Supplementary Information

1. Visualization Script

Set up: PERSPECTIVE IN FIRST PERSON

Imagine yourself playing a game against an important opponent (choose an opponent). Imagine yourself in the uniform and your equipment. Imagine the feeling of being dressed and holding your stick. Imagine you are in the third period of this game and the score is tied 1-1. Imagine yourself sitting on the bench watching the play go by, waiting for your next opportunity to go out and sacrifice for the team. You are sweaty, breathing heavily, and your adrenaline level is high. Picture the sounds of the crowd, your coach, and your teammates around you. Imagine the cool air from the rink hitting the sweat on your skin.

Imagined scenario (*what participants imagined during the "GO" cues**):

Your coach calls you to play and you hop over the boards as your player changes. You are on the (left or right depending on your handedness) wing when your defender passes you the puck as you begin to skate toward the opponent's zone. You cradle the puck with ease and pick up speed. You are flying down the ice handling the puck on your blade with your head up, reading the play and the players around you. You see that you are on a 2 vs. 1 with your other teammate against the defender on the opposing team. Your heart is pumping, but you are composed, ready to seize the moment. At this point, you are at the opposing team's blue line and you have to make a play. You notice their defender cheats toward your player that is on the two-on-one with you. You decide to fake the pass to your teammate, turning your head and stick toward them to fake out the goalie and the defender, but at the last second you turn toward the net and fire a hard shot using your muscle and power high and up to the top (left for right-handed players or right for left-handed players) corner for a goal. The crowd jumps to their feet, you feel a rush of excitement and joy as you throw up your hands to celebrate the goal, skating over to your teammates for a celebratory hug/bear tackle.

Reminders:

- Try to imagine the situation in its entirety, with as much detail and physiological awareness as possible.
- Imagine the sounds, sensations, smells, tastes, emotions, and sights. Channel your focus, heartbeat, sweat, adrenaline, excitement, breath, physical movements, muscle tension, strength, balance, power, the puck on your stick, your hands around the stick, the skates cutting into the ice, your teammates calling, your coaches talking, the crowd cheering, the wind in your face and hair, the deception in your body positioning and any other details that relate to the visualized situation.
- Keep the PETTLEP model in mind: physical, environment, task, timing, learning, emotion, perspective.

*One participant, a goaltender, imagined a different scenario specific to her position. The imagery was a penalty-killing situation (her team playing short one player), with the puck controlled by the opposition team in her own team's zone, the puck moving from one opponent to another through a series of passes in a structured power play formation, her own re-positioning movements mirroring the changing location of the puck handler. The imagined play culminates in a final cross-ice pass just in front of the goal crease and a one timer shot that she saves after a strong lateral push and power slide, having read the play perfectly, allowing no rebound.

The goaltender's scenario presumably differed most from the other participants' scenario in the task and learning elements of the PETTLEP model (and possibly the emotion element, if preventing a goal is more emotionally taxing than scoring a goal, which is likely in hockey).

2. Movement Imagery Questionnaire—Revised second version (MIQ-RS)

The **MIQ-RS**[1] is composed of two subscales, visual and kinesthetic, each represented by seven items. Participants rate the ease or difficulty of imagining the movement on a 7-point scale from 1 = very hard to see/feel to 7 = very easy to see/feel.

Motor imagery: involves vivid mental rehearsal of complex or simple movements without motor execution

- **Kinesthetic motor imagery →** feeling what performing a movement is like without actually doing the movement
- **Visual motor imagery →** forming a visual image or picture of a movement in your mind

Participant MIQ-RS scores

Participant	Level	MIQ-RS Visual Imagery Score	MIQ-RS Kinesthetic Imagery Score	MIQ-RS Total Score
1	NCAA	42/49	42/49	84/98
2	NCAA	32/49	40/49	72/98
3	U Sports	33/49	32/49	65/98
4	Olympic / Professional	39/49	41/49	80/98
5	NCAA	43/49	36/49	79/98
6	Professional	39/49	38/49	77/98
7	U Sports	40/49	43/49	83/98
8	U Sports	45/49	44/49	89/98

3. Non-dominant parietal areas of activation

The lesser significant activation in left > right primary sensorimotor cortex (pre- and post-central gyri) at the group level was most evident when the imagery condition was compared to the mental counting control as opposed to the resting baseline state (Fig. 1), suggesting that the resting state contained greater baseline sensorimotor cortex neural activity than the more focused mental counting state.

At the individual level, lesser significant activation was seen in adjacent left, dominant hemisphere occipital cortex in 2/8 participants and in contralateral right, non-dominant hemisphere parietal cortex in 2/8 participants (most evident in the goaltender, Fig. 2).

4. MEG beamforming versus PET or fMRI localization of activation

MEG is relatively insensitive to neural activity in subcortical or cerebellar sources compared to PET and fMRI. MEG beamforming also works on a different timescale than PET or fMRI, and fast changes in neuronal activity directly detected using MEG may be relatively diluted in the indirect metabolic measurements of PET or fMRI.

The DICS inverse model we employed for MEG localization used a cross-spectral density matrix in the beta band (13-30 Hz), sliding 1-second windows, with 50% overlap, across the entire 30-second block. In practice, this means that every voxel was weighted by how deeply and for how long its beta power was suppressed during each 30-second imagery block. This method inherently favors consistent, long-lasting neuronal activation/beta desynchronization: activation sustained across many consecutive 1-second segments will be identified by the beamformer as a strong source of power contrast. Conversely, regions activated only briefly or sporadically during complex MI will be “washed out” in the averaging of spectral power. Averaging across 10 trials per participant (and, for the group-level analysis, averaging across participants) further amplifies this effect. In essence, the 1-second sliding window of the beamforming technique acted as a low-pass filter that emphasized prolonged activations and de-emphasized transient activations, the latter more likely to be identified as metabolic changes by PET or fMRI. The main parietal hub region of neural activation identified by MEG was desynchronized for a large fraction of each imagery block, and so its signal added up, window after window, to become the strongest peak in the final activation map.

Other, downstream areas may conceivably have had beta power decreases during imagery periods, but for briefer periods of time or in slightly different voxels from one participant to the next. The contributions of these other areas of desynchronization to the overall pattern of neural activation identified by MEG may have been intermittent and/or spatially inconsistent, thus adding only a small amount of power to the group-level average. Spatial inconsistency could occur given that participants are imagining a complex and kinesthetic scene – sweat, noise, different types of movements – which may be processed in different areas in different participants and end up diluted in the grand average. However, as the parietal hub integrates all these modalities, it would remain desynchronized throughout the imagery periods.

Our MEG findings indicate a dominant parietal cortical hub for complex MI and provide neurophysiological and neuroanatomical support for certain theoretical models derived from cognitive neuroscience, specifically hierarchical internal forward[2] and predictive-processing[3] models, which propose that "efference copies" or "emulations" of imagined actions are generated and dynamically updated in posterior parietal cortex situated upstream from frontal motor planning and subcortical motor coordination areas. Viewed in terms of network connectivity, the continuously active parietal integration hub may transiently recruit other areas not needing sustained activation during imagery, but these would either be unidentified by MEG beamforming or show only mild or individual-level activation (e.g., primary sensorimotor, dominant occipital or non-dominant parietal cortices).

Supplementary references

1. Gregg, M., Hall, C. & Butler, A. The MIQ-RS: A suitable option for examining movement imagery ability. *Evid. Based Complement. Alternat. Med.* **7,** 249-257 (2010).

2. Tian, X. & Poeppel, D. Mental imagery of speech and movement implicates the dynamics of internal forward models. *Front. Psychol.* **1,** 166 (2010).

3. Ridderinkhof, K. R. & Brass, M. How kinesthetic motor imagery works: A predictive-processing theory of visualization in sports and motor expertise. *J. Physiol. Paris* **109,** 53-63 (2015).