Swine pudendal nerve intraneural stimulation enables selective neuromodulation of urethral and anal external sphincters

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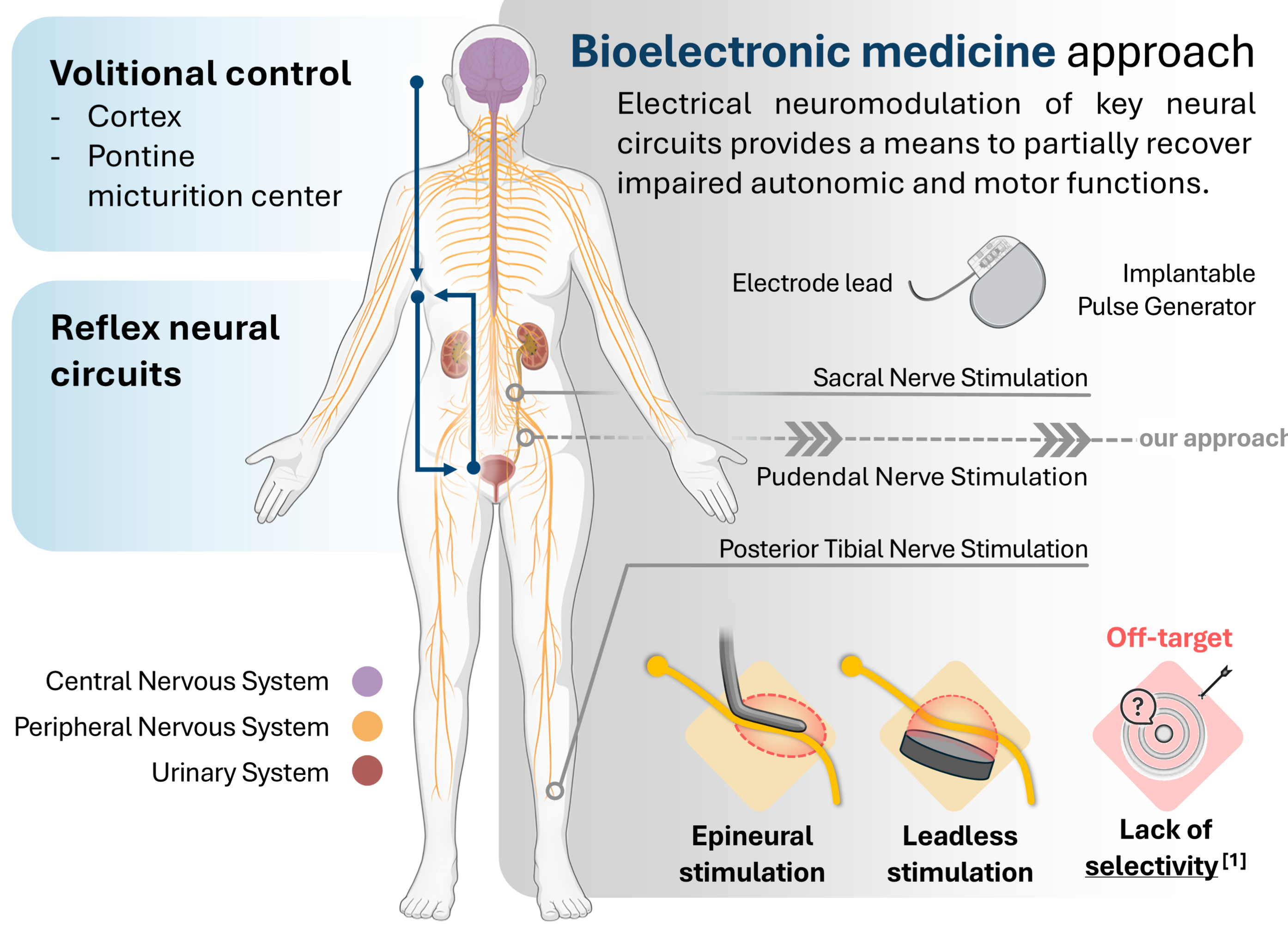
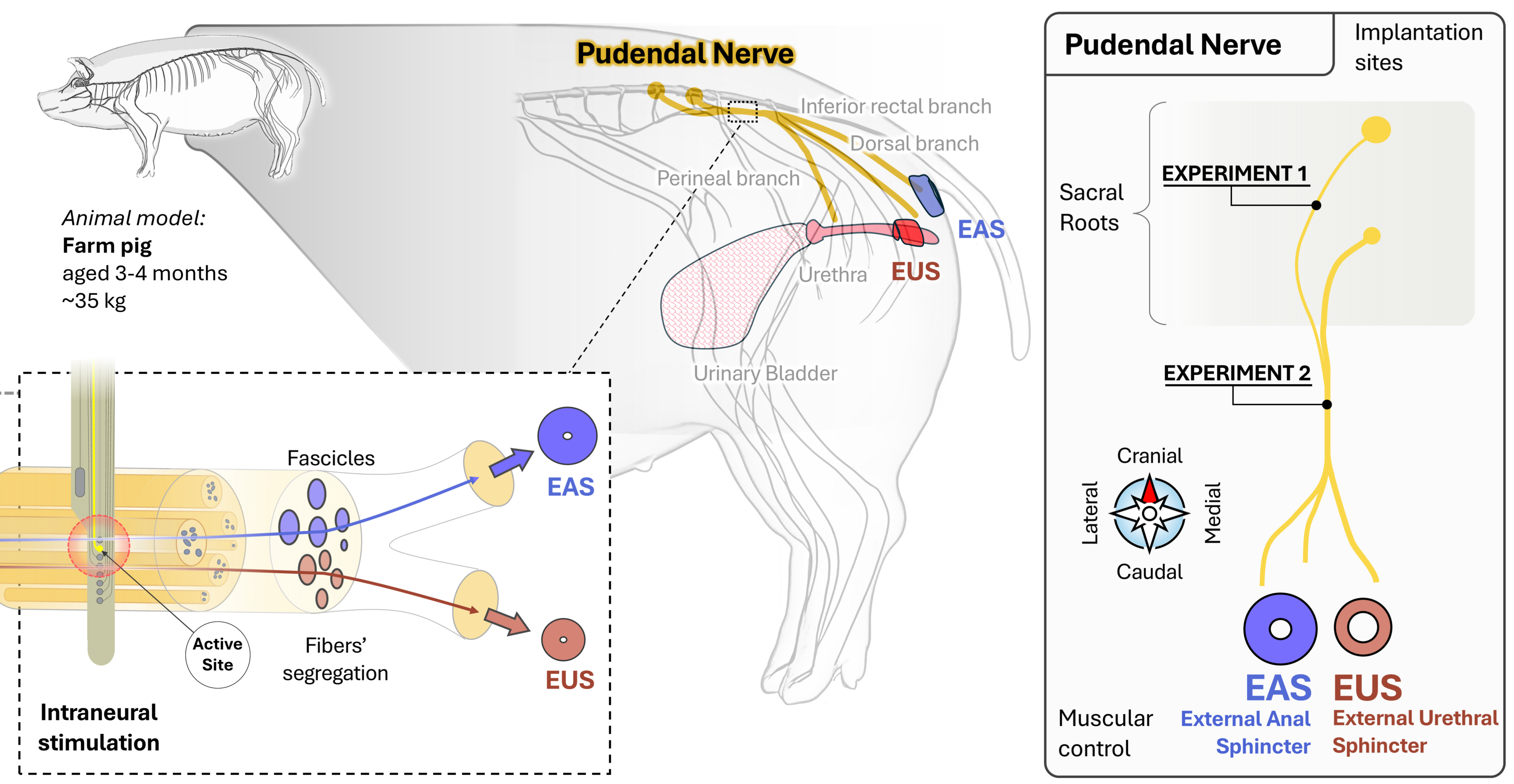
INTRODUCTION

The neural circuitry that controls the micturition process is complex and highly distributed, involving pathways at multiple levels of the brain, spinal cord, and peripheral nervous system. Neurological diseases or injuries can disrupt this control, resulting in the loss of voluntary regulation of the micturition reflex and leading to ***urinary incontinence***.

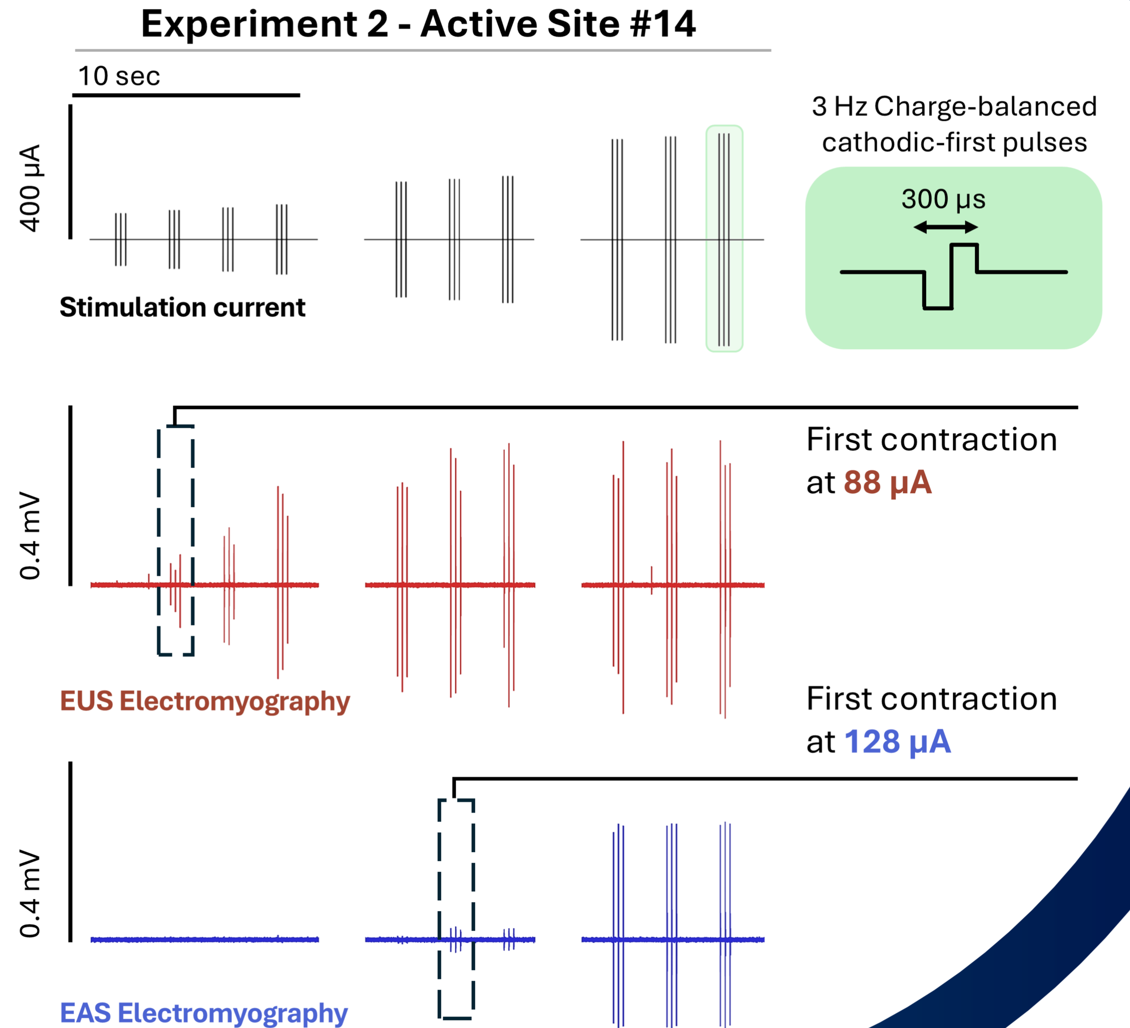


EXPERIMENTAL DESIGN

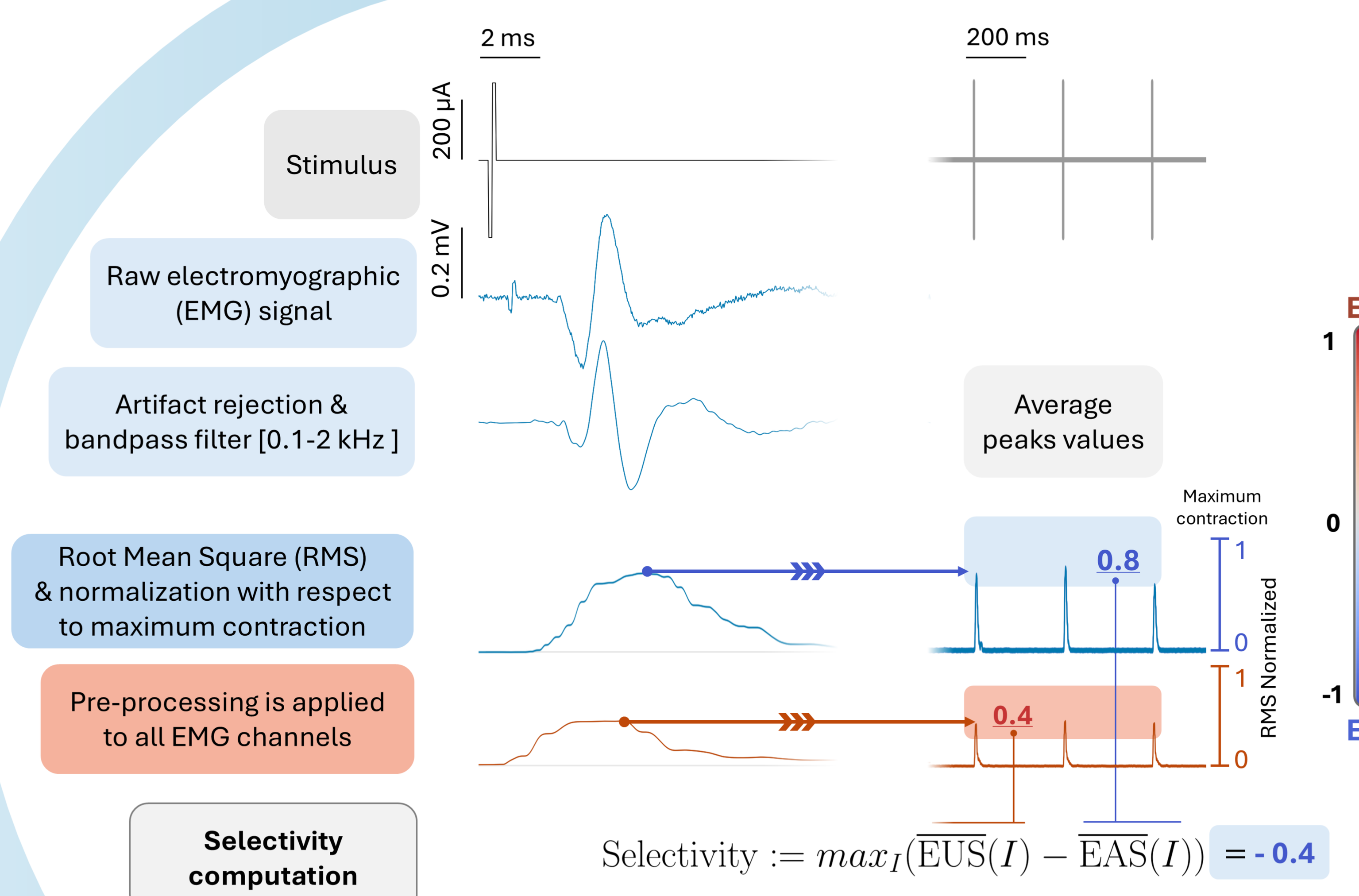
In this study, the TIME electrode was investigated as a more selective interface for neuroprosthetic control of urinary function. Modulation of the external urethral sphincter (EUS) was explored to restore voluntary control over continence.
Two experiments were conducted to evaluate muscle-specific responses to pudendal nerve stimulation at two anatomically distinct sites, selected for their suitability for electrode implantation [2].



For each TIME electrode, all of the 16 active sites (ASs) were tested using different current amplitudes while simultaneously recording electromyographic activity.



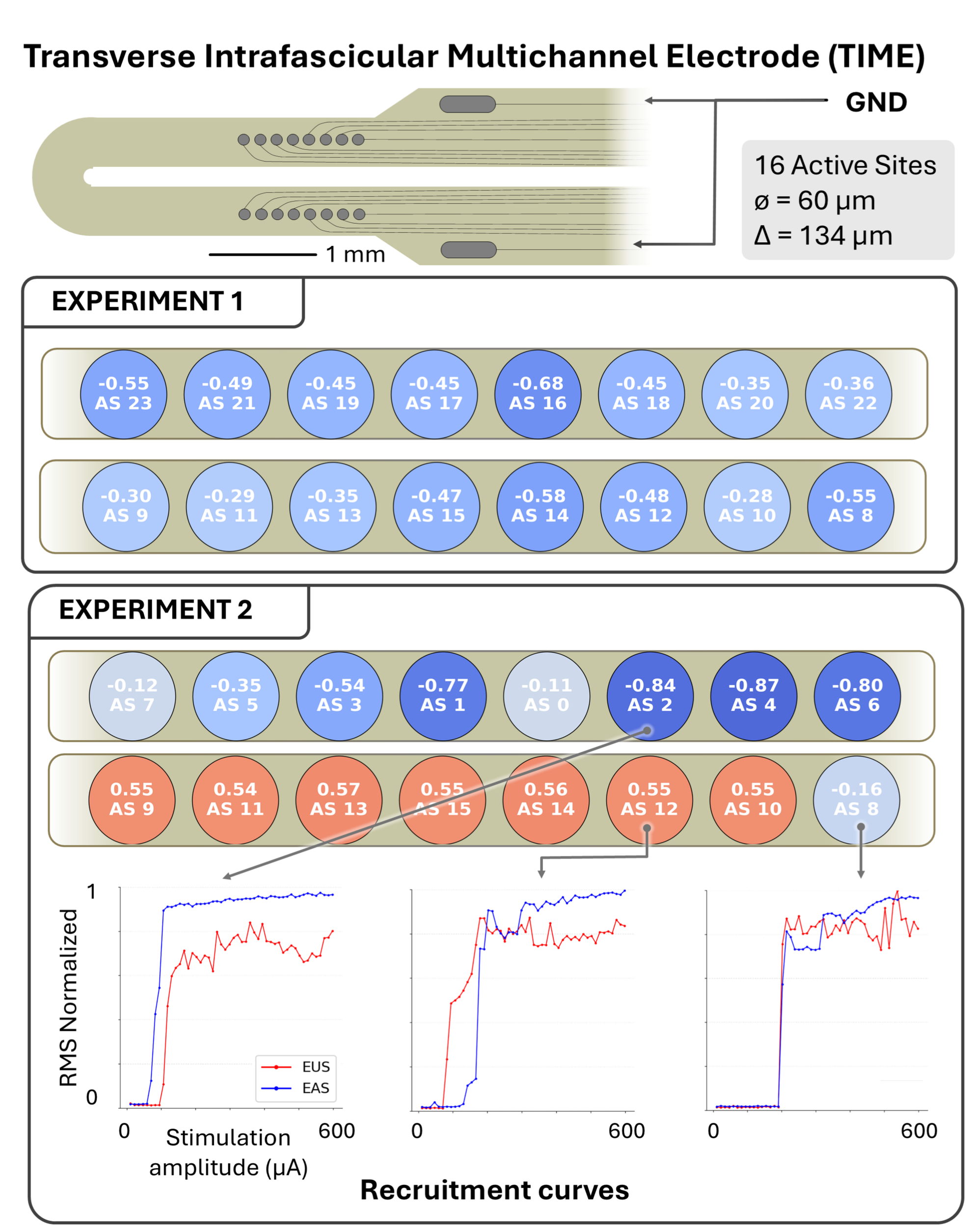
ANALYSIS



$$\text{Selectivity} := max_I(\overline{\text{EUS}(I)} - \overline{\text{EAS}(I)}) = -0.4$$

Recruitment curves were computed [3] for each AS and their maximum difference was used to quantify selectivity. Selectivity values range, by definition, from -1 to +1, where 1 indicates full EUS selectivity, -1 full EAS selectivity, and values near 0 denote near-equal co-contraction (i.e., no selectivity).

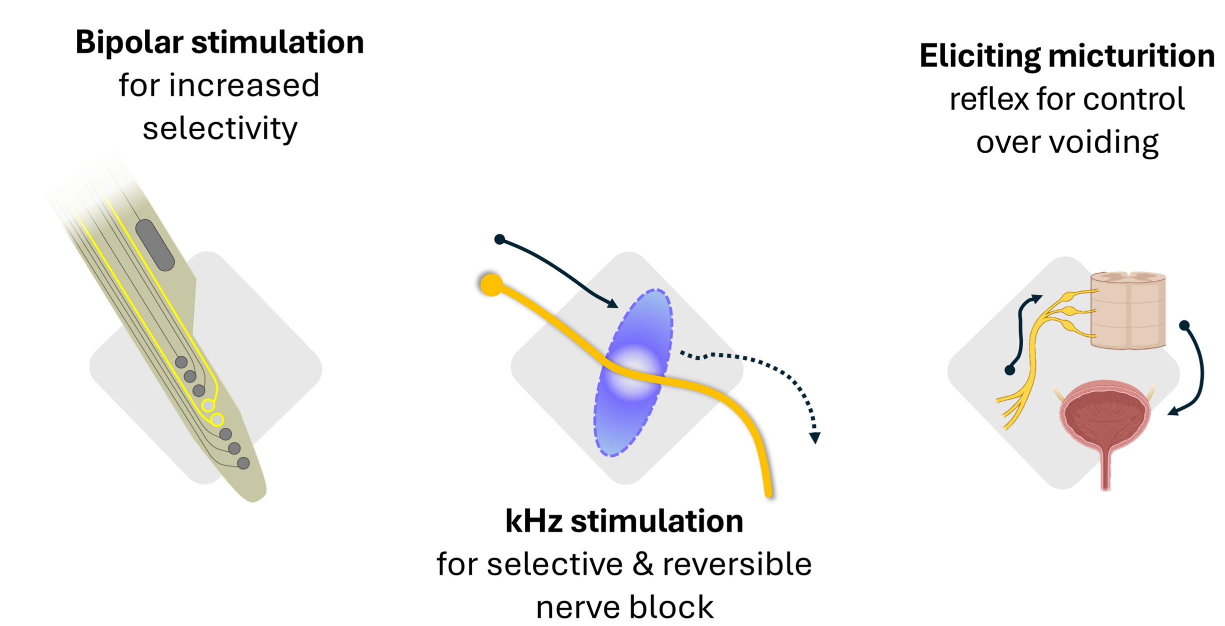
RESULTS & DISCUSSION



Experiment 1 showed consistent EAS recruitment across all ASs, with selectivity values from −0.68 to −0.28. This suggests a distribution of fibers favoring EAS recruitment when stimulating at this level of the pudendal nerve.
In contrast, **Experiment 2**, where TIME was placed more caudally, revealed a clear shift in selectivity: seven active sites preferentially activated the EUS (e.g., AS11, AS14), while four were strongly EAS-selective (e.g., AS4; AS6). These findings suggest the presence of a functional fascicular gradient along the pudendal nerve that can be exploited to enhance stimulation selectivity and reduce off-target effects.

The TIME emerges as a powerful solution to the spatial selectivity challenges, enabling targeted modulation of key effectors involved in continence. The results underscore the critical role of the implantation site in achieving precise activation. The differences in recruitment patterns observed between proximal and distal placements warrants further anatomical and functional mapping. Nevertheless, these findings lay the groundwork for more refined and effective neuroprosthetic strategies for lower urinary tract control that exploit the pudendal nerve as implantation site and TIMEs as neural interfaces.

NEXT STEPS



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