The role of mental practice in developing fast, accurate shooting skill

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The brain processes physical actions for fast, precision shooting using sensory input to compare the current position of the pistol to learned goals for body positions necessary for accurate shooting. Each goal posture (body position) represents a critical control point for making a successful shot. Goal postures cover stance, grip, arm tension, aiming, trigger release and follow-through.

The brain develops mental representations of these control points and, while an action is being performed, the brain can simulate the next action. The goal postures (control points) enable prediction of the actions which will position the sights and complete the trigger movement for fast, precision shooting. Skill development entails enriching the detail of the mental representation of that skill. Importantly, prediction can be trained, improving speed and timing. Methods for this include live firing, dry-firing, mental practice and training exercises which require fast completion of fine movement such as timing accurate aiming to coincide with the fall of the hammer.

Mental practice requires visualisation ability. For those without this capability, research proposes that non-visualisers can build mental representations of critical control points for action by mimicking the actions of an expert. An education program to help non-visualisers learn the component skills of expertise in the event without relying on visualisation is described. Prediction skills are required in all shooting disciplines.

1. Introduction

To refine the aim of a pistol, the brain compares the current position to the intended goal and simulates the actions to move the sights to the desired position. This involves prediction.

The brain mechanisms involved in prediction of movement are called internal forward models. Prediction is essential in all pistol and shotgun events. In the ISSF Rapid Fire event shots must be released in the fleeting moment the sights are on the 10-ring. In shotgun events, prediction is required for tracking a flying clay target. In precision shooting a decision to complete or abandon the shot involves prediction based on rapidly changing sensory information among other things. Reaction time can be shortened and better control of fine movement can be achieved by improving the ability of neural networks to predict the sensory consequence of movement commands (Rannaud et al. 2022).

The importance of prediction is reflected in the comment by former Commonwealth Games Gold medallist: “You have to start shooting before the sights stop moving” (Murray, 1995, referring to starting trigger movement as the pistol enters the minimal wobble pattern of the aim). Rapid fire requires the ability to predict the instant the shot will be released. “You’ve got to know when it’s going to go” (Murray, 1995). Predicting the motor (movement) response to spatial, temporal and force can be trained to predict the sensory outcomes of motor commands (Mohan, et al. 2019, Bennet and Reinder, 2022, Monay, 2022).

Forward models compare *desired* and *actual* sensory outcomes to predict movement outcomes (Maurer et al. 2022, Miall and Wolpert, 1996). They are neural networks that mimic the causal flow of the physical process by predicting the future outcome of movement given the goal of the movement, the efferent (outgoing) copy or copies of the motor command, and the current state” e.g., (the current position of the sights) (Monany, et al. 2022). The efferent copies (outgoing signals from the brain are instructions sent to initiate action and generate representations of the anticipated consequences of movement (Harrison, et al. 2023). Efferent copies are retained briefly and facilitate prediction by enabling error correction. Error correction for movement involving aiming was about 250 thousandths of a second and was related to forward processing of the aiming movement (Maurer, et al. 2015). Involuntary motor control (reflexes) is critically important in movement control. Feedback loops could be referred to as feed-forward mechanisms since they predict movement outcomes from the current position (Schack, 2020).

Predictive ability is thought to stem from the brain's control function located in the frontal lobes responsible for planning, working memory, imaging, organising, maintaining attention, creativity, mentally playing with ideas, meeting novel challenges and self-control (Diamond, 2013). The importance of making skills automatic has appeared in the research literature. Gold and Ciorciari, (2020) explain automatic skills as automatic processes that do not require wilful intervention and operate independent of conscious control. This can result from consistent and frequent practice. "The mentally separate processes are then repackaged into a fluid arrangement of actions that can be set off by a single thought" (Gold and Ciorciari, 2020). This means that an expert experiencing automaticity will find that certain actions can be carried out with considerable speed. For example, the lift to Target 1 and the consequent shot release can be very fast, lifting confidence, especially in the 4-second series in rapid fire. There is a view that execution of movement cannot be entirely automatic since monitoring is always present.

Table 1 below, gives the times for the first shot times for each series for Schuman, Reitz Milev, through a half match in 2011 and Evglevski in 2022. The first shots were between 1.7 – 2.1 seconds in eight second series, 1.6 – 2.2 seconds in the six second series and 1.5 -1.6 in the four second series.

Table 1. First shot times

	Schumann		Milev		Reitz		Evglevski	
	Time	Score	Time	Score	Time	Score	Time	Score
8s	2.0	50	1.7	49	2.1	50	2.1	50
	2.2	50	2.1	48	2.5	49	2.1	50
6s	1.6	49	1.8	48	2.2	49	1.8	48
	1.7	49	2.0	47	1.8	49	1.7	49
4s	1.5	48	1.5	46	1.6	43	1.6	47
	44	#	48	#	48	1.5	46	#

Note: First shot times were taken from the moment the 'green' light came on. # Indicates a slow motion sequence with the first shot time not able to be recorded. Schuman's final 4-second series, included a "5" on the last target because he slowed to correct an error and by the fifth target found he was running out of time so fired a hurried shot. The first shot times were recorded by the author watching the green light come on and marking that to video by flicking the fingers past the lens. [Technical note: Video data from the camera sensor cannot be read by the human eye, necessitating software conversion. It is possible that this conversion process could skip frames, so the times given for the first shot could be 1.5 seconds plus 0.2 seconds. The video files used for the first shot time analysis were converted direct from the digital camera output].

Table 1 shows that competitors shoot the first target in each time series using almost identical timing. The time difference is half a second across the 8, 6, and 4-seconds series. The time difference between the 8, and 6 second series was 0.2 seconds and between the 6, and 4-second series was 0.3 seconds. Making actions similar for each time series was also evident in the traverse from Targets 2-5. The firing tempo was almost identical for each time series, only slightly faster as the time shortened.

Experts classify problems according to underlying functional principles, whereas novices operate more strongly with superficial features (Schack, 2020). He gives the example that high jump experts have a better understanding of the function of the body postures of the high jump movement compared to novices. Individuals tend to perform better in the presence of confidence, arousal and concentration (Jangian, 2023).

During fast sequences the sensory feedback used by internal forward models can be disrupted by becoming aware of outside distractions or from intrusive attempts at self-coaching. These can potentially block the free flow of existing skills by interfering with the brain's prediction mechanisms (forward models). If timing of the shots is hindered the shot group can appear in a different place than usual.

2. Mental practice

The predictive capacity of internal forward models can be improved by mental practice (Monay, 2022). Imagining a perfect shot activates the brain's internal representation of the action so the action appears in conscious awareness and become stabilised by imagining the movement (Frank et al, 2014). This is because brain patterns observed during mental practice (imaging) and physical performance are functionally the same (Frank et al. 2014, Toth et al. 2020), meaning that brain processes present during actual action are also present in imagined action. Physical and mental practice share common neural circuits but draw on different circuits to access specific information for different tasks (Savaki and Raos, 2019). Because there is functional similarity between actual and imagine (visualised) action, mental imagery should be made as similar as possible to the actual physical performance. Simulating movement actions mentally (such as the lift to the first target) is a prelude to execution of action (Schneider et al. 2023, Vernon, 2019, Nanay 2023).

"The rapid reactions of expert athletes are not solely due to the greater speed of their nerve signals, but also their ability to better anticipate future situations and events from surrounding cues … Mental practice can improve future motor performance by fine tuning this process, resulting in more effective predictions and motor execution in the future" (Schneider et al. 2023). Imagery is a collection of abilities, including visual imagery, imagery of movements or combinations of imagery modalities and kinaesthetic imagery (Schack (2020). Imagery plays an important role in planning and executing complex movements (Schack, 2020).

Mental practice involves imagery (visualisation) however the language of the brain is not pictorial but electrical and chemical. Learning and refreshing new skills forms neural pathways of linked brain cells. Information moves along these pathways by electrical transmission, with the transfer to other neuron (brain cell) clusters occurring chemically at junctions (synapses), hence electro-chemical transmission. Neurotransmitters allow brain cells to communicate with other cells, glands or muscles. By detecting electro-chemical activity, blood flow and other chemicals within the brain researchers have identified areas of the brain active in the processing and sending of instructions to the body to perform physical tasks. A summary of research findings on mental practice is given next.

Mental practice: Research summary

Mental practice involves firing a perfect series of shots in the imagination without apparent physical movement. Studies of the effectiveness of mental practice in sport, confirm that it enhances performance. It activates parts of the brain which are activated by physical practice and is an effective addition to physical practice in the days before a match and immediately before firing. It improves the brain's ability to predict outcomes of sensory controlled actions, such as aiming and firing. Skill in the prediction of movement outcomes is especially important in the ISSF Rapid Fire event. Any training which flexes the brain's prediction mechanisms should be pursued, including mental practice of precise, accurate shot release, capturing the look, feel and sound of the actual performance and dry-firing with trigger action timed to occur a fraction of a second after correct sight alignment. Imagery is a collection of abilities, including, visual imagery, imagery of movements or combinations of imagery modalities and kinaesthetic imagery (referring to feel). It requires practice to achieve mastery.

The mental imagery should be similar to and, accompanied by, physical practice. Used immediately before firing it primes the muscles for fast, precision movement. This is particularly effective when the imagery of the forthcoming action connects with the existing mental representation of the body postures or goal-postures which represent the key change points (critical control points) in the execution of the skilled action.

Mental practice gives practice in applying high concentration on performing the skills essential for successful shooting in rapid fire, Prior to a major competition mental practice helps allay anxiety (match nerves). Mental practice effectiveness can be improved by strategies such as "psyching-up, attention focussing, relaxation, self-talk, improving the quality of the mental rehearsal, the degree of imagined effort and mind controllability (concentration). Mental practice sets goals by visualising perfect shots. It should be repeated in at least 20-minute sessions over several weeks when preparing for competition. For those who have difficulty visualising, other forms of mental preparation without relying on mental imagery, using mimicry of expert action, can be just as effective *(a program for non-visualisers is provided on the USB Flash Drive.*

NOTE: "Motor" means movement and "sensorimotor" refers to neural circuits for both sensing and movement. Google is useful for unfamiliar terms. The research presented here arose from innovations in neurotechnology which has given a better understanding of brain functions, including higher-order processing (see Bortollo et al. 2020)

Mental imagery can be auditory, olfactory, tactile and can happen in all senses not just vision (Nanay, 2023). Since mental imagery can be used to fabricate a non-existent scenario, a person can develop "what if" scenarios to try out ways of correcting a problem. Problems can also be an inhibition, such as not being able to keep a series of good shots going.

Memory is "distributed" within different parts of the brain (Fuster, 1998). Mental imagery blends episodic memory, such as the experience of firing a pistol, with knowledge of how to fire accurately (called semantic memory) a type of knowledge which is "learned in various contexts" (Ranganath, 2024). Five areas of the brain are activated during imagery, two in the inferior parietal lobe (Kossyln et al. 2006) This indicates that mental practice links knowledge stored in areas of the brain according to need (Fuster, 1998). Images of colour, shape, sound are sourced from the lateral premotor cortex, part of the brain's neo-cortex (Broughton, 2023) and these along with feel (and control of force) are important in creating mental representations of skilled action by those with difficulty visualising. Mental practice refreshes these connections which is important as memory decays due to lack of use.

Research studies of mental practice

A study which aimed to replicate an influential earlier study of mental practice (Driskell, et al., 1994) found the effect of mental practice on performance is robust and able to be replicated. Mental practice can increase muscle strength (Toth et al. 2020). This indicates that mental practice can supplement physical training when managing an injury (Reiser et al. 2011). The quality of mental rehearsal, the degree of imagined effort and mind controllability (maintaining concentration) have a major effect on performance (Babak and Abbas, 2013).

Analysis of 58 studies of mental imaging by Lindsay (et al. (2021) reported that mental imaging has a statistically significant effect on improving performance in sport-specific motor skills. Another review of 52 research studies where athletes used imagery in sport performance found that mental practice allows athletes to accommodate the rehearsed behaviours and codes (tags) them to be easily remembered and recalled, enhancing performance (Kumar, 2019). He examined the use of mental practice in football coaching and concluded that imagery had to be sport specific and that combining relaxation, goal-setting, imagery, and self-talk (pertinent instructions to self about what works best for you) may be more effective in enhancing sport performance than using imagery alone (2011: 94).

Mental skills training for snipers in the Norwegian Armed Forces showed a positive impact on training outcomes (Yettabol et al. 2023). The training covered goal setting, imagery breathing, positive self-talk, affirmation, and relaxation. The self-affirmation component included asking participants to consider then replicate what they experienced when at their best in specific circumstances. The educational method was close to self-sufficiency/self-actualisation and career-long learning rather than ticking off a series of competencies. The authors concluded that implementation of mental skills training had a positive impact on course performance (Yettabol et al. 2023).

The impact of mental practice when physical practice examined twenty-seven studies prior to 2020 and showed that a balance of physical and mental practice optimised motor skill development and was useful in cases where access to facilities for physical training was limited and minimised the risk associated with excessive physical practice, such as burn-out (Jiminez-Diaz et al. 2023).

A study of mental practice in learning a finger tapping exercise (Truong, et al. 2023) is of interest as trigger finger strength, flexibility and timing are essential in shooting, especially the rapid fire event. The authors reported that all test groups in the study “showed better skill performance one-day later, compared with their initial performance; a finding not affected by time of day tested. However, it was found that improvement in performance occurred if training was in the evening, followed by a night of sleep. Walker’s (2017) sleep research refers to “filters” in the brain’s frontal lobes becoming active when information is moved from short term to long term memory during sleep and determine which memories to keep or discard (Walker, 2017). His “filters” appear to refer to mental representations of expert action which act as reference standards to judge what of the day’s learning to keep or to refresh and what to discard if already existing in memory in an inferior form. His sleep research. also suggests a way to break through the problem of scores plateauing by enriching the detail in reference standards to make the standards a better judgement source (see Appendix A).

Mental practice was found to be more effective in cases requiring response to an external signal (e.g., the green light on electronic targets in rapid fire). Mental practice programs lasting 1-6 weeks gave the strongest benefit (Toth et al. 2020). Visualisation can produce scenarios of action such visualising the sights to be superimposed above the hand when using the “empty hand” traverse across the targets or create a scenario to guide experimentation with new technique. Since visualisation involves firing perfect shots it is a form of goal setting. Other benefits can flow from goal setting, such as turning attention to the equipment, or the ammunition for the match, or physical conditioning or altering the training strategy. Mental practice allows athletes to accommodate the rehearsed behaviours and codes (tags) them to be easily remembered and recalled, enhancing performance (Kumar, 2019).

The importance of precise movements

As mentioned, action is more precise if the forward model contains detail about the movements which constitute the skilled action sequence especially the critical change points during the action sequence. This shows the importance of making actions as precise as possible during practice. Sloppy actions train the brain to make sloppy actions. These models guide action toward a predicted outcome, in real-time, using mechanisms including:

- Proprioception, the processing of information from body sensors including vision;
- the servo-control loop used to refine movement as it occurs and the mechanism for the retention of copies of the instructions sent to initiate movement (called "efferent copies") so that the intended action can be compared to the actual action, facilitating error correction, if needed;
- working memory opened to make temporary calculations for movements to correct an error. This is active during mental imaging;
- skills, distilled from prior learning, about what is essential for accurate shooting, stored as "episodic" and "semantic" memory; and
- the effect of elevated levels of concentration and neurotransmitters on brain processes during performance, including the "Flow State" if it emerges (see Section 5).

Proprioception

When we set an outcome – aim at the target – the brain uses sensory information from proprioceptors, body sensors, in the hand (as touch and pressure sensors), and in joints, muscles ligaments and bones to be aware of the position and movement of parts of the body (Ramachandran, 2011, Rann et al. 2022). Proprioception provides information about internal mechanical events and is used to refine movement. Vision and hearing provide information about external events (Ledermann, 2010). During movement the brain reads areas of varying tensions rather than individual muscles (Ledermann, 2010). This is noticeable when rocking forward and back to set balance.

Knowing which signals are critical for accurate shooting (the critical change points during an action sequence) speeds up skill development. An example, in rapid fire when aiming, is to look at the top of the white spaces either side of the front sight, to ensure it is centred. (Taransky, 2011). Basketball experts spend more time than novices looking at the rim of the basket before the throw (Katwala, 2019). Achieving a high level of performance is helped considerably by making skills approach being automatic and knowing what to look at and what to feel. "Quiet eye" is a phenomenon, observed in experts, which describes holding gaze fixed on what is critical for success (Katwala, 2016). In ISSF Rapid Fire, experts pause the pistol on each target, including the 4-second series allowing a fraction more time to see the sights.

The Servo-control loop and the comparison of intended movement with actual movement

The brain "can detect mismatches between the intended action and the actual action and insert appropriate corrections into the signals being sent, a sort of real-time, feedback-driven mechanism called a servo-control loop" (Ramachandran (2011). Errors can be corrected within 50 milliseconds (Katwala, 2019). When action is repeated such as firing five fast shots in the rapid fire event, if the aim is correct, the same instructions can be repeated for each shot and do not need to be recalculated each time. This may give the feeling of being in the "Flow State" associated with high performance.

Working memory

Working memory regulates the flow of information in the service of current goals (Harrison, et al. 2013). It has the ability to store, update and manipulate goal-relevant information. It supports higher-order cognitive abilities including learning, problem solving and decision-making and holds visual information active to make it resistant to interference (Brady at al. 2015). Working memory is involved in sensorimotor processing and goal-maintenance and underpins most complex cognitive behaviour (Moser et al. 2017). Working memory is thought to hold only 3-4 pieces of information at a time but can access information from long-term memory storage (Lappi, 2022) but this may depend on "exactly what is being remembered" (Brady et al. 2015).

When the brain detects an error which it can also do in 50 milliseconds, working memory is opened to calculate the necessary muscle movements to correct the error (Katwala, 2019). For elite shooters error correction is more likely to be retrieval of a known solution, rather than a new calculation, hence faster. Error correction benefits from a fast-cycling pistol and fast trigger action to recover some of the time lost making the correction. Recent research indicates that working memory can be disrupted and this suggests that intrusive self-talk while firing, can slow response, as mentioned.

Memory chunking

When an expert perceives, remembers, or creates a relation between elements of a situation (a meaningful pattern) a memory chunk is created in working memory and information about the chunked pattern becomes stored in long term memory (Lappi, 2022). Chunking is a way of grouping items to make them easier to process (Brady and Tenenbaum (2013). It is a form of memory compression. Chunking enhances working memory performance and is a memory enhancer (Portrat et al. 2015).

It may be that experts, by having feature-rich, detailed understanding of key moments in shooting the rapid fire event, can form chunked mental representations of key change points and use these to improve anticipation (prediction) of movement change which is about to happen. According to Schack, (2020) the brain represents skilled action, from start to finish, as a sequence of chunked movement postures or goal postures, together with information about how the movements merge. These represent critical control actions (Lappi, 2022). Chunks are information rich representations of groups of elements that have strong if-then associations with each other (Moran et al. 2018). and are change points for use in prediction for specific intended outcomes. A study of visual working memory concluded that chunks are formed from perceptual information before encoding in memory (Brady and Tenenbaum 2013).

Sensory feedback is used to refine movement execution such as the start signal, the recoil from successive shots and so on. The person, acting as a self-directing coach, would identify critical change points for the lift and the traverse across the targets and use this information to tailor technique to suit their personal abilities and current skills and use them as critical points in mental practice.

Heightened awareness of the situation and its demands allows switching between an automated state to a controlled state when adjustment is needed (Moran et al. 2018, Bortoli et al. 2016)). For example, the lift of the pistol to Target 1 could be represented as four chunked movement postures: first, dwelling on Target 1 prior to the call "attention"; second, the start position which containins all the information about balance, orientation, start signal anticipation and heightened concentration; third, the lift chunked as a single body position containing information about the fluid upward acceleration to the reference point where final trigger action begins; and fourth, the movement which positions the sights over the 10-ring for shot conclusion. Holding a mental representation of four chunked positions is within known capacity for visual working memory, especially as they can be progressively deleted.

Schack states that final body postures are represented in memory and that these postures are specified before movements are initiated (2020). This is reflected in Figure 1 in the reference to unconscious imaging (Box 1, of Figure 1). In target shooting, follow-through involves sustaining the set of body tensions established at the beginning of the firing sequence until after the bullet has left the barrel, such as firing a sixth target in ISSF rapid.

The chunked movement postures concept has emerged from brain mapping research, is subject to further investigation and may be confirmed or replaced. However, the concept of movement postures is recognisable in terms of the rapid fire pistol event. Competitors can set the posture for the movement of the lift to Target 1, see the start point for trigger action and the posture goal position for an accurate shot (sights in the 10-ring). They can see the movement positions which correspond to the acceleration between targets and stopping on each.

Using findings from the research literature, Figure 1 shows how a competitor can set-up for fast, precise action using prediction to achieve intended outcomes.

The required immediate action is mentally simulated unconsciously (meaning that task-focussed mental processes have been set in motion). Or the simulation is with intention, in the form of visual imaging or non-visual mental representations unique to the individual; a feeling of alertness, confidence and the perception that muscle tensions:

- are in a high state of readiness;
- the required skills for critical control actions, gained through training, are represented mentally as goal-related body postures or goal postures for critical control actions;
- internal simulation connects with goal postures launching fast, precise movement, monitored and guided by internal forward models, in real time, using sensory feedback where movements are correctly executed, without need for error correction, working memory is freed up to continue fast actions or for fine adjustment of aiming, allowing the outgoing commands to the body (efferent copies) to be repeated, maximising concentration, saving time and improving precision, leading to high performance.

START

Warm-up and build anticipation. Begin imaging specific to the task, simulating the mental representation of goal postures (critical change points for action). Imaging can be unconscious or deliberate,
As action commences, imaging connects with mental representations of movement Goals (goal postures).

→

Movement is accelerated.

The brain's internal forward models use sensory feedback to refine prediction of movement outcome prediction, shortening reaction time and increasing precision. Mental load is simplified. Actions move toward being automatic. Release of neurotransmitters. Perceived control increases.

PROGRESSION

Movement instruction (efferent copies) for successful shots can be repeated. Absence of error alarms (no correction needed). Working memory fully available for monitoring and refining action. Mental processing of physical actions is fast

→

Maximum concentration.

Feelings of calm control.

Actions fast, precise.

OUTCOME

Elevated

performance

↓

High achievement

Note: A heightened awareness of the situation and its demands allows switching between a near automated state and a controlled state when adjustment is needed (Moran et al. 2018)

Figure 1: From mental imaging to high performance

Figure 1 shows the important role of prediction in executing motor commands during fast, precision shooting. The speed and accuracy of these motor commands can be improved by mental imagery (Monany, 2022). Mental imagery may play a part in all thinking, including simulating future scenarios (Pearson et al. 2019) such as when an athlete reimagines a physical action to try out a modification. Images, such as those which anticipate action, can form prior to conscious effort (Pearson, 2019). This points to a link between unconscious mental imagery (which precedes action and the process of connecting to the sequence of body postures (critical control points) which will complete the action sequence. This process would shorten reaction time by setting the body in anticipation for each immediate next action as they unfold. Knowing the critical change points for the whole sequence, would make action more precise and, possibly, contribute to a feeling similar to being in a Flow State.

Visual imagery has "a heightened effect on visual perception" (Pearson, 2019). Voluntary mental imagery starts in the frontal cortex of the brain, then retrieves stored information from the brain areas where movement sequences appropriate to the task are stored then the middle temporal area of the brain and the parietal lobes (Pearson, 2019). Applying attention prioritises what we are seeing and thinking about. Intention guides attention to lock onto something specific (Ranganath, 2024:18).

Repeated performance of a skilled task strengthens neural connections. For example, the areas of the brain of violin masters which control the left hand become bigger as the left hand does most of the work (Walker, 2017). Through repeated use, neural circuits link together and a coating of myelin is deposited on them which speeds electrical transmission (Katwala, 2019). An athlete can suddenly lift to consistent higher scores from training due to physical changes occurring in neural pathways.

During firing the recoil lifts the whole pistol slightly then rocks the front sight upward which levels out when the slide closes. Maintaining level arm movement during the traverse across the five targets requires prediction that the sights will quickly level, and the movement can be accelerated to the next target (see Figure 8 below). Novices, lacking this predictive skill are likely to attempt to pull the sights down to counter recoil producing a likely low shot on the next target. In Figure 8 the recoil recovery seen flattening out on the last shot reflects the beginning of the shooter's follow-through. Figure 8, below, is based on the average of five series of rapid fire shots fired by Scott Anderson (see the opening scenes of the video).

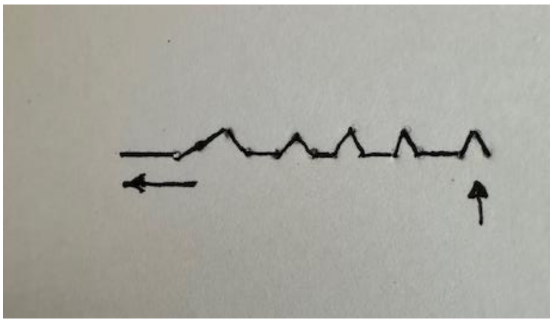

Figure 2. Recoil pattern for five shots (Scott Anderson)

NOTE: The recoil begins from the centre of each target

3. Conclusion: Implication for training

The key strategy elite competitors use in the Olympic rapid fire event is to fire the first shot quickly with only half a second difference between the 8-second and 4-second first shot times (Table 1). The speed required to achieve these shot times relies on the ability to predict fast action outcomes by timing trigger action to conclude in the fleeting moment the sights are stopped on the 10-ring.

Brain imaging research has proposed that fast, precise movements are managed using mental representations of skills held as chunked movement postures or goal postures which identify points for critical control actions such as the moment to start trigger pressure or finalise the shot release. Brain networks simulate this intended action using feedback from body sensors, including vision, in real time and very quickly.

The overall training goal is to make the critical control points for the complete action sequence automatic (but monitored). Sharpening the internal brain mechanisms for prediction, particularly in relation to predicting critical change points for action, will enhance speed and accuracy and speed skill development. (Remember that sloppy actions teach the brain to make more sloppy actions). Mental practice has been shown to improve the brain's ability to predict movement outcomes of sensory controlled actions and also dry firing.

Movement prediction is controlled by internal forward models. These guide actions toward achieving the intended outcome by comparing intended and achieved action as movement progresses toward the intended goal. The person, acting as a self-directing coach, could identify change points for the lift and the traverse across the targets and use this information to tailor technique to suit personal abilities and current skills and also to mentally rehearse the start of the lift and other key timing moments. Recent research indicates that working memory can be disrupted by intrusive self-talk while firing, slowing response. This suggests that having a mind open and intensely ready when about to fire is ideal.

"The more a person monitors their intentions throughout their actions, the more their experiences will be consciously willed and nonautomatic" (Gold and Ciorciari, 2020). Overcontrolling fine actions can make you clumsy. Hence, when a fast action sequence is about to commence, it is better to turn off 'self-talk' and make the mind open and intensely ready (Anderson, 2019). The danger of overthinking or overcontrolling a shot sequence is that muscles can tense up causing increased sight movement and spoiling timing.

Any training which flexes the brain's prediction mechanisms should be pursued, including mental practice of precise, accurate shot release, capturing the look, feel and sound of the actual performance and dry-firing with trigger action timed to occur within a fraction of a second of correct sight alignment. This form of training will help to speed up prediction of movement outcomes.

Training should include mental practice both away from the range as a lead-in to firing, as this has been shown to stimulate similar neural processes as actual physical action. Mental practice should be part of dry-fire training where the emphasis, as mentioned, is on achieving trigger release immediately the correct sight position is achieved, preferably within a fraction of a second. This to improve timing.

Repeated performance of a skilled task strengthens neural connections specific to performing the task. Mental practice should include of firing perfect shot sequences in the 8, 6, and 4-second timing of a half or preferably a full match. The duration of the mental practice session can be short yet effective, but the ideal is to complete a half or full match and the Finals over several weeks before a competition with 20-minute sessions over several weeks recommended. Pistol coaches should include mental practice in training programs.

Combining mental practice and physical (live fire) practice enhances performance. Mental practice can be improved using strategies such as "psyching-up, attention focussing, relaxation, using self-talk (pertinent instructions to self about what works best) and other forms action preparation strategies, including confidence building. The 3-minute program included on the USB Drive is for those with difficulty using mental imagery. It aims to help form mental representation of essential skills for use during training. On the mental side, competitive target shooting requires emotional control, mental concentration, management of stress and anxiety and the ability to control emotional states to perform under pressure resisting mental blockage during the technical execution of a shot. These all benefit from mental practice!

References are on the USB Flash Drive titled *Advanced ISSF Rapid Fire Ver 3*