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Semantic Decoding Advances in BCI via the Novel Graded Inventory of Semantic Triggers (GIST)

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Introduction: Semantic decoding involves directly mapping neural activity to concepts, offering the potential to communicate entire concepts through *Semantic BCIs,* without having to translate them into words, e.g., via traditional BCI spellers [1]. This could significantly enhance information transfer rates, particularly for users with sensory impairments who cannot rely on exogenous stimuli for BCI control. Despite various paradigms for triggering semantic signals having been tested, significant challenges remain, such as the limited functional relevance of concept categories, confounding effects of cue stimuli, and delayed ideation during experiments.

Material, Methods and Results: To address existing limitations in semantic decoding experimental designs, we have developed a novel, gamified paradigm: the Graded Inventory of Semantic Triggers (GIST). GIST is specifically designed to enhance participant engagement and to more naturally evoke concepts, thereby increasing the strength of the associated semantic signals. Our paradigm, a word-guessing game adapted from [2] and [3], incorporates three semantic classes: food, musical instruments, and body parts. A unique set of 3 clues is presented for 432 trials. Each clue increases in specificity across the Superordinate (e.g., 'Is an organic object.'), Ordinate (e.g., 'Has the same colour as its name.') and Subordinate (e.g., 'Is high in vitamin C.') levels. Participants are instructed to perform a spacebar press when they have correctly identified the target word. This paradigm feature has been integrated to assist with intra-trial signal tracking and to boost participant engagement, as per [4]. Our preliminary analyses currently focus on the comprehensive extraction of signal features across different domains, feature selection using a fusion of filter-based methods and classification with Support Vector Machines (SVM). Thus far we have collected data from 8 participants, with the intention of collecting 20 participants in total. We have successfully classified all 2-class problem variants at the single-participant level, food *vs* musical instruments (avg.=72.5%, $p<0.05$), food *vs* body parts (avg.=73.2%, $p<0.05$) and body parts *vs* musical instruments (avg.=73.3%, $p<0.05$) in 4 of our 8 participants. Work is ongoing to enhance classification accuracies for the 3-class problem (food *vs* musical instruments *vs* body parts). Notably, the GIST paradigm demonstrates significant potential as the foundation for a mental imagery feedback training system that could enable real-time, bottom-up, concept decoding. GIST thus represents an important stepping-stone towards advancing BCI communication systems, with broad implications for the future of BCI design.

Conclusion: We introduce the Graded Inventory of Semantic Triggers (GIST): a gamified paradigm for naturally evoking semantic concepts and corresponding neural signals. Given our preliminary results, we believe that this platform and associated analysis pipeline will significantly improve the effectiveness of Semantic BCIs for communication applications.

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