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Recursive Queries for BCIs: SSVEP Shuffle Speller

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Introduction: A BCI has two fundamental jobs: classifying the user's physiological inputs (e.g. SSVEP) and finding the meaning of these inputs in the task domain (e.g. letter selection in the spelling task). This work offers a framework for recursively mapping SSVEP stimuli (user symbols) to letters (task symbols) [1]. In particular:

Recursive Framework Feature	SSVEP Shuffle Speller
Performs inference over a task symbol set which is larger than the user symbol set	Selects from among 26+ letters using only 6 SSVEP stimuli
Leverages context prior distributions over task symbols	Uses an N-gram language model to leverage local context
Leverages the varying accuracy of user symbols for inference on task symbols	Letter inference trusts queries whose SSVEP stimulus estimate is typically more accurate than others
Offers a task symbol decision mechanism which is **robust to single classification errors**.	Rarely makes a letter decision mistake when the classifier or user selects a single incorrect SSVEP.

Material: The prototype uses MATLAB and g.USBamp.

Methods: As a test bed for our framework, we offer the SSVEP Shuffle Speller (Fig 1). A Shuffle Speller query associates sets of letters to each SSVEP stimuli; the user is asked to look at the stimuli closest to their target letter. In decision tree tree style code (Sequential or Huffman) a letter decision is made by successively pruning away all letters which are not associated with the estimated SSVEP stimuli. As a result, any incorrect SSVEP classification necessarily results in a letter selection error. Alternatively, in the recursive style codes (Uniform and Max Mutual Info) no evidence ever precludes the user from selecting a particular letter until a final decision is made. To contrast the two styles of coding 10 neurotypical users typed 5 words using each of the 4 codes.

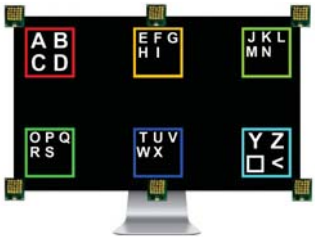

Figure 1: SSVEP Shuffle Speller, see this video.

Results: Recursive codes were more accurate than both decision tree style codes at a modest cost in speed.

Discussion: Recursive codes query the user until some confidence threshold in a letter decision is reached (85% for this experiment). This has the effect of adjusting the number of queries to suit the letter difficulty. In other words, it takes fewer queries to select likely letters (via the language model) and more queries to select unlikely letters.

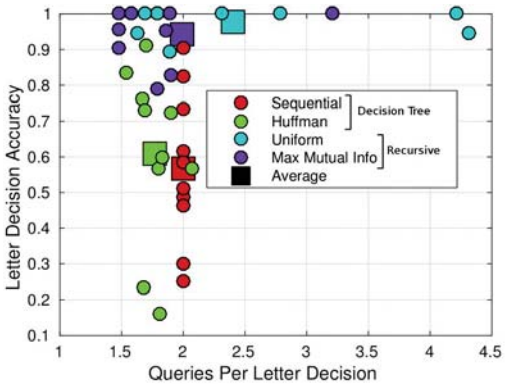

Figure 2: Speed (Queries Per Letter Decision) vs Letter Accuracy, each circle represents a user-code pair. Remember that the classifier was identical across all codes for each user.

Significance: Decision trees are popular within the BCI community; they offer an intuitive structure which BCI users can easily adopt [2-3]. While potentially less user friendly, we suggest that the performance benefits of recursive codes may outweigh their HCI considerations. A live demonstration of Shuffle keyboard which uses keyboard entry rather than EEG, will be provided at the workshop to contrast the performance of different coding schemes.

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