor solutions are polymerized under UV for 8-10 hours to form the sticky conductive gel. When the gel is in the solid-like state, the highly adhesive property of the gel ensures firm adhesion between the scalp and the electrodes. The developed gel can also extend extensively with unaffected electrical conductivity. This allows EEG headset to experience head movements but still ensures high quality signals and adequate adhesion between the electrodes and the scalp. When needed, the bonding in the polyampholyte hydrogel can be disrupted by high concentration of salt. As a result, the solid-like gel is transitioned into a water-like flow using salt water. This transition in consistency allows for easier cleanup process after the end of the headset usage. This sticky hydrogel has been tested and compared to the current commercially available gel typically used in BCI systems. The EEG Quality Index was calculated and compared between the two gels under several different conditions including with and without the use of the chin strap. The preliminary data has indicated our proposed hydrogel was able to maintain a greater similarity in signal quality to the cleaned epoch of data even once the chin strap was released, as compared to the commercially available gel.

Conclusion:

This early result highlights the potential of our proposed gel to maintain high signal quality without applying continuous tension. With the highly adhesiveness and the controlled detachment of proposed gel, the EEG headset design is promising in providing reliable signals in less constrained conditions making the headset suitable for more situations in real life.

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