1-1 Principles of S-R Compatibility and Translation:

Define S-R compatibility.
It is the degree to which a person's perception is compatible with the required action. Has been described as the "naturalness" of association between stimulus and its response. (Left-oriented stimulus with response from left side of body)

Define basic compatibility types.

- Conceptual Compatibility – degree to which codes and symbols correspond to people's conceptual associations
- Movement Compatibility – degree of correspondence between movements of displays and controls and response of system being controlled
- Modality Compatibility – degrees of correspondence between stimulus-response modalities (the way you are getting input (auditory, visual etc) and your ouput)
- Spatial Coding – compatibility in spatial arrangement of controls and displays, or stimuli and responses
    - Stimulus and response sets "coded" (represented) in terms of spatial locations
    - Can be explicit (based on absolute spatial positions) or implicit (responding to symbols)
    - When stimulus and response codes match, responses faster and more accurate than when don't match

Describe everyday examples of SRC.
Stovetops are an example of SRC because the knobs to turn each specific stove do not usually match up, causing a compatibility error. Computer mouse

Define and describe phenomenon of spatial compatibility.
When a stimulus and its response are on the same side (Ipsilateral), reaction time is faster than when they are on opposite sides (contralateral).

Define and describe the characteristics of spatial coding.

- Stimulus and response sets "coded" (represented) in terms of spatial locations
- Can be explicit (based on absolute spatial positions) or implicit (responding to symbols)
- When stimulus and response codes match, responses faster and more accurate than when don't match
- SRC effects attributed to more efficient translation between S-R codes

Distinguish between cognitive coding and anatomical coding mechanisms.
Cognitive coding is coding a response to a set stimulus. If the stimulus is presented, there is one option to respond. Anatomical coding mechanisms are based off the anatomical congruence between the cerebral hemispheres processing the stimulus and response. In an ipsilateral case, when responding to a stimulus on the left side, the sensory neurons of the eye pick up the stimulus and transmit the information to the right hemisphere, and then send a signal to the left hand to press the response button. This is much faster than a

contralateral case where if the stimulus is presented on the left side, the information goes up to the right side of the brain and then must transfer to the left side of the brain to signal the right hand.

Define and explain how frames of reference impact compatibility effects.
Depending on the performer's frame of reference, spatial coding of stimulus and response sets can be flexible and very different.

Describe and explain the basis of the Salient features coding principle.

- Stimulus and response sets can be coded in terms of the salient features (features that stand out) of each dimension
- Translation is faster when the salient features of stimulus and response sets mapped together and correspond than when they don't correspond

Define orthogonal spatial compatibility and the purpose of examining orthogonal spatial relations.
Orthogonal spatial compatibility is when stimulus and response dimensions don't correspond (stimulus are vertical while responses are horizontal). People code the response to the stimulus to whatever they see as more dominant. For example I would code a right response to an up stimulus and a left response to a down stimulus. In an experiment, the more you move the response (joystick) to one side, the response to that side becomes quicker because the response dimension becomes more salient.

Define and describe the Simon Effect.

- Respond to a stimulus feature (colour, shape, etc)
    - Location of stimulus is irrelevant
- Stimulus features are mapped to spatial responses (left or right)
- If stimulus is spatially compatible (on same side) response is faster

Distinguish between the spatial compatibility and Simon effects.
Spatial compatibility effect is determined by the location of the stimulus, as a response is coded to where the stimulus appears. The Simon effect has locked responses to a stimulus feature, and the location of the stimulus is irrelevant. In both effects, responses are faster when the stimulus and response is spatially compatible.

Explain the Dimensional Overlap and Response Competition account of SRC and Simon effects.
Dimensional Overlap Model – When stimulus response sets have dimensions that overlap, elements in stimulus set can automatically activate corresponding elements in response set. If activates response is required one, is initiated rapidly, but if the activated response is not the require one, it will be initiated slowly and prone to errors.
Dual Process Model – Stimulus onset automatically primes spatially corresponding response. If automatic and intentional process (response conclusion) is congruent, reaction time is fast. If they are incongruent, need to abort the automatic response, program the right response and initiate it, which will lead to a slower reaction time.
Describe and discuss the empirical evidence for dual-process models of SRC effects.

1-2 Motor Program & Preplanned Movements – A Review

Define the characteristics of response programming stage.

- Organize and prepare a response
- Send appropriate motor commands

Explain the arguments for feedback (peripheral) versus feedforward (central) control.

Peripheral

- Mott & Sherrington (1895) did a study where they performed a unilateral deafferentation on monkeys which results in the monkeys not using the deafferented limb.
- Sherrington's (1906) Spinal Cat – They separated the spinal cord from the cortex and brainstem but rhythmic activity in the cat's leg remained without decrease in control
  - The spinal cord generates rhythmic movement through the **Reflex Chain**
    - Sensory feedback from on muscle burst serves as a stimulus for the next muscle burst, thus sensory feedback is necessary for movement production

Central

- Brown's (1911) Spinal Cat – They severed the sensory roots attached to spinal cord, but rhythmic leg contractions remained. This shows that the spinal cord can generate rhythmic activity without sensory input.
- Grillner's (1981) Spinal Cat – They deafferented spinal preparation and paralyzed leg muscles to eliminate any feedback from muscles to record activity from motor-neurons innervating muscles. The cat still displayed rhythmic neural activity which was consistent with requirement for movement.
- Taub & Berman (1968) used bilateral deafferentation on monkeys. These monkeys retained the use of their limbs (to climb, reach, grasp) although performance was clumsy and inaccurate.
- Polit & Bizzi (1979) used deafferented monkeys. The monkeys could still make target-directed movements, although the movements were not as accurate.

Distinguish between feedback vs. open-loop contributions to movement control.

- Open-loop is central control while feedback loop is peripheral.
- Feedback isn't necessary for movement production, but is important for fine tuning and control of movement
- Central control organizes in advance of movement, while peripheral happens during movement
- ANT and AG2 are affected by the loss of feedback (amplitude decreases)
- AG2 is in response to movement = peripheral control
- Stretch reflex is dependent on sensory feedback from movement
- In deafferented patient GL, triphasic EMG is achieved in both normal arm movement and in blocked movement, when no displacement is achieved showing that the triphasic pattern is planned as one motor program

Define the concept of motor program and describe its characteristics.

- A pre-structured set of neural commands, organized in advance, and capable of producing movements with minimal role for sensory information
  - Organized in advance and executed as a unit
- Movement is carried out open-loop until enough time has passed to allow feedback processes to operate

Describe the characteristics of the triphasic EMG pattern in rapid movements and explain its central and peripheral origins.

The triphasic EMG pattern consists of an:

- Agonist burst (AG1)
  - Precedes movement onset
  - Burst amplitude and duration are dependent on movement amplitude
  - Burst amplitude reflects force
  - **Central Origin**
    - **Happens without feedback**
- Antagonist burst (ANT)
  - Burst amplitude and timing influenced by movement extent and velocity
    - Earlier onsets with small, fast movements
  - May represent “braking”
  - **Mixed central and peripheral origin**
    - **Can be present without feedback**
    - **Can also be influenced by feedback**
- Agonist burst (AG2)
  - Influenced by strategy
    - Helps to “clamp” limb at target positions
  - **Central and peripheral origin**

Describe and explain the use of the blocking paradigm and EMG measurements for investigating response programming and advanced movement preparation.

By using the blocking paradigm we can see if the triphasic pattern is programmed and executed as one unit by blocking the movement at various points. In shorter movements we see that the antagonist burst follows the first agonist burst within 100ms, this shows that it may be preplanned along with the agonist, while antagonist bursts that happen later than 100ms after onset of the first agonist burst may mean that the preparation for the antagonist burst occurs after the initiation of agonist activity.

Explain how the results of experiments using the blocking paradigm show evidence for the advanced preparation of movements, the characteristics of a motor program, and the interaction between open and closed-loop processes.

The results of deafferented patient GL show that even without feedback, a whole triphasic EMG pattern is shown in full effect in both normal and blocked trials. This shows that the movement is carried out in open-loop, as feedback can alter the triphasic pattern by changing the amplitudes of the bursts or onset of the bursts, and shows that the triphasic pattern is programmed and executed as a unit, making it a motor program. In her normal trial, we see that the first agonist burst precedes onset of movement, and even without sensory feedback, the antagonist burst and second agonist burst are present.

1-3 Describe the basic characteristics of methods for imaging cortical activity (EEG, MEG, fMRI)

- Electroencephalography (EEG)
    - Looks at cortical activity through the use of surface electrodes on the scalp that picks up neural signals
        - Movement of ions inside, across, and outside neural cell membranes create electrical currents in excitable tissue
        - Electric potentials created by these currents travel to the scalp surfaces
    - Advantages
        - Non-invasive
        - High temporal resolution
        - Inexpensive/low hardware requirements
    - Disadvantages
        - Poor signal to noise ratio
            - Have to amplify the signal over and above any other electrical noise you may get
        - Inter- and intra-trial variability
        - Noise artifacts
- Magneto encephalography (MEG)
    - Measures magnetic fields of the brain created by electrical neural currents
        - Uses a big ass machine where you sit in and it goes over your head
    - Has sensors that are super conducting
    - Advantages
        - Non-invasive
        - High temporal resolution
        - High spatial resolution
        - Quick setup
        - Magnetic field is invisible in body tissue and goes unbothered through scalp compared to EEG
    - Disadvantages
        - Not as sensitive to cortical activity within gyri
            - Certain activity, according to how neurons are coordinated
        - Expensive
- Functional Magnetic Resonance Imaging (fMRI)
    - Looks at blood flow to certain regions of the cortex
    - Advantages
        - Non-invasive
        - High spatial resolution
    - Disadvantages
        - Poor temporal resolution (slower) – dependent on blood flow)
        - Expensive

Cortical Correlates of Motor Preparation: Event-Related Potentials:

Describe how EEG is used to study cortical responses to sensory, perceptual, and motor events.

EEG is used to study cortical responses by placing electrodes on the scalp in places that are associated with various activities (C3 and C4 = hands). The movement of ions inside, across and outside neural cell membranes creates electrical currents in excitable tissue. The electrical potentials created by these currents travel to the surface of the scalp and are measured by the electrodes.

Define and describe what event-related potentials are, and how they are extracted from EEG.

It is a voltage change recorded from the scalp synchronized with an event, which is used to determine time-course (and location) of processes in the brain. They provide an electrophysiological window into brain function. To extract an ERP from an EEG, you need to take a chunk of EEG around the stimulus, and average them all together. This washes out anything that is random and not related to the event and gives you all the activity that is consistently there.

Describe the Contingent Negative Variation, the CNV's components, derivation, and relation to anticipatory processes.

A negative change that is dependent on something (e.g. anticipation). It has two components, the early orienting-related wave characterized by an early rise, and a late expectancy-motor preparation related wave characterized by a sustained negative portion. It is a slow negative wave during the foreperiod between a warning and imperative signal. CNV amplitude decreases with long foreperiods due to not being able to hold anticipation state for long periods.

Describe the Readiness Potential, the RP's components, derivation, and relation to volitional motor preparation.

Readiness Potential is a slow shift in cortical potential, which precedes a self-initiated voluntary movement. It starts up to 1000-2000ms prior to movement and is a bilateral, slowly increasing negative wave. It appears over precentral, central, and parietal areas and is associated with volitional preparation of movement.

3 components:

- Early RP
  - Starts 1-2s before EMG onset
- Late RP (Negative Slope – NS')
  - Starts 300-500ms before EMG onset
- Motor Potential
  - Initial slope starts 50-100ms before EMG onset

RP will only show up if individual is voluntarily making the movement, people with involuntary movements will not show readiness potentials.

Already have readiness to move before you're aware that you want to move (300-800ms before). The side that is activating the effector (muscle response) will have a higher RP amplitude.

Describe the Lateralized Readiness Potential, the LRP's components, derivation, and relation to the LRP and selective motor preparation.
LRP is derived from asymmetric lateralization of RP immediately preceding response. (Average the (contralateral EEG – ipsilateral EEG) of both hands). LRP onset is an index of response selection and the polarity indicated activation of the correct/incorrect hand. Whether you get a positive or negative LRP, it will tell you if the correct hand is activated without seeing the EMG.

<u>Motor Cortical Potentials and Division of Reaction Time</u>

Describe how reaction time is fractionated (divided) with the use of EMG.
It is split into Premotor Time and Motor Time. Premotor time is the period of time between stimulus and onset of EMG and Motor time is the period between onset of EMG and onset of movement.

Describe and explain how reaction time is fractionated with the use of LRP.
It is split between **Premotoric processes** and **Motoric Processes**.
Premotoric:

- Occur between stimulus onset and LRP onset
    - Reflects early cognitive processing during RT
    - Stimulus identification – Response Selection

Motoric:

- Occur between LRP onset and EMG onset
    - Reflects final selective motor preparation
    - An index of end of Response Selection and start of Response Programming

Define, distinguish, and explain the stimulus-locked LRP and response-locked LRP.
Stimulus-locked LRP show different LRP waves based on the onset of the stimulus. Can see the reaction times and amplitude of the LRP of the different waves and see what effects were causing these differences in different trials. The more info people know about an upcoming trial, the larger the amplitude of the LRP because already specifically preparing a hand therefor one side of the cortex is more activated than the other.

Response-locked LRP shows different LRP waves based on the onset of a response. It shows the difference between the response and the onset of the LRP. The different distances between the LRP waves and the response time is due to Motor Programming.

Describe and explain the use of LRP in the study of motor preparation, and its division of response selection from response programing processes.
LRP divides response selection from response programming because of the lateralization of the cortex that occurs. This clearly shows that the brain is preparing a movement. Movement also does not begin until after the onset of LRP so it cannot be a part of response selection.

Explain how the LRP can be used to isolate processing effects to early versus late stages of information processing.

Explain how the functional locus of the LRP can be confirmed and supported by experimental evidence.
Masaki et. Al (2004) did an experiment to determine whether or not the onset of LRP divides response selection and response programming. They manipulated compatibility, which effects response selection to see the results. They found that there was a compatibility effect when the LRP's were stimulus locked, and a velocity effect when the LRP's were response locked. If the onset of LRP was in the middle of the response selection stage it would affect both the S-LRP and LRP-R, but that isn't the case. When manipulating compatibility, the effect was seen only on the S-LRP, the LRP-R was unaffected. This proves that the onset of LRP divides response selection and response programming.

Describe how the Dual-Process Model of Response Activation is supported by experiments using the LRP.
Experiments show that in an experiment with the Simon effect using LRP, at the same time of onset of LRP on the compatible side, the incompatible goes the opposite way. This suggests that the automatic response activated the wrong response, which then needed to be inhibited, and restore the correct response, causing the greater increase in amplitude and later onset

1-4 Excitability of Motor Cortex and Corticospinal Pathways

Describe the TMS technique and its basic uses in neuroscience.
TMS results in a trans-synaptic activation of corticospinal neurons and direct activation of corticospinal neurons. Using a TMS over the primary motor cortex produces a motor evoked potential (MEP) in the muscle.

Describe and define the motor evoked potential and motor silent period when using TMS.
MEP is a muscle potential in response to TMS. It is the result of activating corticospinal neurons in the primary motor cortex, and it shows up as a blip on EMG after the TMS 'artifact'. The silent period of TMS is a refractory period and involves the activation of inhibitory interneurons of the motor cortex.

Describe the time course of motor cortex excitability as measured by TMS during self-paced and reaction time movements.

Describe the modulation of MEP amplitude and silent period duration during temporal preparation.
The larger the MEP, the more excitable the cortex is. The longer the silent period, more inhibition in the cortex. In short foreperiods, there is a consistent drop in the size of MEP. When you anticipate and you anticipate well, MEP is dropping because inhibition is going on.

Discuss and explain the “dual-nature” mechanism involved in the temporal preparation for an upcoming action.
Reduction of MEP amplitude suggests inhibition, while shortening of the silent period duration suggests activation. This indicates increasing preparation.
If we inhibit Excitable connections to the Corticospinal tract during preparation, it stops premature starting of the system. If we inhibit Inhibitory connections to the Corticospinal tract during preparation we are trying to remove anything that will slow down a response when it is ready to go. With better anticipation and preparation, MEP amplitude decreases and silent period duration decreases.

Describe and discuss the modulation of MEP amplitude during the inhibition of a prepared action.
During foreperiod there is a consistent drop in the size of MEP caused by inhibition of the CS tract because we are trying to stop premature starting of the system. When you anticipate and anticipate well, MEP drops.

Describe the temporal relations between cortical indices of preparation provided by ERP (RP, LRP) and TMS methods.

<u>Modulation of Spinal Reflex Excitability</u>

Describe the basic monosynaptic reflex circuit.
Stimulation of a muscle spindle results in contraction of agonist/effector muscle.
Afference, then efference.

Distinguish between the mechanisms for the stretch reflex and H-reflex.
The mechanisms for the stretch reflex and the H-reflex are exactly the same, except that the H-reflex bypasses the muscle spindle.

Describe and explain how an H-reflex is elicited.
H-reflex
- Electrically stimulate nerve bundle
- Activates large sensory neurons
    - If stimulus large enough, can activate motor neurons and generate direct muscle response
        - H-Wave
- Sensory afferents synapse with and recruit motor neurons in spinal cord
- Generates muscle response
    - M-Wave

Explain the concepts of reflex excitability and reflex gain.
Excitability
- Determines size of H-wave, more excitable the reflex circuit, bigger H-Wave

Reflex Gain
- High Gain

    - Larger response for a given input
- Low Gain
    - Smaller response for a given input

Describe how the H-reflex can be used as a probe for motor preparation.
Compatibility has no effect on H-reflex magnitude, which confirms that compatibility affects earlier preparatory stages and has already happened. It can be used as a indication of the size of the reflex response to a given stimulus. Can see inhibition and activation.

Describe and explain the modulation of H-reflex amplitude during foreperiod and reaction time intervals.
During the foreperiod, the amplitude of the H-reflex decreases because the body is tuning down incoming peripheral input to be more sensitive to signals for activation.
During the reaction time interval there is a facilitation of the H-reflex magnitude, causing it to increase. In lateral tests (reaction time tests using both hands), we see that excitability of the responding hand goes up, while the other hand gets inhibited.

2-1 <u>Sensorimotor Integration and the Reafference Principle:</u>

Describe the four themes/issues in the study of sensorimotor integration.
Sensorimotor Delays
- Synaptic connections do not travel fast

Predictive Control
- Have to stabilize before making any movements

Sensory Confirmation
- Brain makes a prediction about what sensory feedback should be produced after a movement. Any inconsistencies are the result of ex-afference

Sense of agency
- asda

Distinguish between efference, afference, exafference, reafference, and define these terms.
Afference – Signals from receptor cells (sensory input – in or outside body)
Efference – Motor output (motor generation – signals to muscle effector)
Re-Afference – Sensory input generated by self-produced movement
Ex-Afference – All sensory info coming from external world

Explain the basis for von Holst's Reafference Principle.
The brain makes a prediction about the expected consequences of self-produced movement

Describe and explain the concepts of efference copy and sensory prediction and discuss their roles in sensorimotor control.
The efference copy is a copy of the motor command that predicted sensory feedback is based on. Whatever actual feedback matches with the predicted feedback is predicted as a

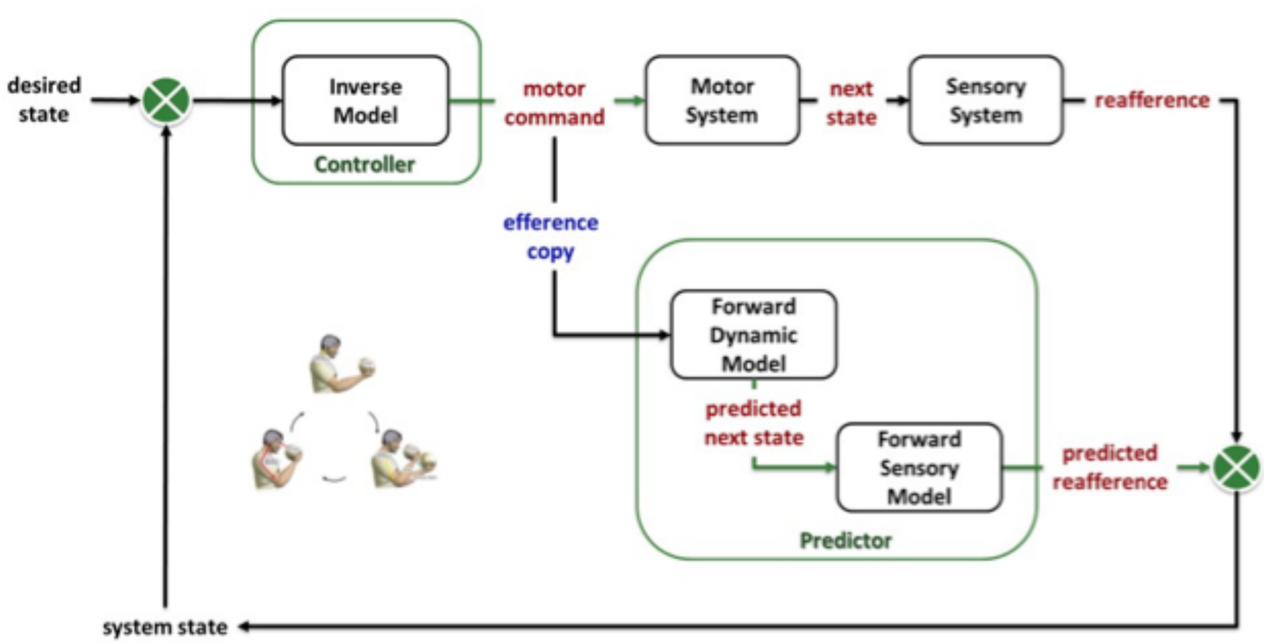
result of self-generated movement, while feedback that doesn't match with the predicted feedback is predicted as a result of the external environment.

Explain the importance of integrating efference and reafference in adapting to sensorimotor conflicts.
You need to integrate efference and reafference because without both, proper visual-motor development cannot be attained. Feedback must be associated with self-produced movement. You need to experience the sensory consequences of your own self-produced movement. Kitten Carousel showed that the passive kitten (kitten carried in carousel) showed impaired visual-motor development, while active kitten developed normally.

Describe the main findings and explain the theoretical implications of adaption (e.g. prism adaption) studies with respect to issues in sensorimotor integration and control.
The main finding was that there was adaption only after viewing active movements through the prisms. The participants recalibrated their system because of the change in vision due to the prism. Adaption requires the association of visual and kinesthetic feedback with own active movements. Afference is compared to the predicted re-afference and the discrepancies in feedback are noted by the comparator. The comparator then sends a training signal to the controller.

2-2 <u>Forward and Inverse Computational Models in Motor Control</u>

Describe and define the concepts of forward and inverse models in motor control.



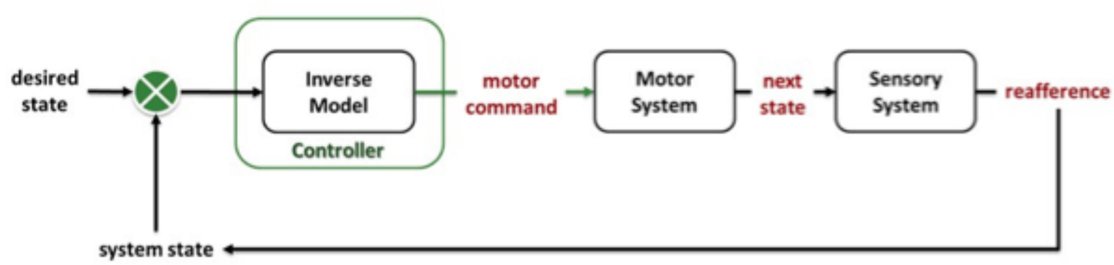
Describe and explain the roles of forward and inverse models in sensorimotor control.

The forward model simulates behavior of the body in response to motor commands and captures causal relation between actions and their consequences. It predicts what the next state will be after execution of the motor command. The inverse model simulates behavior of motor apparatus and estimates in advance the motor commands required to achieve a desired state. It estimates what kind of command needs to be sent to bring about a certain change of state or outcome.

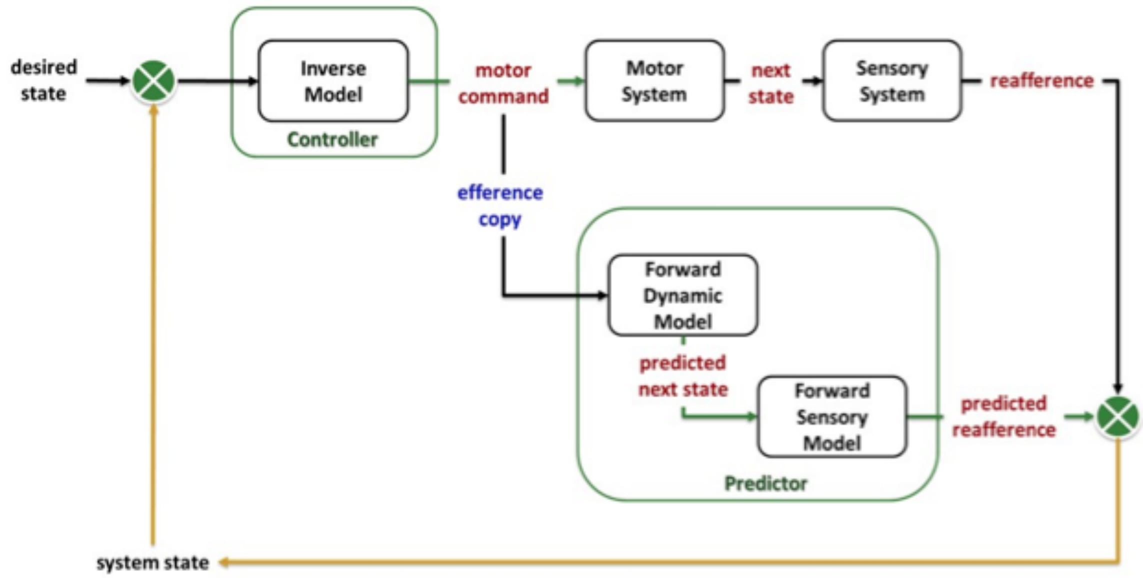
Describe and discuss the internal forward model as a mechanism for:

- **Internal Feedback loops**
    - Point and reach experiment to target in periphery shows that movement time is not effected by target jump from 20 to 10 degrees because it is around same movement time as for reaching to just 20 degrees
    - If it was based solely on feedback there would be an increase in movement time
    - Deafferented patient GL corrected her limb movements in the absence of sensory feedback so the correction must be due to something else
        - System predicts how limb is going to move based on command given and this is what she is comparing with the target changing (PREDICTOR)
    - We can use predicted feedback faster than sensory feedback to make corrections while waiting for delayed feedback

Feedback Loop

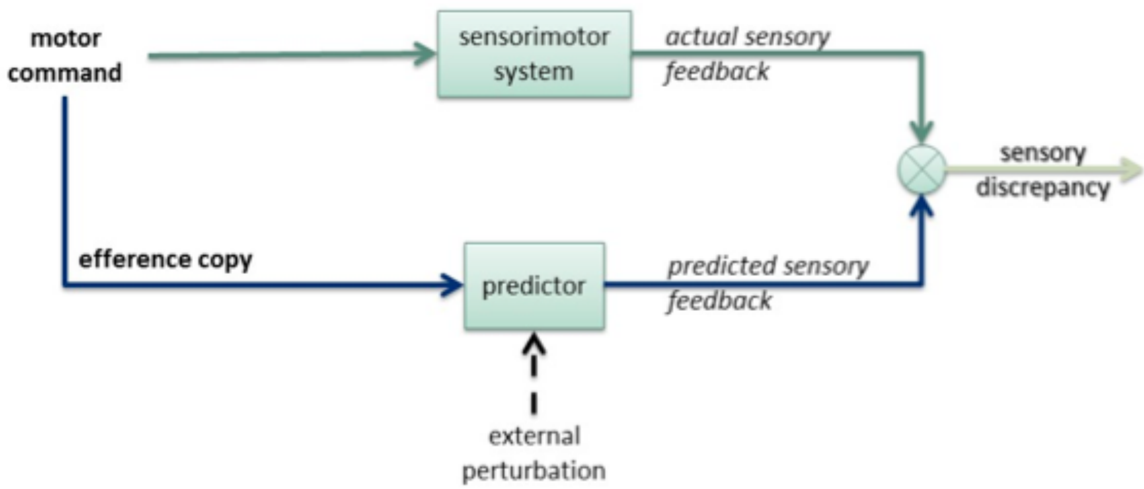


Feedback-based Control



- **Predictive and anticipatory control**
  - Use the efference copy of the motor command to anticipate next predicted state
  - Externally generated things cannot be accurately predicted
  - Rely on reafference and predicted reafference
  - If there is a disruption of the forward modeling process (predicted reafference) the system would have to rely on just delayed reafference info
  - Experiment shows that when TMS is used to knock out cerebellar function of estimating hand position, there is a reliance on delayed feedback
- **Sensory confirmation and cancellation**
  - Used to distinguish what feedback is generated by own movement
  - Self produced tactile stim doesn't produce tickle response while externally produced tactile stim does
    - Predicted and actual reafference don't match up
  - Force matching experiment shows that you increase force because reafference will never match up to predicted reafference so feel like getting hit harder than you actually are so to match the force you increase the force to get over own sensory cancellation of event

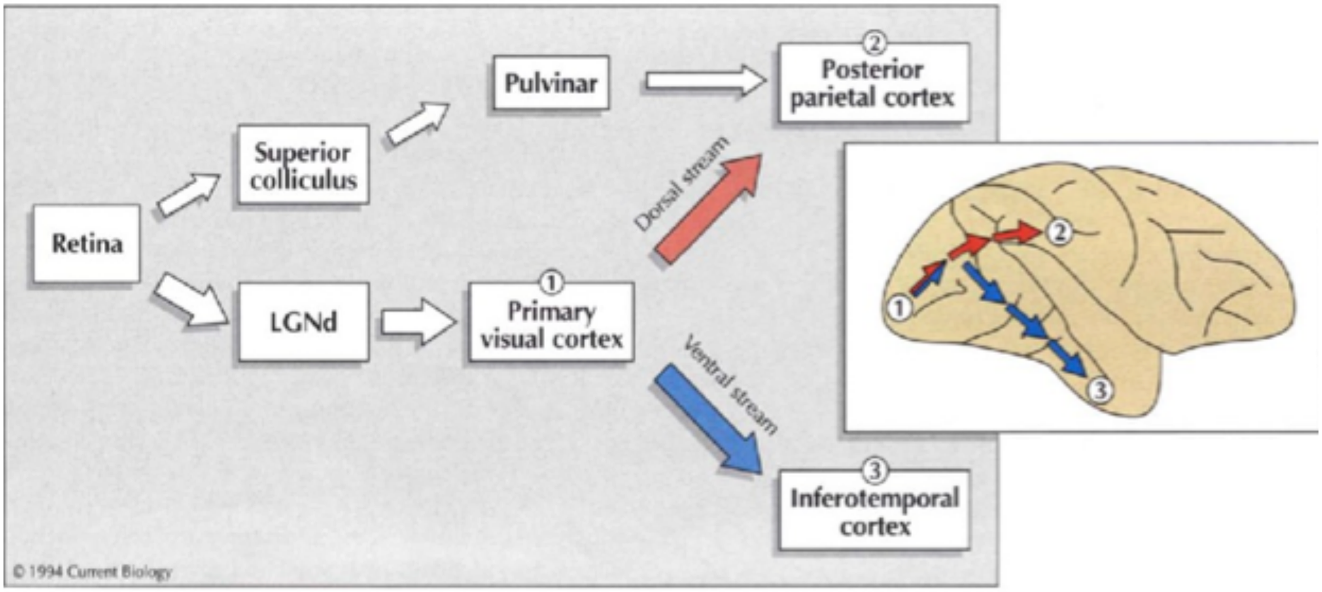
Sensory Confirmation and Cancellation



- **Action agency**
  - Rely on comparison of reafference and predicted reafference as well as production of predicted reafference
  - Imprecise predictions lead to relying more strongly to external cues
  - Schizophrenia patients showed that it took a larger degree of rotation for them to notice a change, those who noticed at larger rotations had more delusions
  - Patients more skewed to direction of rotation and more variable due to rotation of feedback
  - Patients more reliant on feedback
  - **For each mechanism/role, describe and explain the experimental evidence. Discuss how each study demonstrates and supports an internal forward model.**

3-1 <u>Visual Systems for Perception and Action</u>

Dorsal and Ventral streams



Cortical vs Midbrain System = What vs Where
Ventral stream vs Dorsal stream = What vs How

Describe and distinguish the different functional and anatomical divisions of the visual system, based on past and present models of the visual system.
Visual Perception processes that serve the recognition and identification of objects and events and their relations. Visual-Motor Control (action) the complex processes that serve the control of movement or action. These two systems don't always interact with each other; there is some independence between them.
Cortical pathway (retina to visual cortex) – if cortically blind, cant process visual info

- Ventral stream (inferior-temporal) = "What"
- Dorsal stream (posterior parietal) = "Where"

Midbrain pathway (retina to brainstem) – Rapid eye shifts/movements send visual info directly to midbrain for movement production = "How"

Describe and explain the blindsight phenomenon.
Blindsight is the phenomenon that occurs when a person can "see" what they physically don't see. There is damage to the visual cortex resulting in cortical blindness. The patients report having no visual experience but can respond accurately on visual tasks. This is mediated by sub-cortical visual pathways and/or secondary visual pathways (outside of visual cortex)

Describe the anatomical and functional characteristic of the dorsal and ventral visual streams.
The Ventral stream sends the information from the occipital lobe to the inferior-temporal cortex, while the Dorsal stream sends the information to the posterior parietal cortex. The Ventral stream is used when you are consciously using information to perceive what an

object is. Retina → LGNd → Primary Visual Cortex → Inferior-Temporal Cortex. The Dorsal stream is used when you are using the information to act on an object. Retina → LGNd → Primary Visual Cortex → Posterior Parietal Cortex

Discuss and explain the experimental evidence for the what/where model of the visual system.
Monkeys with inferior-temporal lesion (ventral stream) show impairment in visual pattern recognition (they can't identify/differentiate the objects/shapes while monkeys with posterior parietal lesion (dorsal stream) show impairment in spatial discrimination (can't tell which object is closer to which landmark, but object discrimination not impaired.

Distinguish between the what/where vs what/how models.
The what/where model's emphasis is on the analysis of visual input while the what/how model's emphasis is on the purpose of the visual input.

Discuss and explain the experimental evidence for the what/how model of the visual system.
Monkeys with inferior-temporal lesion (ventral stream) show impairment in visual pattern recognition (can't differentiate shapes) which supports the "What" system because they cannot consciously tell what an object is. Monkeys with posterior parietal lesion (dorsal stream) show impairment in spatial discrimination (can't tell whether object is closer to which landmark) which supports the "Where" system because they cannot distinguish the location of the object.

Describe and explain the cases of patients DF and RV from the current two-visual systems perspective.
DF has visual form agnosia (vision without form), which has impaired the ventral stream (inferior-temporal cortex) which is required for perception and recognition of objects. RV has parietal damage, which has impaired the dorsal stream (posterior parietal cortex) required for visually-guided action.

Describe and explain the basic findings from patient studies in support of the current two-visual systems model.
Experiments done with DF show that she cannot distinguish what objects are consciously, she can search for colour, but cannot distinguish orientation of objects, and cannot copy items that she is looking at but she can draw them from memory. DF can adjust her hand to objects of different sizes she is reaching for such as a pen or a beaker, putting a letter in a card slot, but when she is asked to orient hand in the position of the slot, she cant do it, and cannot perceptually estimate the size of an object.
Experiments done with RV show that she cannot draw objects that she is looking at cannot accurately grab objects she is reaching for, cannot guide her hand through a slot, cannot adjust her hand to objects of diff sizes.
Experiment done with a display of three objects with question "are the displays the same or different from each other?" Different parts of the dorsal visual pathway may be involved in different functions. Right inferior parietal lobule for perception of spatial

location (where) and the bilateral superior parietal lobule for visual guidance of action (how).

Dissociations between Perception and Action Streams

Discuss how visual illusions are used to study dissociations between conscious perception versus action.
The illusion affects the ventral stream but not the dorsal stream because the dorsal stream operates in terms of real time control with visual info available throughout the movement. If movement is controlled unconsciously then it falls to the ventral stream.
In an experiment where subjects were first asked to judge the size of the object and then grab it, there was an illusion effect with the subjects having a higher peak grip aperture when there was no vision before the movement started. There was no difference in movement times with vision or without vision.

Distinguish between real-time vs. memory-based control of action.
Real-time control of action involves having visual information while executing the movement. Memory-based control of action is when your movement is produced with the use of information stored from memory.

Describe and discuss the evidence for, and theoretical implications of, real-time and memory-based control with respect to the roles of the dorsal and ventral streams.
The dorsal stream runs off of real time control with visual information available throughout the movement so it is not affected by the illusion. The ventral stream is affected by the illusion because it is based off of memory.

3-2

Intentional and Automatic Processes in Visual-Motor Control

Describe the basic characteristics of eye-hand coordination during reaching movements.
Eye moves first, followed by head and hand. Eye movement typically completed while hand is still moving

Describe the double step paradigm.
It is done for reach and point tasks where the participant points to a target as fast as possible, but as they are moving towards the target, it jumps to another position. The target jumps during the time that the eye is still moving towards the initial target, so you don't consciously know that the target has moved. Subjects are still able to respond to the target jump without conscious awareness.

Define saccadic suppression.
During rapid eye movement there is reduced sensitivity to visual information, so reduced overall awareness of visual stimuli that occur during the eye movement.

Explain how the double step paradigm is used to show dissociations between perception and action.
Double step is during eye movement so not consciously aware if the target has jumped or not. Even though you aren't conscious of the movement of the target, you are still able to make a correction/movement towards the new location of the movement. You can hide visual event from ventral stream but the dorsal stream picks up the target jump and corrects the hand placement.

Distinguish between volitional vs. "automatic" control.
Volitional control is having conscious control of movements being produced while "automatic" control is movement that is effected by internal processes that make adjustments to the voluntary movement.

Explain how a distinction between conscious volitional control vs. unconscious "automatic" control is made and discuss the empirical evidence.
In experiment where subject is asked to point to target, and target moves location before movement; there is conscious awareness of the target movement, and high accuracy in hitting the target in both "Go" and "Stop" trials. Adjustments were made in both cases, either correcting to the new correct location, or turning toward the new location before being aborted in the "Stop" trial. When same experiment done was with following colour change, only half the time people were able to switch locations, but switching was still good. This shows us that we are slower at processing colour than location change. There was no automatic correction of pointing direction in the colour change trial. This shows that automatic correction is triggered much faster than you becoming consciously aware of the visual event. The colour change triggers slow voluntary corrections, location change triggers fast automatic correction
Dorsal stream always faster than ventral stream so in antipoint trials the initial response is to follow the target (fast automatic correction) then there is a late voluntary correction to the other side
Colour change only targets ventral stream
Location change triggers dorsal stream

Explain how the parietal lobe is implicated in on-line control of reaching movements.
The parietal lobe is involved in the process of fast dorsal stream correction of on-line reaching movements. When TMS is applied, knocking it out, subjects were unable to correct their movements.

Discuss the perception-action dissociations from 2 visual systems framework.
As seen in the double-step paradigm experiment, even though subjects did not perceive and were unaware of he change in target position, they were still able to respond to the target jump. This is because even though the visual event was hidden from the ventral stream, the dorsal stream still picked up the target jump and corrected the hand placement.

Conscious Perception vs. "Subconscious" Action

Discuss how distinctions between conscious volitional control vs. subconscious "automatic" control are made.
Fast corrections are made automatically by the dorsal stream showing subconscious control because the dorsal stream is faster than the ventral stream which requires conscious control of movement. This is seen in the antipoint trial of the experiment in the previous lecture where the subjects first made movements to the light, and then there was a late correction because the subject consciously noticed that they needed to go to the opposite side due to the condition of the trial.

Describe and explain the target "blanking" experiment and how it shows dissociation between conscious perception and non-conscious action.
The target "blanking" experiment is done where a subject is asked to say which object, the target or the distractor, is moved. In the experiment the subjects were more likely to identify the object that disappeared as the one that changed position. So in cases where the target moved and the target blanked, there was higher accuracy regarding which object changed position and same with when the distractor blanked and moved. If both were blanked there was around chance levels of correct answers.
In action experiment subjects asked to point to target as quickly and accurate as possible with a target / distractor event happening during saccade and reporting which object jumped. When the target was blanked, the subjects were more likely to report that the target jumped as well than the distractor and vice versa. If the target jumped, corrections were made to adjust pointing to the target. The movement automatically corrected itself, but consciously were biased towards whatever object blanked. BLANKING OBJECT APPEARS TO JUMP. CONSCIOUS SYSTEM NOT ABLE TO TAP INTO MOTOR SYSTEM INFO.

Describe the basic visual masking procedure.
A prime stimulus is briefly shown and then disappears and is followed up by a mask. The mask hides the prime from conscious awareness but results of experiments show a facilitation of the congruent movement associated with the prime even though the subjects weren't consciously aware of the prime.

Describe and explain how visual masking techniques have been used to show subliminal guidance of action.
Results of experiments show a facilitation of the congruent movement associated with the prime even though the subjects weren't consciously aware of the prime. Congruent primes lead to faster correction then neutral and incongruent primes in pointing task.

4-1 Coordination Dynamics: Bernstein's Challenges to the Study of Coordination

Describe the characteristics of the 19th century view of executive control.
Open-loop operation: movement is a result of a program that is insensitive to feedback conditions
Address-specific control: The executive exerts control over each individual variable

One-to-one control: Assumes a one-to-one correspondence from motor command to movement output. If it is the same command, the same output should be produced.

Define and discuss the challenges posed by Bernstein to the 19^{th} century perspective.
The challenges posed by Bernstein were the Degrees of Freedom Problem and Context-Conditioned Variability. The DoF problem was a challenge of the address-specific control characteristic of the 19^{th} century perspective stating that an executive exerts control over each individual variable saying that a system with too many independent degrees of freedom would be difficult to control. The Context-conditioned variability challenged the 1-to-1 control characteristic saying that the correspondence between motor command and motor consequence is dependent on existing context.

Explain the degrees of freedom problem.
The DoF problem states that a system with too many independent degrees of freedom would be difficult to control. If you have too many degrees of freedom you have to freeze some of them to coordinate your movements, just like when starting to learn how to skate. There have to be functional linkages over individual DoF to reduce the number of DoFs that have to be controlled.

Explain the problem of context-conditioned variability.
The outcomes produced by motor commands cannot be the same every time because there are different contexts in which the commands can be sent. The same muscle can perform the same movement but still produce separate outcomes.

Describe and discuss the functional solution to the degrees of freedom problem.
The functional solution is the functional linkages in coordination. These linkages decrease the degrees of freedom that have to be controlled because they control multiple DoF. People restrict movements in some way to reduce the number of DoFs to be controlled and attempt to reduce the function DoF as part of the control strategy. Instead of cotnrollign two unimanual movements, the body initially defaults to controlling both hands at the same time to reduce DoFs

Describe and explain the evidence for functional constraints in controlling multiple degrees of freedom.
If movements were individually controlled, then a reaching task of short distance by one hand and longer distance of the other would be similar in reaction time to when both hands complete the same movement but this is not the case showing that they are not individually controlled.

Define coordinative structures and discuss their importance as a solution to degrees of freedom problem.
Coordinative structures are functional groupings of muscles (same muscle groups) that are constrained to act as a single functional unit. This reduces the degrees of freedom of the movement because it reduces the DoF in the movement by producing the same movement for each limb.

Coordination Dynamics: Dynamical Systems and Pattern Transitions

Briefly describe the concept of self-organization and dynamical systems.
Dynamical systems are a general class of systems which have mutually interacting components and that settle or tend toward equilibrium or attractive states. Self-organization is a process in which a global pattern of a system emerges from numerous interactions among lower-level components of the system

Describe and discuss the concept of an attractor state.
An attractor state is a state at which a pattern is more stable, so the pattern is attracted to that certain state.

Describe the behavioral dynamics of damped and forced mass-spring systems as examples of attractor states.

Define von Holst's magnet effect and maintenance tendency.
Maintenance tendency is the tendency to maintain a certain frequency, while the magnet effect causes an attraction to a certain state.

Define von Holst's rules of coordination.

1. Only a few patterns can be easily performed – these patters are distinguished by their stability
2. Stable patterns are maintained until some critical limiting condition is reached, at which point transition to another pattern can occur
3. Tendency towards states of increasing stability

Discuss the relevance of pattern stability and pattern transitions to the study of self-organizing dynamical systems.

4-2 Coordination Dynamics: Phase Transitions in Coordination

Discuss the key features of von Holst's coordination rules.

1. Only a few patterns can be easily performed – these patters are distinguished by their stability
2. Stable patterns are maintained until some critical limiting condition is reached, at which point transition to another pattern can occur
3. Tendency towards states of increasing stability

Describe and discuss the basic phase transition paradigm and key characteristics of pattern transitions.
There are 2 stable phase relations, in-phase which is 0* and anti-phase which is 180*. When frequency is increased in-phase remains stable while anti-phase becomes unstable. This results in a transition from anti-phase to in-phase due to in-phase being more stable.

Define pattern stability and pattern transition and the relation between them.
Pattern stability is the stability of a phase relationship. The more stable a pattern is, the less variable it is thus causing a greater attractor state. Anti-phase is more variable even at lower frequencies than in-phase showing that it is less stable than in-phase. Pattern transition is the transition from an unstable pattern to a stable pattern, such as anti-phase to in-phase.

Distinguish between egocentric and allocentric constraints.
Egocentric principle is the symmetrical activation of homologous muscles and Allocentric principle is symmetrical direction of movement. The egocentric principle states that patterns are more stable when similar muscles are activated than when different muscles are activated (ex inphase vs antiphase). The allocentric principle states that patterns are more stable when the direction of each limbs movement is similar.

Describe and discuss the modulation of cortical and spinal pathways and their relation to stable patterns of coordination.
When we activate the foot we see facilitation of the spinal pathway to the hand becomes more excitable. Ipsilateral limbs see facilitation in movements therefor patterns are more stable when ipsilateral limbs are moving.

Describe phase transition phenomena in inter-limb, visual, and auditory-motor coordination.
When movements are produced in the same direction in different limbs, it is more stable (allocentric principle). Experiments show that if homologous muscles do not produce the movement, the allocentric principle determines stability. If you see someone else doing a pattern you are more inclined to synchronize with them than following your own pattern. You synchronize with auditory

Coordination Dynamics: Observations, Theoretical Model, Predictions

Describe the operational approach to modeling and examining coordination dynamics.
Identify collective variables (relative phase) capture movement patterns.
Map observed stable patterns onto attractor dynamics (in-phase / anti-phase)
Identify control parameters that move the system through its collective states (frequency of movement)
Study the stability and loss of stability of movement patterns and their correspondence with underlying attractor dynamics

Describe and explain the characteristics of the HKB model of coordination dynamics.
2 stable attractors (in-phase/anti-phase)
Phase transition (from anti-phase to in-phase)
Single attractor beyond transition (can’t go back uphill because in-phase is most stable)
Stability/loss of stability (as seen if transition, or no transition)

Critical Fluctuations (pattern stability decreases (variability increases) as system approaches phase transition)
Critical Slowing Down (system takes longer to return to original pattern after a perturbation)

Discuss the correspondence between theory and experiment as shown in the HKB model.
The changing shape of the graph is the phase transition of stable patterns. Once transition occurs there is only a single attractor state left, inphase. Once the phase transition has occurred the ball doesn't spontaneously go back to antiphase, so the behavior is one-way.

Describe and explain the predictions of the HKB model with respect to coordination.

Discuss how intention is incorporated into the dynamics landscape.
There is always a combination of intention and intrinsic dynamics in play. The competition/cooperation between specific intentional information and intrinsic dynamics determines resulting patterns and their stability.

Discuss and explain the interaction between intention and intrinsic dynamics.
If intention dynamics match up with intrinsic dynamics, such as making a movement in-phase or anti-phase, there is cooperation resulting in more stable patterns. If the intrinsic and intention dynamics do not match up there is competition which causes a less stable pattern to be produced. If we switch from a less stable pattern to a more stable pattern it takes less time than going from a more stable pattern to a less stable pattern, as expected.

Explain the purpose of scanning the coordination landscape.
It is done to show the error between what the subject does and what they are asked to do. It can show the critical error of the movements. In people with two attractor states it usually shows up as an "M" which is known as the "Seagull effect". The critical errors are low at 0, 180, and 360 degrees, with peak critical error at around 30 and 330 degrees.

Explain how learning is conceptualized in coordination dynamics.
There are two ways of learning, adding another attractor state if you only have 2, or shifting the middle attractor state between inphase and antiphase to a new location. Adding a new attractor state seems to be more persistent while shifting an attractor state isn't persistent leading to forgetting of the coordination pattern.