Storyline of the project:

The influence of response effector on decision adaptations due to prior expectations and speed pressure

**Key elements**（decision & motor; speed-acc/ time pressure; prior; continuous flow; muscle difference; decision adaptation）

# Introduction (example)

~~When playing the party game "Egg Smasher," participants are required to perform one of the predetermined actions under a progressively accelerating rhythm (e.g., slapping the box, tapping the table next to the egg, or grabbing up the box to trick the opponent into smashing the egg). However, what factors influence players' decision-making and the formation of their final actions? Is the brain's decision-making process sequential to the execution of actions, or do they occur simultaneously and mutually influence each other? Are muscles in different locations governed by the same strategic control? Does the increasing time pressure compress players' decision-making time or their action execution time? To what extent is the final action decision influenced by an aggressive or conservative game strategy?~~

Ver2:

When catching an object thrown by another person, the arm and fingers continuously adjust their positions in real-time, working in coordination with the brain to determine the optimal grasping point. Upon contact, the fingers and arm dynamically regulate grip force to ensure a stable hold. This process raises several fundamental questions about decision-making and motor execution: Do decisions precede movements in a strictly sequential manner, or do they occur simultaneously, exerting mutual influence? Additionally, do muscles in different locations—such as the proximal arm muscles and distal finger muscles—operate under the same strategic control mechanisms, or do they rely on distinct adaptations? Furthermore, as time pressure increases, does it primarily shorten the decision-making stage, or does it affect movement execution? Lastly, how does an individual’s game strategy (the value of the object), whether aggressive or conservative, shape the final action decision?

# Background and Motivation

~~Current research on decision-making often employs simple actions (such as button presses or mouse clicks), leading to two issues. First, motor processes are oversimplified as mere delays. Second, the focus is primarily on distal muscles (e.g., finger or thumb movements). However, there are inherent physiological and functional differences between the control of muscles in different locations. For example, the connections between the hands and brain regions are more numerous and complex compared to those of the arms. Whether the ‘perception-decision-action’ relationship derived from experiments using distal muscles is the same as that for proximal muscles remains an unresolved question.~~

~~With the assistance of a myoelectric interface, combined with EEG technology, we can more effectively investigate the decision adaptations and differences in the perception-decision-action relationship between muscles in different locations.~~

Ver2:

Current research on decision-making frequently relies on simple motor actions, such as button presses or mouse clicks. This enables perceptual decision-making (PDM) models to treat the motor process as a mere delay, significantly advancing our understanding of evidence accumulation. However, not all sensorimotor processes operate in such a straightforward manner. There is still limited understanding of how other types of movements fit into the ‘perception-decision-action’ framework and how different ‘decision processing level’ interact within this process. A key aspect of this complexity lies in the physiological and functional differences between muscles in different locations. For instance, the neural connections between the hands and brain regions are both more numerous and intricate than those linking the arms to the brain. This distinction raises an important question: Is the perception-decision-action relationship established in experiments using distal muscles applicable to proximal muscles, or do these systems operate under fundamentally different principles? This remains an open question in the field, highlighting the need for further research to uncover how decision-making processes adapt across different muscle groups.

There is growing evidence supporting the continuous flow of information to the motor system, along with increasing research suggesting that decision-making (DM) is ‘embodied’. Given these perspectives, we would expect differences between effectors due to their distinct physiological properties. With the aid of a newly designed myoelectric interface, combined with EEG technology, we can leverage perceptual decision-making (PDM) models to provide a more precise cognitive neuroscience interpretation of these physiological differences at a finer temporal scale. Specifically, our objectives are: 1) To use EMG signals to precisely identify the initiation point of movement, allowing for a clear distinction between the decision stage and motor execution stage within PDM. 2) To demonstrate that physiological differences between muscles manifest at different stages of the PDM process, reflecting how motor-specific properties shape decision-making. 3) To refine existing models to account for the distinct decision-making mechanisms of proximal and distal muscles, ultimately providing a more comprehensive framework for understanding the interaction between perception, decision, and action.

# EEG-Related Literature

## Mathematical Models for ‘Perception-Decision-Action’ Process

Mainstream cognitive neuroscience research employs Sequential Sampling Model (SSM), including the Drift Diffusion Model (DDM), and the more recent neurally informed model (NI) to describe the perception-decision-action process.

SSM suggests that individuals do not acquire all information for decision-making at once. Instead, they rely on sequential sampling steps, gradually accumulating information for decision-making. Each sampling step depends on the prior sensory input, iteratively adding new evidence until a decision threshold is reached. This model allows for strategy adjustments based on the current context to determine whether additional information gathering is necessary. However, SSM cannot distinguish the three critical processes: sensory, cognitive, and motor, limiting its applicability to explain motor control, which is often overlooked in research.

~~The DDM is widely used for two-choice decision-making tasks, emphasizing the ‘drift’ of evidence (bias towards one decision) and its stochastic ‘diffusion’ during accumulation (related to the noise in the real world). The threshold setting influences both decision speed and accuracy. There’s four key elements in DDM: 1) fixed starting point as the starting of the decision making process/ evidence accumulation process; 2) constant decision boundary as the threshold to make the decision; 3) no-decision time including sensory input time and motor execution time; 4) drift rate related to evidence strength.在加速决策任务中，紧迫感信号变得更加明显，反映出大脑对速度压力的适应。这种紧迫感信号可以调节决策信号的流动（例如从感觉区域到运动区域），优先考虑更快的反应，而不是更慎重、更准确的决策。Like the SSM, the DDM lacks sufficient consideration of motor control and decision adaptation. 目前主流的解释是在DDM的基础上加一个塌缩边界it’s difficult to identify the correct model from behaviour alone. Which is why the multilevel view from EEG is so useful。~~

The Drift Diffusion Model (DDM) is widely used to describe two-choice decision-making tasks, emphasizing the ‘drift’ of evidence (a bias toward one decision) and its stochastic diffusion during accumulation, which accounts for real-world noise. The threshold setting plays a crucial role in influencing both decision speed and accuracy. The DDM consists of four key components: (1) a fixed starting point, marking the beginning of the decision-making and evidence accumulation process; (2) a constant decision boundary, serving as the threshold at which a decision is made; (3) non-decision time, which includes sensory input processing and motor execution; and (4) drift rate, which reflects the strength of the accumulated evidence.

In speeded decision tasks, an urgency signal becomes more pronounced, reflecting the brain’s adaptation to time pressure. This urgency signal can modulate the flow of decision signals—such as those from sensory regions to motor areas—favouring faster responses over more deliberate, accuracy-driven decisions. Similar to other Sequential Sampling Models (SSMs), the DDM does not adequately account for motor control and decision adaptation. A common extension to the DDM framework introduces a collapsing decision boundary, which adjusts dynamically over time. However, distinguishing between competing models based on behavioural data alone remains challenging. This is why a multilevel approach, incorporating EEG, is essential for gaining deeper insights into the underlying neural mechanisms of decision-making.

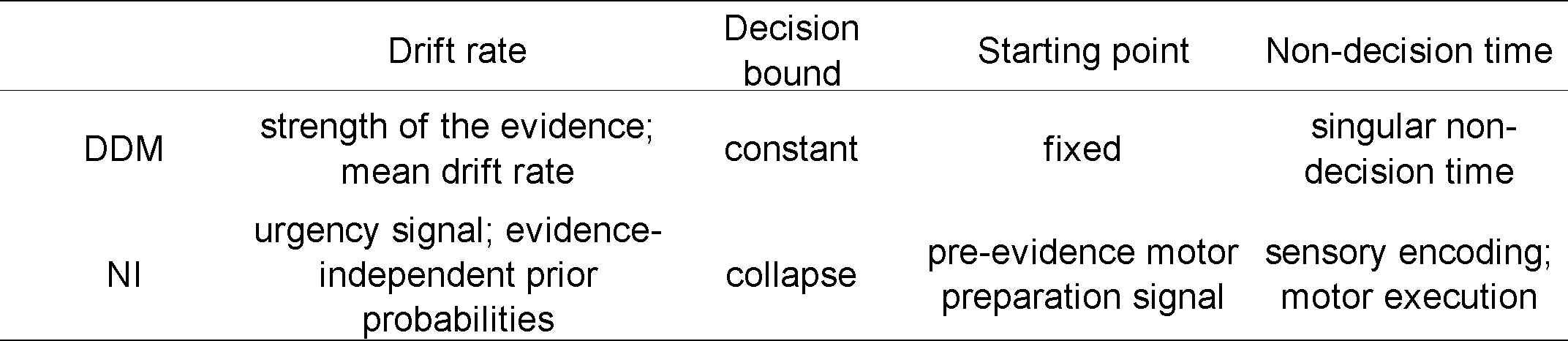
Neurally Informed (NI) model integer neural data alongside behavioural data, providing a more biologically grounded description of decision-making. Unlike traditional models that rely solely on abstract cognitive mechanisms, the NI model explicitly incorporates brain activity, enabling a more accurate representation of the decision process. Similar to the DDM, it retains four core elements: starting point, drift rate, decision threshold, and non-decision time. Additionally, the NI model divides decision-making into three distinct phases: evidence encoding, onset of evidence accumulation, and post-decision motor execution. However, a key distinction lies in the source of evidence accumulation. While the DDM considers evidence strength as the sole driving factor, the NI model include the urgency signal that is independent of sensory evidence and emerges before evidence encoding begins. This urgency signal accelerates decision-making, providing an additional mechanism for time-adaptive decision strategies, much like a collapsing decision boundary. Similarly to DDM, the prior probabilities in NI could be also described as the initial bias towards one direction, which affect the speed of evidence accumulation. Furthermore, the NI model accounts for pre-evidence motor preparation signals, modelled as race-to-threshold dynamics that influence the starting point of the decision process even before stimulus presentation. This framework allows for investigating whether decision strategies vary depending on the effector involved. Specifically, we can examine whether different muscles (e.g., proximal vs. distal) exhibit distinct starting points in decision-making, offering deeper insights into how response effectors shape decision processes.

~~作为对DDM的补全，最新的NI模型在行为数据的基础上还结合了神经数据。这意味着NI模型不仅依赖于抽象的认知机制，而是以实际的大脑活动为基础，更准确地描述决策的过程。The NI model divides the decision-making process into three stages: evidence encoding, onset of evidence accumulation, and the post-decision motor execution phase. By integrating behavioural and EEG data, the NI model enables multilevel understanding of decision-making phases. As DDM, it also has four key elements as DDM: starting point, drift rate, threshold and no-decision time. 对于证据积累的来源，在DDM模型仅与证据强度相关的单一来源的基础上，NI模型还把紧迫性信号归类为独立于证据的，在感官证据被编码前就有的，加速决策过程的另一种证据积累来源。这与collapsing bound一样都解释了决策对时间的适应性。It also accounts for pre-evidence motor preparation signals (race-to-threshold) that influence the starting point before stimulus presentation. For example, the motor preparation stage is modelled as differing starting points. Based on this model, we could check whether the decision strategies might change depending on the muscle that is being used regarding these four key elements (e.g. distinct starting points during decision-making) to get a better explanation of the effect of different response effectors on the decision making process.~~

~~The newer NI model outperforms the DDM in explaining behavioral data, incorporating motor control and decision adaptation concepts.~~ It also has four key elements as DDM: starting point, drift rate, threshold and no-decision time. ~~But it introduces urgency signals that are unrelated to evidence strength, which provide more understanding of drift rate/ collapse threshold . It also accounts for pre-evidence motor preparation signals (race-to-threshold) that influence the starting point before stimulus presentation. Moreover, t~~~~he NI model divides the decision-making process into three stages: evidence encoding, onset of evidence accumulation, and the post-decision motor execution phase. By integrating behavioral and EEG data, the NI model enables multilevel understanding of decision-making phases.~~

~~For example, the motor preparation stage is modelled as differing starting points. Based on this model, we could check whether the decision strategies might change depending on the muscle that is being used check whether different muscles have different strategies regarding these four key elements (e.g. distinct starting points during decision-making) to get a better explanation of the effect of different response effectors on the decision making process.~~

#### Table XXX: Comparison of DDM, and NI Models



Time pressure studies XXX

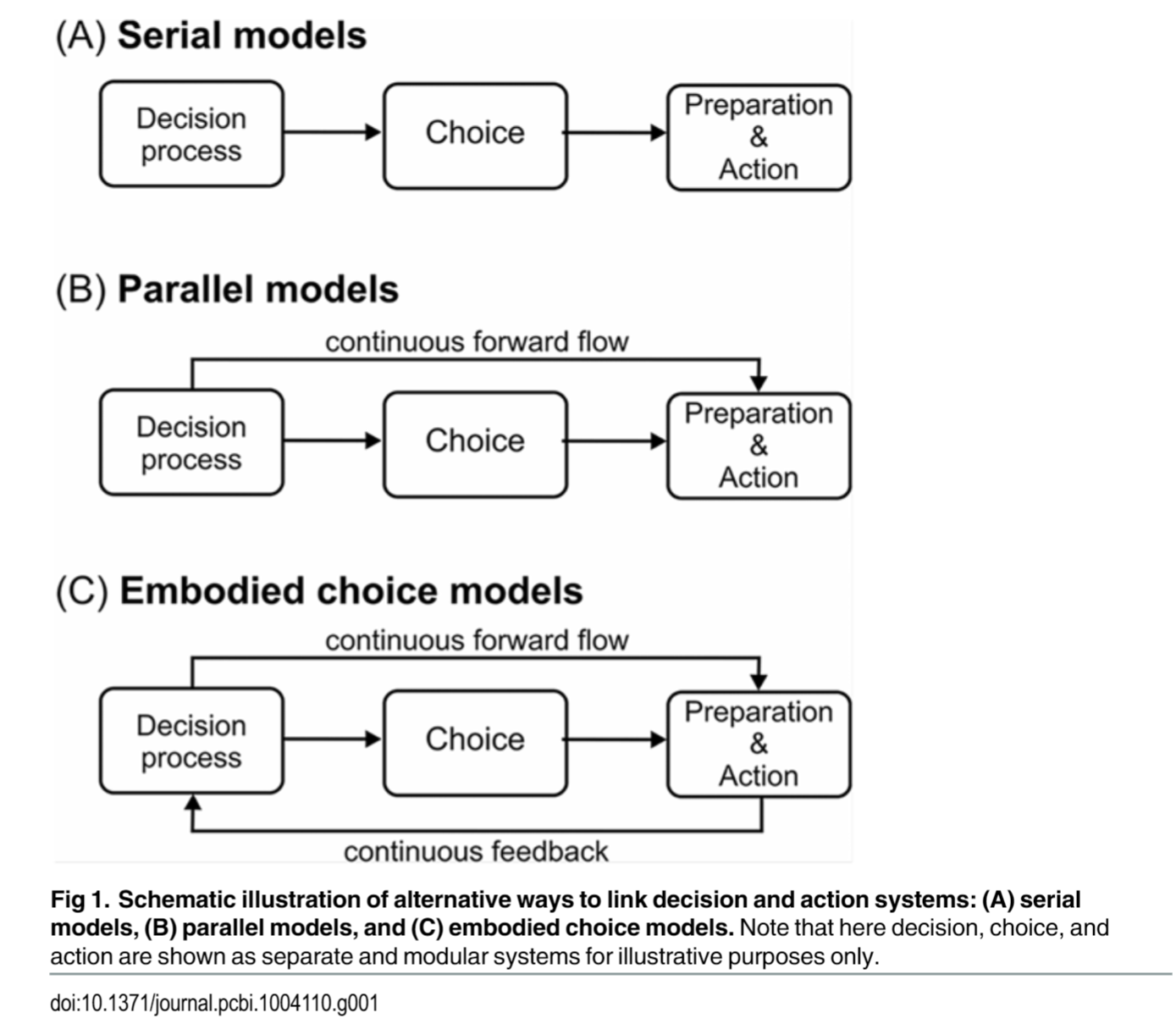
Prior expectation studies XXX

## Behavioural Theories and Decision-Motor Interaction

Recent behavioural research categorizes decision models based on the relationship between ‘decision processes’, ‘choices’, and ‘motor preparation’ into three paradigms:

1. Decision-Then-Action (Serial Model):  
   Classical models like SSM and DDM belong to this category, where sensory information is processed first, followed by decision-making, and finally, motor execution.
2. Decision-And-Action (Parallel Model):  
   Represented by the NI model, this paradigm emphasizes a continuous flow of information. Motor signals for planning or execution begin as soon as sensory input is received, meaning that potential motor actions are prepared even before a decision is finalized.
3. Action Feedback Into Decision-Making (Embodied Choice Model):  
   This newer paradigm introduces a feedback loop, where the real-time state of the motor system influences decision-making. It incorporates a commitment effect, predicting fewer Changes of Mind (CoMs) during action execution. This model suggests that decision-making involves continuous interplay between sensory and motor systems, allowing actions to shape decisions in real-time.

#### Figure XXX: Visualization of Three Decision Models



This figure can visually distinguish the characteristics of the decision-then-action, decision-and-action, and embodied choice models.

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## Key Features of ideal Decision Models

Studies on ‘decision-and-action’ and ‘action feedback paradigms’ highlight the importance of top-down information flow from sensory inputs to motor systems. This flow enables real-time decision adaptation by continuously integrating new information to adjust motor plans. This means that even before a decision is consciously made, the motor system is already preparing for potential actions. But ‘action feedback paradigms’ shows there’s highly possible that there also exists a ‘continues feedback flow’ from motor area to sensory area. This allows for adjustments in motor preparation based on ongoing sensory input and even for sensory processing to be influenced by the state of motor planning. For example, if a certain action is being prepared, sensory attention may be biased towards information relevant to that action. Additionally, the concept of dynamic decision boundaries could be newly explained by to the idea of ‘feedback loop’, where the level of motor preparation influences decision-making threshold. Or in other words, readiness for action can increase the brain's sensitivity to sensory information. This suggests that motor planning directly affects decision-making systems.

~~Additionally, the concept of dynamic decision boundaries emerges due to continuous flow model (Coles et al., 1985), where the level of motor preparation influences decision-making th. For example, readiness for action can increase the brain's sensitivity to sensory information. This suggests that motor planning directly affects decision-making systems.~~

~~Additionally, the concept of dynamic decision boundaries emerges, where the level of motor preparation influences decision-making. For example, readiness for action can increase the brain's sensitivity to sensory information. This suggests that motor planning directly affects decision-making systems. (Coles et al., 1985)~~

However, confirmation bias may also influence sensitivity to new information, though its relationship with motor preparation remains unclear.

(Doner XXX)

## Changes of Minds (CoMs) and Decision Adaptation

V2:

The Change of Minds (CoMs) phenomenon plays a crucial role in decision adaptation. CoMs occurs when an individual initially makes a decision based on accumulated evidence but subsequently reverses that decision during the execution of movement (Resulaj et al., 2009). In other words, decisions and actions remain modifiable until the final action is fully executed. This phenomenon suggests the existence of two decision boundaries: the initial boundary, which marks the point of early commitment to a decision, and a second boundary, which represents full decision commitment. Once this commitment threshold is crossed, the decision becomes irreversible. While CoMs is well explained within the framework of a feedforward loop (continuous flow), it remains unclear whether decision commitment is influenced by response mode. For instance, a key question is whether the timing of decision commitment in CoMs is primarily determined by the completion of the motor action after the first threshold is crossed or simply by further evidence accumulation beyond the second threshold. Additionally, it is unknown whether different muscles exhibit distinct CoMs mechanisms. Investigating these questions would provide valuable insights into how the motor system contributes to decision-making, ultimately refining the conceptual understanding of CoMs.

COM和beta下降的关系

~~The Change of Mind (CoM) phenomenon is also an important part of decision adaptation. CoM is defined as a situation where a subject initially makes a decision based on accumulated evidence but then reverses that decision during the execution of a movement (Resulaj et al., 2009). In other words, decisions and actions can still be altered before the final action is executed. This implies the existence of two decision boundaries: the initial boundary for early decisions and a second for decision commitment . Once the commitment threshold is crossed, decisions become irreversible. Thus, CoM is well explained from the feedforward loop, but whether the decision commitment is effected by the response mode is not studied. For example, CoM 的decision commitment时间点是更有关于证据的积累超过第一个阈值后开始形成完整动作的完成度，还是仅仅依靠于证据的积累超过第一个阈值后继续超过第二个阈值的证据积累量。以及是否会因为不同肌肉而有机制上的不同。总的来说，motor system在决策中的应用可以更好的补全CoM的概念。~~

~~CoM reinforces the idea that the real-time state of the motor system significantly impacts decision-making .~~

~~The Change of Mind (CoM) phenomenon illustrates that decisions and actions can still be altered before the final action is executed. This implies the existence of two decision boundaries: the initial boundary for early decisions and a second for decision commitment. Once the commitment threshold is crossed, decisions become irreversible. CoM reinforces the idea that the real-time state of the motor system significantly impacts decision-making.~~

## Feedback Flow

~~\*Sensory feedback=~~ **~~proprioceptive here mainly + visual~~**

~~While most studies focus on forward flow (evidence inputs guiding motor outputs), evidence shows that the real-time state of the motor system also affects the sensory areas, such as through reflex gain. Additionally, optimal feedback control (OFC) is a neural control theoretical framework that describes how the brain optimally controls movement to minimize cost function and optimize motor performance. OFC believes that motion control relies not only on pre-planned instructions (feedforward control), but also on real-time adjustment of feedback control. The exist of feedback control means the nervous system continuously monitors sensory inputs (\*) and adjusts motor outputs in real-time to achieve a desired movement goal. This process relies on sensory feedback (mostly~~ **~~proprioceptive~~** ~~here not visual, The hypothesis is that the readiness of the motor system or the completion of the movement will in turn affect the decision-making process and even the sensitivity of accumulated sensory information) to correct deviations from the intended trajectory or action. Recent study using motor perturbation (e.g. applying vibration to the hand) reveal that reflex gains dynamically adjust under different sensory signal strength and duration, proven that there exist feedback loop from muscle spindle to sensory area to modulate the movement in real time. This feedback loop between sensory processing and motor planning demonstrates that motor planning is not only influenced by sensory inputs but also by the state of motor preparation. This interaction indicates that sensory and motor systems operate as a dynamic interplay, adjusting decision-making based on both sensory inputs and motor states. Thus, it’s would be interesting to study in different muscle type, will the readiness of the motor system or the completion of the movement will in turn affect the decision-making process and even the sensitivity of accumulated sensory information~~

**Feedback Flow and Its Role in Decision-Making**

While most studies emphasize forward flow, where sensory evidence guides motor outputs, increasing evidence suggests that the real-time state of the motor system also influences sensory areas. One such mechanism is reflex gain, which dynamically adjusts sensory processing in response to ongoing motor activity. Additionally, Optimal Feedback Control (OFC) provides a theoretical framework for understanding how the brain optimally controls movement to minimize cost and maximize motor efficiency. Unlike purely feedforward control, which relies on pre-planned motor instructions, OFC posits that movement control is a continuous process, integrating both pre-planned instructions and real-time sensory feedback adjustments. The existence of feedback control means that the nervous system is constantly monitoring sensory inputs, particularly proprioceptive signals (rather than visual feedback in this case), to fine-tune motor execution in real-time. This mechanism ensures that deviations from the intended movement trajectory are rapidly corrected, optimizing overall motor performance. Recent studies using motor perturbation techniques (e.g., applying vibrations to the hand) provide direct evidence for this feedback loop. These studies demonstrate that reflex gains dynamically adjust depending on sensory signal strength and duration, indicating a bidirectional interaction between muscle spindle feedback and sensory processing areas. This suggests that motor planning is influenced not only by sensory inputs but also by the ongoing state of motor preparation, reinforcing the idea that sensory and motor systems operate as a dynamic interplay. This continuous exchange allows decision-making processes to be adjusted based on both sensory inputs and real-time motor states. An important, yet underexplored, question is whether these feedback-driven modulations differ across muscle types. Specifically, does the readiness of the motor system or the completion of movement affect decision-making processes and the sensitivity to accumulated sensory information in different muscle groups? Investigating this relationship across proximal and distal muscles could provide critical insights into how motor preparation dynamically shapes perceptual decision-making.

~~For instance, studies on motor perturbation (e.g. applying vibration to the hand) reveal that reflex gains dynamically adjust sensory signal strength and duration, resembling adjustments to accumulated evidence or decision variables (DV).~~

~~This feedback loop between sensory processing and motor planning demonstrates that motor planning is not only influenced by sensory inputs but also by the state of motor preparation. This interaction indicates that sensory and motor systems operate as a dynamic interplay, adjusting decision-making based on both sensory inputs and motor states.~~

# EMG-Related Literature

## Challenges in Explaining Neuro-Muscular Patterns

~~Although EEG-based decision models have advanced our understanding of brain decision mechanisms, they fail to adequately explain the neuro-muscular patterns across different muscles. Variations in brain-muscle connectivity strength and muscle fiber types between muscles influence behavioral outcomes.~~

Although EEG-based decision models have significantly advanced our understanding of brain decision mechanisms, they fall short in capturing the neuro-muscular patterns across different muscles. EEG alone cannot fully account for the role of motor preparation and execution, as it primarily reflects cortical-level activity without directly measuring muscle activation. In contrast, EMG provides additional insights beyond what can be observed from EEG, such as partial bursts and Changes of Mind (CoMs)—critical markers of real-time motor adaptation. This project aims to investigate whether variations in brain-muscle connectivity strength and muscle fibre composition influence behavioural outcomes. Different muscles have distinct motor unit structures and neural control mechanisms, which may lead to differences in decision-making strategies and motor execution dynamics. By integrating EEG and EMG, this study seeks to uncover how these physiological differences shape the perception-decision-action process, providing a more comprehensive model of sensorimotor decision-making.

## Insights from EMG Signals in Decision-Making

~~通过EMG信号我们能得到更多对于决策的见解。首先对于EMG onsite time, 在EEG模型中对应decision time和motor time的交界点，可以更好的在时间上被定义来观察前后的不同。In electromyography (EMG), onset time refers to the moment when electrical activity is first detected in a muscle, indicating the initiation of muscle contraction. Accurate detection of EMG onset is crucial for understanding motor control and timing in various movements. A review by Vieira et al. (2023) discusses various methods for detecting EMG onset, highlighting its importance in applications such as biomechanics and rehabilitation robotics.第二，尤其是对于EEG研究中的CoMs现象, EMG可以在时间上用更精确的partial EMG burst来定位。In electromyography (EMG) studies, partial response EMG (prEMG) refers to muscle activity initiated by a 'go' signal that decreases after a 'stop' signal, preventing a full response, as described by Raud et al. (2022). In contrast, partial EMG bursts/ partial error are small EMG responses that begin but do not reach sufficient amplitude to lead to an overt response (通常是无意识的), as discussed by Jana et al. (2020) and Inga et al. (2020). 这个项目由于实验设计的原因我们不需要‘stop’信号，且partial EMG burst于CoMs现象EEG模型假设中的第一个边界更符合，所以之后的谈论全采用partial EMG bursts/ partial error。~~

~~Like EEG studies, most EMG decision models focus on distal muscles, leaving the neuro-muscular decision processes of proximal muscles less explored.但是对于EMG信号的解释会比EEG更简单且更好的反应决策模型的结过端（输出），补全了EEG信号从输入端与有限的行为数据建立模型的弊端。能更直观的同时从输入输出比较不同肌肉决策过程的不同。~~

~~The latest Double Threshold Diffusion Model (DTDM), a parallel decision model, introduces key advancements:~~

EMG signals provide valuable insights into the decision-making process, complementing EEG-based models by offering a more precise temporal resolution of motor execution. One of the most critical aspects of EMG analysis is EMG onset time, which marks the point at which electrical activity is first detected in a muscle, signifying the initiation of muscle contraction. In EEG-based models, this corresponds to the boundary between decision time and motor time, making it possible to observe pre- and post-decision dynamics with greater temporal precision. The ability to accurately detect EMG onset is essential for understanding motor control and movement timing, as emphasized in a review by Vieira et al. (2023), which discusses various methods for detecting EMG onset and highlights its importance in fields such as biomechanics and rehabilitation robotics.

Beyond EMG onset detection, EMG is particularly useful for investigating Changes of Mind (CoMs), a phenomenon frequently studied in EEG research. While EEG provides indirect neural markers of CoMs, EMG allows for a more precise localization of these events through partial EMG bursts. In electromyography studies, partial response EMG (prEMG) refers to muscle activity that initiates after a "go" signal but decreases after a "stop" signal, preventing full movement execution (Raud et al., 2022). However, partial EMG bursts (also known as partial errors) refer to small, often unconscious muscle activations that begin but do not reach the necessary amplitude for an overt response (Jana et al., 2020; Inga et al., 2020). Given the experimental design of this project, where a formal "stop" signal is unnecessary, partial EMG bursts align more closely with the first boundary in EEG-based CoM models, making them a more relevant measure for tracking decision reversals in real-time.

Similar to EEG-based decision studies, most EMG decision models have primarily focused on distal muscles, leaving the neuro-muscular decision processes of proximal muscles largely unexplored. However, compared to EEG, EMG signals provide a more direct and interpretable measure of decision outcomes by capturing the motor system's output stage. This helps address a key limitation of EEG-based decision models, which rely solely on sensory inputs and behavioral data to infer decision dynamics. By integrating EMG and EEG, we can simultaneously examine both input and output processes, allowing for a more comprehensive comparison of decision-making mechanisms across different muscle groups.

One of the latest advancements in decision modelling, the Double Threshold Diffusion Model (DTDM), extends traditional diffusion models by incorporating two distinct decision boundaries. This framework enhances our understanding of parallel decision processes, capturing the interplay between early decision formation and commitment thresholds. Regarding to pervious EEG literatures, DTMT is a parallel decision model, introduces key advancements:

A diagram of a heart rate monitor

AI-generated content may be incorrect.

~~Most EMG decision models focus on distal muscles, leaving the neuro-muscular decision processes of proximal muscles less explored.The latest Double Threshold Diffusion Model (DTDM), a parallel decision model, introduces key advancements:~~

1. First Boundary: Similar to the Change of Mind (CoM) phenomenon, it represents a partial burst allowing for adjustments.
2. Second Boundary: A commitment threshold beyond which decisions are final and irreversible.
3. Response/Action Preparation: Building upon the NI model, DTDM permits early action initiation even before the accumulated evidence crosses the decision boundary.

The DTDM divides reaction time (RT) into two components: 1) Premotor Time (PMT): Encompasses sensory accumulation and decision-making; 2) Motor Time (MT): Reflects motor execution and aligns with traditional decision models. By integrating EMG data, DTDM achieves greater precision in locating decision commitment time compared to EEG-based models. Which also verifies another study’s result that 300-400 ms of non-decision time can be divided into 220 ms of sensory encoding and 80 ms of motor execution.

## Physiological Insights and Muscle-Specific Findings

~~Studies reveal that motor delay in the forward loop increases with distance from the brain, e.g., Neck → Biceps → FDI (First Dorsal Interosseous). When feedback loop delays are also considered, reaction times—e.g., visual stimulus to response—become significantly prolonged due to sensory encoding delays. However, it remains unclear whether feedback delays vary across muscles or if all muscles utilize feedback pathways equally.~~

To better investigate the differences between proximal and distal muscles during the perception-decision-action process, we selected two commonly studied muscles as research targets: the biceps (BCP) and the first dorsal interosseous (FDI). 显而易见的是这两种肌肉存在着明显的生理差异。The biceps contain larger motor units and a higher proportion of Type 1 fibres, providing greater resistance to fatigue and supporting sustained and stable movements. According to the Broadman Map, the brain regions controlling the biceps are located closer to the central motor areas, with a simpler neural connection. In contrast, the FDI comprises smaller motor units with a higher proportion of Type 2 fibres, enabling faster activation, greater precision, and adaptability, though these muscles are more prone to fatigue~~.~~Its extensive connections to brain regions, including the cerebellum and basal ganglia, facilitate fine-tuned motor control and real-time adaptability. These distinctions between the biceps and FDI highlight how muscle fibre composition, motor control strategies, and neural connectivity shape motor planning and execution, offering valuable insights into the differences between proximal and distal muscles under varying sensory and motor demands.

有很多对比或包含这两个所选肌肉的研究。首先是运动控制信号传导时间上的差异。Studies reveal that motor delay in the forward loop increases with distance from the brain, e.g., Neck → Biceps → FDI (First Dorsal Interosseous).肌肉向大脑皮层投射的研究也表明离大脑越近的肌肉在受Motor-point stimulation后脑电潜伏期越快，比如16.4ms for biceps，以及25.0ms for first dorsal interosseous. 这表明了从自体感受而产生的sensory feedback loop对不同肌肉存在差异，且离大脑进的BCP会比FDI快约10ms，意味着离大脑近的肌肉天生的能更快的反应作为肌肉纤维反应慢的补偿。However, EEG amplitudes remained consistent across muscles, indicating no significant differences in the sensorimotor cortex's activation between proximal and distal muscles. But this study did not explain the motor control of different muscles well because all of the responses are automatic responses and not triggered by active motor control.

第二，行为框架的研究进一步暗示了这种控制信号传导时间上的差异的不同会对两种肌肉的控制机制特别是反馈回路产生影响。A review introduces a three-core framework for motor control: (1) Behavioral Goal (WHAT): the desired action outcome; (2) Body’s Present State (WHERE): the current state of the body; and (3) Motor Commands (HOW): the instructions to achieve the action. This framework underscores the critical role of sensory feedback in facilitating smoother, more accurate, and effortless motor actions. In relation to our project, sensory feedback plays a pivotal role in tasks requiring force maintenance (e.g., maintaining a threshold force). 然而，有些研究的feedback loop是依据视觉信息输入的改变来研究的，在这个情况下reaction times become significantly prolonged due to sensory encoding delays. 这种情况下，由于视觉信息改变而产生的sensory change由于视觉信息的处理被延后了30ms，然后从上而下传导至肌肉优化控制(总共90ms)。而由于自体感受而产生的feedback loop传导到大脑再优化控制至少需要60ms。在两种feedback loop的调整下，先前的研究已证明进远端肌肉呈现不同的反应时间。对于我们的项目，由于使用了视觉刺激，所以应该小心考虑不同feedback loop对结果带来的差别以及不同肌肉的反应时间差。For example, it remains unclear whether 进远端肌肉的上下通路的时间差异是否会会造成运动控制策略的不同甚至影响到决策阶段。

第三是控制力度调整后两个肌肉的差异。Motor unit synchronization 的研究表明在小力/精细控制时（30% MVC）FDI同步率更高，大力时（80%）BCP同步率更高（[https://doi.org/10.1016/j.jelekin.2008.06.003](https://doi.org/10.1016/j.jelekin.2008.06.003" \t "_blank" \o "使用数字对象标识符的持久链接)）。

FDI 肌肉的平均功率频率 (MPF) 通过施加的力量水平线性增加。与 FDI 肌肉相比，BB 肌肉中的 MPF/%MVC 关系分解为四个特定区域：(1) 相对快速增加 (<34% MVC)，(2) 缓慢增加 (34–53% MVC)，(3) 暂时减少 (53–62% MVC)，(4) 进一步快速增加 (>62% MVC)。 (<https://doi.org/10.1007/s00421-003-0835-1> ) Motor unit的 激活策略在不同肌肉的形态和组织化学类型方面有所不同这一事实。

~~To better investigate the differences between proximal and distal muscles during the perception-decision-action process, we selected two commonly studied muscles as research targets: the biceps (BCP) and the first dorsal interosseous (FDI). The biceps contain larger motor units and a higher proportion of Type 1 fibers, providing greater resistance to fatigue and supporting sustained and stable movements. Once an action involving the biceps is triggered, it becomes less likely to change mid-execution. Due to their reliance on pre-programmed instructions, the biceps primarily operate under a serial, top-down control model with minimal reliance on feedback loops. According to the Broadman Map, the brain regions controlling the biceps are located closer to the central motor areas, indicating a simpler neural connection. In contrast, the FDI comprises smaller motor units with a higher proportion of Type 2 fibers, enabling faster activation, greater precision, and adaptability, though these muscles are more prone to fatigue. The FDI heavily relies on real-time sensory feedback, functioning through a parallel control model for continuous adjustments during movement. Its extensive connections to brain regions, including the cerebellum and basal ganglia, facilitate fine-tuned motor control and real-time adaptability. These distinctions between the biceps and FDI highlight how muscle fiber composition, motor control strategies, and neural connectivity shape motor planning and execution, offering valuable insights into the differences between proximal and distal muscles under varying sensory and motor demands.~~

第四是单独研究对不同肌肉运动观察后大脑活动的差异，即Sensory Feedback and Motor Planning的研究。An experiment compared participants resting, observing handwriting, or observing arm movement while recording Motor Evoked Potentials (MEP) with TMS to study motor activation during observation. Key findings include: Motor area inhibition decreases prior to movement only in contracted muscles (e.g. biceps when arm is flexion), not in relaxed muscles (e.g.triceps when arm is flexion). Similar effects were observed with Mu-beta (MB) decreases after post-cue presentation. Interestingly, observing arm movements elicited MEPs in proximal muscles (e.g., biceps) but not in distal muscles (e.g., FDI). These findings suggest fundamental differences in the control strategies of proximal and distal muscles. 换句话说，FDI有着更明显的‘抑制/反馈机制’来优化或实时调整动作，即同一肌肉的收缩力度可以快速调整。而BCP更依赖与和TCP的contracted与relax的协同来控制移动，从而提高了稳定性但降低了灵敏度。从而我们提出我们的假设：Proximal muscles favor pre-programmed, top-down serial strategies, while distal muscles rely on feedback loops for real-time adjustments. Once an action involving the biceps is triggered, it becomes less likely to change mid-execution. Due to their reliance on pre-programmed instructions, one of the hypothesis is the biceps primarily operate under a serial, top-down control model with minimal reliance on feedback loops. The FDI heavily relies on real-time sensory feedback, functioning through a EEG parallel control model for continuous adjustments during movement.

Thus with above supported literature it’s necessary to study the integration of EMG decision models (e.g., DTDM) , motor control framework with EEG models, in order to provide a more comprehensive understanding of the ‘perception-decision-action’ process. Proximal and distal muscles are highly likely to exhibit distinct motor control strategies, with biceps favouring pre-programmed, serial control and FDI relying on real-time feedback loops. Understanding these differences, particularly in feedback flow and forward flow pathways, can enhance our knowledge of motor planning and execution in response to sensory inputs.

## ~~EEG Latency and Amplitude in Proximal vs. Distal Muscles~~

~~A study with electrodes placed on various muscles found that EEG latencies increased with the distance of the muscle from the brain (e.g., BCP: 15 ms, FDI: 25 ms). However, EEG amplitudes remained consistent across muscles, indicating no significant differences in the sensorimotor cortex's activation between proximal and distal muscles. But this study did not explain the motor control of different muscles well because all of the responses are automatic responses and not triggered by active motor control.~~

## ~~Behavioral Framework and Sensory Feedback~~

~~A review introduces a three-core framework for motor control: (1) Behavioral Goal (WHAT): the desired action outcome; (2) Body’s Present State (WHERE): the current state of the body; and (3) Motor Commands (HOW): the instructions to achieve the action. This framework underscores the critical role of sensory feedback in facilitating smoother, more accurate, and effortless motor actions. In relation to our project, sensory feedback plays a pivotal role in tasks requiring force maintenance (e.g., maintaining a threshold force).~~

~~Another study further emphasizes the importance of sensory feedback and top-down continuous flow, demonstrating: (1) reactions to limb feedback occur within 60 ms, with distal muscles requiring an additional 10 ms, and (2) visual feedback requires 90 ms due to sensory encoding delays. This study corroborates previous findings that the time differences between muscles are evident not only in the forward loop but also in the feedback loop. However, due to limitations in measurement precision, it is more reliable to conclude that time differences exist in the forward loop between distal and proximal muscles. For the feedback loop, further research with a more carefully designed experimental setup is needed to confirm these differences.~~

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~~Thus with above supported literature it’s necessary to study the integration of EMG decision models (e.g., DTDM) with EEG models, in order to provide a more comprehensive understanding of the ‘perception-decision-action’ process. Proximal and distal muscles are highly likely to exhibit distinct motor control strategies, with biceps favoring pre-programmed, serial control and FDI relying on real-time feedback loops. Understanding these differences, particularly in feedback flow and forward flow pathways, can enhance our knowledge of motor planning and execution in response to sensory inputs.~~

V2:

To better investigate the differences between proximal and distal muscles in the perception-decision-action process, this study focuses on two well-researched muscles: the biceps (BCP) and the first dorsal interosseous (FDI). These muscles exhibit distinct physiological properties, shaping their roles in motor control. The biceps consist of larger motor units with a higher proportion of Type 1 fibers, which provide greater resistance to fatigue and support sustained and stable movements. According to the Broadman Map, the brain regions responsible for biceps control are positioned closer to the central motor areas, reflecting a simpler neural connection. In contrast, the FDI has smaller motor units with a greater proportion of Type 2 fibers, allowing for faster activation, higher precision, and real-time adaptability, though these muscles are more prone to fatigue. The FDI is also more extensively connected to higher-order motor regions, such as the cerebellum and basal ganglia, which facilitate fine-tuned motor control and continuous sensory feedback integration. These differences in muscle fiber composition, neural connectivity, and motor control strategies provide important insights into how proximal and distal muscles operate under different sensory and motor demands.

The distinction between these two muscle groups is further supported by neurophysiological evidence, particularly in the timing of motor control signal transmission. Studies show that motor delay in the forward loop increases with distance from the brain, with response times following the pattern of Neck → Biceps → FDI. Research on cortical motor projections indicates that motor-evoked potential (MEP) latencies after motor-point stimulation are 16.4 ms for the biceps and 25.0 ms for the FDI, demonstrating that proximal muscles benefit from a faster sensory feedback loop than distal muscles. This suggests that biceps compensate for their inherently slower muscle fiber response time by having a more efficient neural transmission speed. However, EEG amplitudes remain consistent across muscle groups, indicating no significant differences in cortical activation strength. While these findings highlight a fundamental difference in sensory-motor latencies, they do not fully explain how motor control mechanisms differ between the two muscles, since prior studies primarily focused on automatic motor responses rather than movements driven by voluntary decision-making.

The role of sensory feedback loops in motor control further differentiates BCP and FDI. The three-core framework for motor control highlights three essential components: the desired behavioural goal, the current state of the body, and the motor commands required to achieve the action. Within this framework, sensory feedback plays a crucial role in optimizing movement and ensuring smoother, more precise motor execution. In the context of this study, sensory feedback is particularly relevant to force maintenance tasks, where fine motor control is needed to sustain a threshold force level. However, previous research has shown that different feedback mechanisms can significantly affect reaction times. When feedback adjustments are driven by visual input delays, reaction times are prolonged by an additional 30 ms due to sensory encoding delays. The total delay from visual processing to muscle activation is approximately 90 ms, whereas feedback loops originating from muscle proprioception require at least 60 ms to reach the cortex and optimize movement. Given these processing delays, prior research has confirmed that proximal and distal muscles exhibit different response times under varying feedback conditions. In the present study, which relies on visual stimuli, it is essential to carefully account for how different feedback mechanisms influence motor control strategies and whether differences in sensory-motor transmission times affect the decision-making process across muscle types.

Another significant distinction between BCP and FDI lies in their force control and motor unit synchronization. Studies on motor unit activation strategies indicate that distal muscles, such as the FDI, exhibit greater synchronization at low-force levels (30% MVC), whereas proximal muscles, such as the BCP, show higher synchronization at high-force levels (80% MVC). Additionally, research on mean power frequency (MPF) has revealed fundamental differences in activation patterns between the two muscle types. In FDI, MPF increases linearly with force level, whereas in BCP, MPF follows a nonlinear trajectory, displaying four distinct phases: a rapid increase at low force levels, a gradual increase in mid-force ranges, a temporary decrease at intermediate force levels, and a final rapid increase at high force levels. These findings suggest that motor unit activation strategies are inherently linked to the morphological and histochemical composition of the muscles, reinforcing the idea that proximal and distal muscles employ different motor control mechanisms.

Further evidence for muscle-specific motor planning and sensory feedback mechanisms comes from TMS-based studies on motor evoked potentials (MEPs). One experiment compared brain activity across three conditions: resting, observing handwriting, and observing arm movements. The results showed that motor area inhibition decreases prior to movement only in actively contracting muscles (e.g., biceps during flexion) but remains unaffected in relaxed muscles (e.g., triceps during flexion). A similar pattern was observed in Mu-beta (MB) oscillations, where post-cue MB decreases were linked to motor activation readiness. Interestingly, observing arm movements elicited MEP responses in proximal muscles (e.g., biceps) but not in distal muscles (e.g., FDI). These findings suggest that proximal and distal muscles follow fundamentally different control strategies. The FDI exhibits stronger feedback-driven control, allowing for real-time adjustments in force output in single muscle, whereas biceps movements rely on coordinated activation with antagonist muscles (e.g., triceps; two muscle together) to maintain stability. This reliance on pre-programmed movement sequences enhances stability at the cost of flexibility.

Based on this evidence, it is hypothesized that proximal muscles favour pre-programmed, top-down serial control, whereas distal muscles rely on real-time feedback loops to continuously adjust motor output. Once an action involving the biceps is triggered, it is less likely to be altered mid-execution, reinforcing a serial control model with minimal reliance on feedback. Conversely, the FDI heavily depends on real-time sensory feedback, operating within a parallel control framework that allows for continuous movement refinement. This fundamental difference in control strategies has significant implications for decision-making processes, as proximal and distal muscles may engage in distinct decision adaptation mechanisms based on their respective motor planning and execution demands.

Given the clear distinctions in neural transmission times, feedback loop mechanisms, and force control strategies, it is crucial to integrate EMG-based decision models (such as DTDM) with EEG-based motor control frameworks to achieve a more comprehensive understanding of the perception-decision-action process. The present study aims to explore how proximal and distal muscles differentially contribute to decision-making and motor adaptation, focusing on the integration of feedforward and feedback mechanisms. Understanding these differences will enhance our knowledge of motor planning and execution, particularly in response to varying sensory inputs and decision-making constraints.

# Research Questions and Hypotheses and Expected Outcomes

Current decision-making research primarily focuses on distal muscles while oversimplifying the influence of motor states. Traditional models, such as the DDM, often simplify motor processes time into perceptual or cognitive stages, neglecting the distinct contributions of motor preparation and execution. To address these limitations, this study investigates whether decision-making processes from sensory to motor areas differ between proximal and distal muscles. Furthermore, it examines whether decision adaptation phenomena, observed in motor preparation signals under manipulated experimental conditions such as speed pressure or prior probabilities, can be consistently observed across different muscle groups. In essence, the study aims to determine if real-time decision adaptation and decision-making strategies are dependent on the muscles involved.

By integrating myoelectric interfaces (EMG) with EEG and behavioural data, this research provides a more precise temporal resolution for analysing the decision-making processes of finger (FDI) and biceps (BCP) movements. Unlike previous studies that focus predominantly on sensory and cognitive processes, this study incorporates motor-level designs. For example, EMG data allow for the identification of the EMG onset point, which defines the initiation of the final action. This facilitates a more precise temporal division between decision time and motor time. Moreover, the EMG data can identify partial EMG bursts, enabling the investigation of Change of Mind (CoM) events and their timing and frequency across muscle types, further enhancing the granularity of decision adaptation analysis.

The primary hypothesis of the study posits that FDI and BCP exhibit distinct decision-making modes due to their physiological and functional differences. The BCP is expected to align with a decision-then-action sequence, reflecting a more serial process that relies on pre-programmed motor commands. This reliance stems from the biceps’ larger motor units and greater resistance to fatigue. Conversely, the FDI is hypothesized to operate with a decision-with-action-feedback-to-decision strategy, where continuous forward flow and feedback loops simultaneously influence decision-making. These differences are further expected to manifest in the temporal dynamics of motor execution. For instance, BCP is likely to exhibit faster motor times compared to FDI, while FDI is anticipated to show a higher probability and frequency of partial EMG bursts as task difficulty increases.

~~Further distinctions are expected to emerge in brain region activation, where BCP and FDI are hypothesized to involve different neural pathways and control regions. The premotor time (PMT) and motor time (MT) ratios between these muscles are also likely to differ, reflecting their unique motor preparation and execution strategies. Additionally, decision-making models are expected to reveal that the starting points for BCP and FDI differ due to variations in motor preparation, consistent with prior findings in the field（steinemann2018）. For example, a possible strategic adaptation would be that the bicep, given it is difficult to reverse once initiated, would have a lower starting point (require more evidence to initiate movement? longer decision time).~~

Further distinctions are expected to emerge in brain region activation, as BCP and FDI are hypothesized to engage different neural pathways and motor control regions. Given their distinct roles in movement execution, these muscles are likely to exhibit differences in premotor time (PMT) and motor time (MT) ratios, reflecting their unique strategies for motor preparation and execution. Specifically, proximal muscles like the biceps may rely more on pre-programmed movement patterns, while distal muscles like the FDI incorporate real-time sensory feedback for continuous adjustment.

Additionally, decision-making models are expected to reveal differences in the starting points for BCP and FDI, driven by variations in motor preparation processes. This is consistent with prior findings (Steinemann et al., 2018), which suggest that the readiness of the motor system influences the initial state of the decision process. A potential strategic adaptation could be that the biceps, given its difficulty in reversing movement once initiated, would exhibit a lower starting point in the decision process. This would imply that more evidence is required to initiate movement, leading to a longer decision time compared to the FDI, which is more adaptable to rapid adjustments. Such differences in starting thresholds and movement reversibility would provide further insight into how proximal and distal muscles influence decision-making strategies and motor adaptation processes.

Overall, this study aims to refine existing decision-making models by providing a detailed comparison of proximal and distal muscles in the perception-decision-action process. By examining the interplay between continuous forward flow and feedback loops, it seeks to offer novel insights into real-time motor decision-making, advancing both theoretical models and experimental methodologies.

# 

# Methods and Experimental Procedure

## Preparation Phase

The experiment is conducted over two days, with the first day dedicated to training and the second day to data recording. The preparation phase lasts 15 minutes for EMG setup and 25 minutes for EEG preparation. Before starting the experiment, participants are asked to sign informed consent and complete a demographic questionnaire, which anonymously records their age, muscle length, and head circumference. Participants also complete the Edinburgh Handedness Inventory to confirm right-hand dominance. Only right-handed individuals aged 18-40 years are included in the study.

For the EMG setup, the target skin areas are cleaned with medical alcohol to reduce impedance. Muscle positions for the FDI and BCP are identified through palpation during voluntary muscle contraction. The electrodes are placed parallel to the middle of the muscle bundle as shown in figure XX. For EEG preparation, an appropriately sized cap is chosen based on head circumference. The Cz electrode is positioned at the vertex, determined by aligning the nasion-inion line and the preauricular points. Impedance for all electrodes is ensured to be below 10 kΩ before recording.

## Training Phase

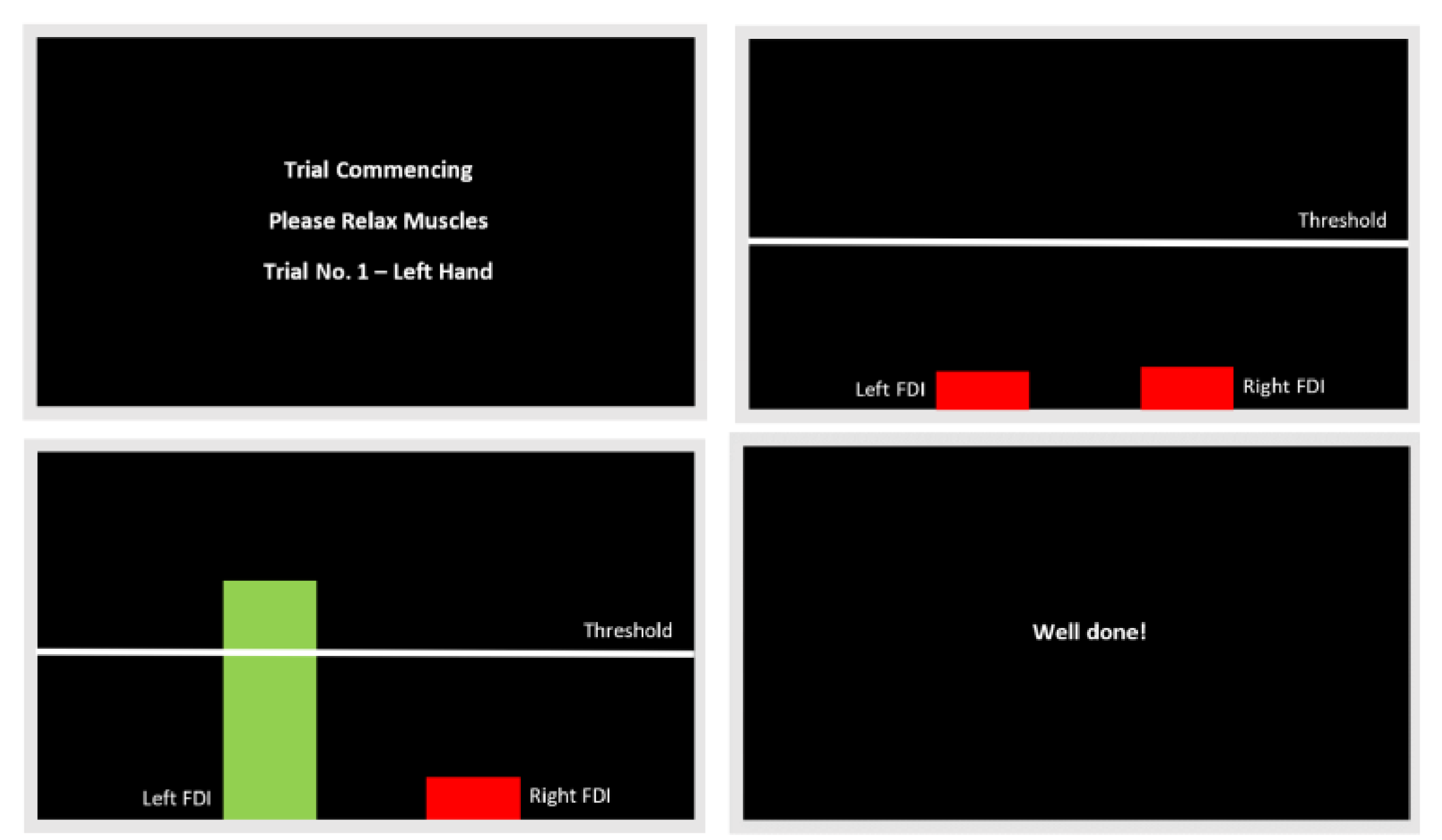
Figure XX exact positioning for both of the movements

The first day’s training phase lasts approximately 50 minutes and begins with participants learning how to control their FDI and BCP muscles. EMG signals are recorded during relaxed states and maximum comfortable contractions to establish MVC (maximum voluntary contraction) values. Non-electrode areas are marked on the skin for reference during the second day's experiment. Muscle activation at 20% MVC is set as the response threshold, and force feedback is displayed as a progress bar on a screen. Participants are instructed to reach the target force as quickly as possible without significantly exceeding it. For finger movement, participants are required to perform a spontaneous isometric contraction[?] by maintaining a half-clenched fist position, with the thumb pressing against the second phalanx of the index finger in a pinching-like motion. Throughout the task, the movement must remain consistent and stable, ensuring no changes in force or posture.

For biceps contraction, participants must voluntarily contract their biceps in a controlled manner, similar to how one would contract their calf muscle. During this contraction, it is crucial that all other muscles remain relaxed, ensuring that the biceps activation is isolated without unintentional engagement of surrounding muscles.

For biceps contraction, participants are instructed to voluntarily contract their biceps in a controlled manner, similar to how one would contract their calf muscle. During this contraction, all other muscles should remain relaxed, ensuring that only the biceps are engaged in the movement.

Training is divided into two feedback modes: real-time feedback (force size is displayed instantaneously) and delayed feedback (force progression is shown as a replay after the response is detected or at the deadline). Over approximately 20 minutes, participants practice alternating between one set of real-time feedback and two sets of delayed feedback, with each cycle repeated three times. Each set consists of 8 trials, where each muscle is used twice per set.

* + Training section (real-time feedback)
  + 10 min EMG calibration
  + 15 min for force control training (20%)
  + 15 min for contrast discrimination task learning

Following the EMG training, participants are introduced to the contrast discrimination task. They use their learned muscle response skills to decide whether a flickering striped circle on the screen tilts toward the right or left. The experiment employs a "ready-steady-go" design:

* Trial initiation: Participants fixate on a central yellow dot while an interleaved grating (neutral, with equal left/right tilt) is displayed.
* Cue period: After 0.6 seconds, the dot turns green, signaling that the grating’s contrast will soon change.
* Evidence presentation: After 0.6 seconds, the evidence phase begins, lasting between 0.8 and 2.5 seconds, depending on response speed. During this phase, the grating tilts left or right with higher contrast.

Muscle responses between 0.2 and 1.8 seconds after the onset of the evidence phase are classified as valid. After the response, evidence remains on the screen for 0.2 seconds before disappearing, ensuring the total trial duration does not exceed 2.5 seconds. Responses that are too fast, too slow, or involve the wrong muscle are recorded, and participants receive immediate feedback. The training phase typically lasts 20 minutes, with the grating contrast gradually decreasing from 0.4 to 0.1 to help participants acclimate. A minimum accuracy rate of 60% is required at each contrast level before moving to the next, with an ideal post-training accuracy of 70%.

## 

## Experimental Phase

The second day is dedicated to data collection. EMG electrodes are placed based on the positions marked during the first day, and MVC values are recalibrated at day 2 or between any block when participant report difficulty while responding. Fatigue levels between 1-5 are recorded after each block, and participant are ask to take a 3 min rest after each block. The experiment involves four conditions:

1. Difficulty levels: Two contrast modes (0.14 and 0.07).
2. Muscle usage: FDI and BCP.

Muscle activation is set at 20% MVC, with sensitivity adjustments of ±5% as needed. The experiment consists of 8 blocks, with each block separated by a mandatory 3-minute rest period to alleviate muscle, attention, and visual fatigue. Before each block, participants complete a delay feedback practice session to recalibrate muscle force control and adjust the EMG interface sensitivity. Each block contains 128 trials, with equal distribution across the four experimental conditions. Trials are randomized to avoid predictable patterns. The total data collection phase lasts 85 minutes.

## Data analysis Techniques (to be continued)

## EEG: XXX each find one literiture

* + SSVEP: Steady-state visual evoked potentials to track sensory encoding.
  + CPP: Central parietal positivity for decision-making monitoring.
  + LRP: Lateralized readiness potential for motor preparation assessment.
  + Mu-Beta Oscillations: Indicators of motor readiness and inhibition.
  + NI Modeling: Combines EEG and behavioral data for decision process modeling.

EMG:

* + ENV XXX
  + FzEn XXX

EOG: XXX

This multi-modal approach ensures precise data collection, enabling a detailed analysis of sensory, decision-making, and motor processes in the perception-decision-action framework.