**Spring 2022 BMC Comprehensive Exam**

**Motor Learning**

**1. A.** What are the processes of sensorimotor integration, feed-forward control, and feedback control? How do reflexes contribute to goal-directed movement (be sure to provide some examples of short-latency and long-latency reflexes, voluntary movements)? In your discussion of sensorimotor integration, describe the visual system including the two visual systems, the receptors and the type of eye movements.

**B.** Compare and contrast two of the three motor control theories (Generalized Motor Programs, Dynamical systems theory, internal model). Make sure to describe the parts. Which do you think is most plausible and why? And relate your theory of choice to byproducts or outcomes of motor learning (e.g., attention, practice considerations, memory)

A: Before we perform any movement, we need to take in some form of sensory input. This requires us to take in sensory information and integrate it into our motor plan. Although we have the two major cortices for sensorimotor integration, primary motor cortex and primary somatosensory cortex, the association cortexes still play an important role in understanding our information. The parietal lobe of the brain cortex is our receiving ground for all of our information and is responsible for our ‘where’ information discerning where we are in space. The temporal lobe is responsible for handling auditory information and recognition, therefore our ‘what’ lobe. Both the parietal and the temporal lobe receive information from the occipital lobe via two different streams. The dorsal stream takes the information to the parietal lobe to discern where we are in space (so for hand-eye or foot-eye coordination the dorsal stream would take the information to the posterior parietal cortex). The ventral stream takes the information to the temporal lobe to discern what it is we are looking at. For both lobes, and a lot of our sensory functions, we are heavily integrated with our visual system. Our visual system has two types of vision, focal vision and ambient vision. The focal vision is our clear vision and is able to discern what we are looking at, so it would be using the ventral stream to the temporal lobe. The ambient vision is our where vision and operates off of an optical flow, so any change in our optical array is taken through the dorsal stream to the parietal lobe. Overall, both visions operate based on two visual fields split into left and right halves. So the focal vision and ambient vision for both fields combine and are filtered through the lens which projects the image to our retina. The cones in our eyes are for the clarity of the image and the rods are to tell us about the absence of light. Based off the visual information we can then base our proprioception based on that information. For Tau, we are anticipating the time to contact based off our understanding of physic based off the visual information. Our balance can be thrown off if we have a sudden visual change in the environment due to the our relationship with the vestibular system and visual dominance. However, we need to be able to find the information we are looking for which leads me to 3 types of eye movements. First there are saccadic eye movements which are our fast tracking movements. They have many fixations on information, and the longer the fixation the more information we get, but too many fixations can instead lead to saccadic suppression. Next are our pursuit eye movements which are for tracking an object in space. Then we have the Quiet Eye, which is our final fixation point before the initiation of the movement. So now that we have obtained all of our sensory information, we create a plan and execute it via a feedforward loop. Then while going through the feedforward loop we are also working with a feedback loop. The movement is initiated (parameters set by the basal ganglia), sends the information down the brain stem, the cerebellum gets an efferent copy, the information goes down the spinal cord where we send back proprioceptive feedback, the movement is executed and then feedback from our exteroreceptors is sent out. The two feedbacks will then combine and allow the cerebellum to correct the resulting action based on the difference between the intended action. With that new sensory information, we go back into the feed forward loop and plans then executes the movement.

Our reflexes are important for contributing to our goal-directed movements because it is essentially the ‘go’ signal we need in order to initiate our movements. Our reaction time is a form of the reflex and has a pre-motor time, response time and movement time. The pre-motor time of our reflex is primarily controlled by the type of reaction. There is simple reaction time, choice reaction time and discriminating reaction time. An example of the short latency reflex would be the simple reaction time that is waiting for one stimulus and has one response. This can be seen in sports with start guns, the reflex is based on when the gun goes off which causes us to start our movement. A longer latency reflex would tied to the choice reaction time, because as we increase the amount of stimuli and responses the longer cognitive processing there is. For example, deciding when to go on a left turn. You can go at any point but do you go when the car is a certain distance, do you go fast in response to try to sneak between cars, do you take your time in response because there aren’t really any cars there.

B: I will be comparing the Dynamical Systems Theory (DST) and the General Motor Programs (GMP). The GMP are based on prestructured commands of the brain in order to initiate the movement and follows a top-down approach. It says that we store all of our motor programs within our head and apply them towards that movement. Within that plan, there are variant features and invariant features. The variant features are the parameters the GMP can change, like the speed of the movement or how fast the movement is, as long as those parameters are within the movement’s program. The invariant features, such as the muscle order and relative muscle timing, are parameters we are unable to effect. However, with the GMP it doesn’t describe how we learn new movements and only describes known movement. To answer this, the Schema Theory was applied which said we are able to take in new information and assimilate it with our already known motor programs. So with practice, experience, etc. we are refining our motor programs by either adapting a current program or branching off a previous program to create a new program. For DST, it is not focused as much on the top-down approach and more on constraints. The DST is setup for being able to handle abrupt changes in motor programs based off of self-organization due to three constraints which are environmental, task and individual. The task constraint is based off our goal (so if playing basketball, the rules of basketball place a task constraint on our movement. The environmental constraint focuses on how the environment itself is constraining our task (uneven playing surface for example). Lastly, the individual’s constraints is based on the physiological and biomechanical processes of that individual. Based off the three constraints, we then self-organize towards being as stable as possible. Within perception-action coupling, the DST says our perceivation of the 3 constraints are what regulates and times the resulting action/motion. Both of these programs are able to explain how we execute our response programming but come with different approaches. The GMP focuses more on an internal approach and is more based on our cognitive processes. On the other hand, the DST is more of an external approach and is focused on the three constraints and us self-organizing in response to those constraints.

Both theories are plausible and have evidence supporting them but I would say that the Dynamical Systems Theory is more plausible. While the GMP can be seen present like in the study that had people right with their right and left hand, the gap for me begins when looking at the transition between motor programs. If following the GMP theory, we would constantly be switching between motor programs until we settle down into one and to me that’s too chaotic and not as feasible. DST answers that gap in a way and was able to see smooth transitioning between motor commands in the swim stroke analysis study. Another factor that makes DST more plausible is the fact that it takes into account various factors that are relevant to every day life. We are always interacting with our environment, going through various tasks and the performance depends on each person’s constraints/abilities. Also, the DST integrates well with our motor abilities behind our skills/motor commands. For example, under the specific motor ability hypothesis, one person can have poor perceptual motor abilities and exceptional physical motor abilities and another vice versa. Both people can reach the same result but the difference is their motor commands are based off two different individual constraints. Another piece of evidence for me is when considering learning with Gentile’s learning model. In the first part of the model, we see that beginners will organize themselves in a way that allows some form of success. Since the focus is some form of success, that person self-organizes themselves to the most stable state possible in order to reach that success. As we learn, we are able to coordinate our structures better and work towards refining the motor skill. Then as our skills improve, we are getting better at reaching the stable state and can apply these skills in various environments. So even though we may have never performed a specific skill before, we can learn that new skill by self-organizing ourself for some degree of success and then further coordinate our structures. When it comes to attention, the DST aligns to me more especially when looking at external focus. Since external focus, depending on the goal, improves learning and performance the focus is more on a general outcome. Based off the desired outcome, we organize ourselves to be able to adapt to our goal. So for example, when shooting a basketball we often teach kids to hold the follow through. By focusing on the follow through, the individual will organize themselves and result in improved wrist flexion and elbow extension. Not to mention for practice, one of the most effective forms is the constraints led approach that follows the dynamical systems theory. By allowing a constraints led approach we allow for more self-discovery and implicit learning which has a stronger connection to growth in performance. Operating based off the individual’s ability to self-organize themselves. Finally, in a memory aspect the fact that the GMP has to hold as much information (even with the schema theory) as suggested leads me to believe that the Dynamical Systems Theory has a more plausible interaction with our memory.

1. Tissues throughout the body adapt to exercise, disuse, and aging. There are structural and biochemical changes to muscle, tendon, ligament, cartilage and bone. Discuss the changes to the tissues that influence the mechanical properties of the tissues. Describe what is known about the overall changes to each of these tissues material and structural properties in response to exercise, disuse, and aging. Discuss how these changes might be important for function of these tissues. Use evidence from research studies whenever possible to justify your conclusions.
   1. Bone is a material that is organized to be strong in multiple directions, but its anisotropy is designed to be specifically strong along the longitudinal axis. Through modeling and remodeling, the osteoclasts and osteoblasts change the structure and material for our bone. For example, when going from primary bone to secondary bone the osteoclasts eat out the middle of the old bone and the osteoblasts build on top of it. What is important to note though is that bone reacts based off a mechanical stimulation which determines the resulting effects. So we apply a load to the bone from whatever motion and the osteocytes sense the amount of strain caused by the load which determines how the bones adapt. According to wolff’s law, the bone will adapt to the proportional load placed on it. So it needs that mechanical stimulus in order to induce change, but an absence of mechanical stimulus can induce change as well. When exercising, we actually see an increase in bone mineral density and increase in bone strength as an adaptation. This is because of a response of loading up the bone, but the adaptation is specific to the loading mechanism. So doing vertical jump squats won’t help you’re your humerus’ bone mineral density. The adaptation due to an absence of load is present in disuse or not meeting a certain load threshold. When people are inactive, we see an opposite effect as exercise and get a lower mineral density within the bone. Disuse isn’t strictly a sedentary lifestyle (like being on bed rest) and can be observed with astronauts after being up in space. Although they attempt to load the bone with exercise and movement, the load is lightened by an absence of gravity and the bones aren’t sensing enough mechanical stimulation to adapt. Another factor that effects bones material properties is aging. As we get older, the bone mineral density tends to increase as well for everyone but specifically so for woman. I believe that is tied to their hormonal system/reproductive cycle. Eventually, the loss in bone mineral density is classified as osteoporosis which is significant weakness in bone/significant bone loss. However, the type of mechanical stimulus to induce adaptatoin isn’t only from bodyweight movement. The stimulus needed can come from a variety of ways such as strain magnitude, strain rate, strain frequency, etc. (i.e doesn’t only respond to load from walking). This is shown with research on vibration as a therapy for bone loss. A given frequency and magnitude of vibration showed promise improving bone mineral density in sheeps but not as much in humans. It did show that lighter individuals had a more positive remodeling effect while heavier individuals had a slower decline in bone mineral density. This could be because of complicity too where humans can not do their therapy while sheep didn’t have the freedom of choice. Hence for bone, the mechanical stimulation from exercise, disuse and aging have a direct impact on the adaptation and function of the bones.
   2. Tendons are a material that contain elastin and have the role of transferring forces from muscles through elastic storage. Tendon’s performance is heavily reliant on factors that effect elastic storage, length and stiffness of material. The longer the tendon, the more elastic energy that can be stored based on the equation that takes into account the change in length. This effect can be observed in animals like the camel that have insanely long tendons and are able to perform almost nonstop because they can store so much elastic energy. The other factor that effects elastic storage is the stiffness of the tissue. The stiffer the tissue, the more energy that can be stored. However, there is a conflict between the two factors. We want to be stiff but we also want to have as much length as possible. The most important factor though is the change in length, so we would rather have a longer tendon than a stiffer tendon because a stiffer tendon won’t be able to stretch as much/undergo deformation which would have more of an impact stunting energy storage. Similar to bone, tendon undergoes change in structure and material properties for exercise, disuse and aging. When exercising, we tend to see an increase in tendon size with site specific adaptations. This can be beneficial because with increased CSA, the tendon can handle more forces and store more elastic energy. When going through disuse, the tendons decrease in fibers and collagen content especially closest to the muscle. The decrease in fibers can have a direct impact on how much elastic energy can be stored and when failure occurs. If failure does occur, it’ll likely be closest to the muscle site. The effects aging has on the function of the tendon isn’t as clear. As we get older we don’t see a change in young’s modulus, we see a decrease in physiological cross-sectional area and an increase in cross-linking. The no change in young’s modulus is odd because we would imagine the tissue to become stiffer, so it seems that the cross-linking occurs to compensate for the changes in material property that we are not seeing. Although cross-linking can be good, it is likely the cross-linking between collagen and sugar which creates a weaker link effect. That leads to a worse performing material that is more susceptible to fatigue failure.
   3. Muscles are what produce our forces through the sliding filament theory. There are multiple components to producing force, but the mechanical properties of the muscle play a crucial role for the force produced during a movement. The mechanical properties of the muscle are modeled based on the hill model which has a Series Elastic Element and a Parallel Elastic Element. There are multiple fibers that run parallel to one another and produces force down the muscle, which is the parallel elastic element. Then when all of the forces come together and meet at the tendon junction, that is the series elastic element. So by changing the fiber lengths (thin filament, total length, etc.) we can have a direct impact on the mechanical properties of the muscle. This is due to the interaction of actin and myosin during muscle contraction. The shorter the muscle length, the slower velocity and that means a lower amount of force being produced. The longer the muscle length, the faster the lengthening velocity and that means a higher amount of force being produced. The moment arm is another important factor that determines how much force can be produced. The moment arm is the amount the muscle changes at a specific angle and determines how much force is produced at that angle. So by shortening the muscle length, it changes which portion of the force curve that a movement is producing force (so by decreasing length, a moment arm could shift towards the descending portion of the force-length curve). For exercise, we see an increase in hypertrophy and a lengthening effect when performing eccentric exercises. This results in us being able to produce more force and gives a higher plateau for force production before the filaments (especially myosin) crash into one another. For disuse, we lose muscle very fast, essentially use it or lose it but can be reversible. This change from disuse means a decrease in muscle size, which decreases the muscle length and impacts where the moment arm is working when investigating the torque-angle relationship.
   4. Articular Cartilage is what transfers force between bones. It is a viscoelastic material that heavily relies on the interaction between structure and function. The AC has 4 layers where the first layer are parallel fibers meant to resist tension forces, the second layer helps with smooth transitioning and is tightly packed random fibers, the third layer is the deep zone which contains a lot of our proteoglycans and are perpendicular fibers packed tightly and then lastly a calcified zone to help transition into the bone so we don’t have too high of a stress concentration. The first layer doesn’t hold water very well so is effective for that tension resistance while the third layer is oriented to resist compression and holds in more water with the proteoglycans to also resist compression more. AC also responds to loading differently due to its viscoelastic properties. Static loading can actually be more harmful than intermittent loading because with static loading the water leaks out and doesn’t come back in until static loading is done. In fact, it seems the properties of the AC respond better to faster applied loads. In response to exercise, there is an unclear relationship between AC and exercise. Exercise has been shown to lead to osteoarthritis and it has also shown to have therapeutic effects. A factor that may give more insight is the relation to muscle weakness because that changes how the load is placed onto the AC. With disuse, we see a decrease in proteoglycan production and decreased cartilage strength. So it can’t hold onto the water as well which emphasizes the impact that things like static loading have, the impact of water leaking out is higher. Also the decrease in strength could result in earlier damage to the AC which is bad because the AC has limited remodeling ability. A similar effect is seen with disuse where proteoglycan content in general is decreasing, which impacts the viscoelastic properties and how it holds the water.
   5. Ligaments are bundles of collagen fibers that guide a movement and restricts the movement. They also contain 4 different layers of material but these are more focused on minimizing stress concentrations in order to avoid failure. The importance of the gradient is evident wen looking at the scar biochemistry of the ligament. After the ligament is injured, we see a decrease in ultimate tensile strength by 65% and a different material as a whole. Because of the different material of the scar, there is less of a transition which results in a weaker material that fails earlier. In response to exercise, we see an increase in fiber number and collagen content and glycoproteins which helps maintains and strengthens the toe region of our stress-strain curve. It also has a positive impact on our ultimate tensile strength and effects our viscoelastic properties when lengthening. With disuse we see an opposite effect where there is a decrease in fiber number, collagen content and glycoproteins which leads to a worse stress-strain curve with a longer plastic region. However it is important to note that when the material fails, we don’t see total failure only partial failure. With aging, we see decrease in crimp which leads to a lower toe region for stress-strain curve. That leads us to the plastic region earlier which results in some damaging and could lead to fatigue failure. Also with aging, there is a shorter ultimate tensile strength which again increases the opportunity for partial failure within the ligament. Then as previously mentioned, the fibroblasts come in to fix the partial failure which results in a scar that disrupts the stress-concentration gradient and results in a worst performing material.
2. **A.** You have been hired as a lab manager at a sport science clinic and are tasked with making recommendations as to which type of instrumentation you should purchase. You will also need to set up the lab once the equipment is acquired. Please describe the instrumentation you would recommend (doesn’t have to be brand specific, so you can say digital camera instead of a Nikon camera) including desired instrument specifications (max sampling frequencies, number of cameras, etc.) and the pros and cons of your suggestions. You should also justify your decisions based on potential research projects your lab will conduct.

**B.** Explain in detail how you would set up the equipment you recommend with respect to the primary research goals of the facility. Describe the space, where you would locate each piece of equipment, and why you made those choices.

A:

Overall, the focus on the research projects within my lab would be for the biomechanics of elite athletes of various sports (basketball and baseball primarily). The instruments I would recommend are a motion capture system, force plate, EMG and ultrasound. These instruments would allow me for in-depth analysis through various approaches. For the motion capture, I would likely take an outside-in system such as a markered motion capture system. I would probably aim for 10-12 cameras (2 of them being high definition) that are able to handle motion as fast as a baseball bat. So the cameras would preferably be able to handle roughly 600 fps before losing definition, want to cater the motion capture to the fastest movement. However, this is unavoidable to a certain extent (i.e, miss some data points when releasing a baseball because it is too fast than the frame rate set for the motion). The negative of this is the more cameras, better quality cameras and a marker capture system would be very expensive and not as mobile. Also, markers are going to be necessary while although not the most expensive part a significant amount will be needed for flexibility choosing marker sets (i.e cluster technique) and also repair (whether lost, broken etc.). With this set up we can handle explosiveness as high as a baseball swing and as low as walking while applying various marker sets to fit our needs. Then for force data I would want to have at least 2 force plates on the floor and one force plate that is able to simulate a baseball mound. I personally believe that it is important to not only see the force being produced but how the body is distrubiting the forces during different phases of the movement. So force plates that have tri-axial sensors would be preferred since each sensor are able to read an X, Y and Z direction. The mound force plate would be important because it would help simulate the motion that the pitchers go through and get a better understanding on the real life applications. The negative of that is again money and also the amount of space needed for a mound-like force plate and 2 different force plates. Since the force plate data is analog data based off voltages, we would need an amplifier to control the gain depending on the motion (the higher the gain for more explosive movmenets), an A-D board to translate the analog data to digital data and a computer that is able to process all that information (also being able to handle the digitization of the motion capture data). So again, this equipment adds on to the price even more. I also not only believe how much force is being produced, how fast the movement is, etc., but also in the timing and sequencing of the muscle activations. EMG allows me to measure the electric potential differences when the muscle’s action potentials are firing which can give insight on activation. I am not about invasive studies (also scares away some participants), so surface EMG electrodes would likely be the route that I take. Although the electrodes would add on to the price again, it can also use the same A-D board as our force plate data. Then we would have the capability to understand the timings of elite athletes and how those may differ from beginners/general population. Lastly, an ultrasound machine would be a crucial key to the lab as well. It is important to also think about how are material properties effect our performance. This can not only gain its own insights, but can be information used within models. Therefore, I would like an ultrasound machine that not only handles b-mode ultrasound but also Shear Wave Elastography. The SWE would allow us to understand potential changes in material stiffness which can be especially valuable when paired with physical characteristics of the muscles (CSA, pennation angle). The ultrasound machine must also be able have at least two probes so the researcher can handle more superficial muscles and deeper muscles as needed. Gel warmer of course to make the subjects happy. The research from the ultrasound machines would be valuable for potentially identifying overuse injuries and gaining insight on the conditions of the athletes. Again, if I didn’t have a blank check the price of the ultrasound machines would be a negative as well.

B:

We would need a large amount of space based on the primary research goals. With elite athletes, their size and athletic ability alone would require a larger space. For example, testing a college basketball player’s vertical would require a much higher ceiling than the one in the ECU lab because of his exceptional athletic ability and shear height. Also, there would need to be space for having a force plate that is supposed to be designed/set up for a mound. That isn’t something you can always just pick up off the ground so would likely need its own section of space. The motion capture system and two other force plates will be set up next to each other since movements not as extreme as pitching could be taken there. That being said, the location would have to be relatively close to the force plate mound since we still want to gain valuable knowledge for the component of pitching being looked at. So either the cameras are set up to be slightly more mobile or the mound is close enough to make adjustments to the camera’s directions. The headquarters so to speak would be placed closer to the two force plates and motion capture system since we need to be able to connect back to the amplifier and A-D board. This will pose a minor issue about how to get the mound’s analog data to the amplifier-AD setup but that can be solved with specific location or placement of the wire going there. It all really depends on how much space is available and the shape of the space, which we can’t always control. Luckily with the EMGs, they are fairly mobile since only the base needs to be connected to the A-D board while the electrodes relay back to the base. Although mobile, the location of the electrodes still need to be within range of the base but that shouldn’t be too much of an issue with today’s Bluetooth ranges. Lastly, the ultrasound would be in a more separated section of the space. That gives the ultrasound user the space they need to work through the subject while not interfering with data collection for things like motion capture. Also, it gives the researcher the ability to focus more since ultrasound for material properties need to be concise and consistent.

1. Describe a potential framework for a software application which will be used to analyze lower extremity biomechanics from 3D motion capture. Provide details, explain your choices, and justify each decision. Complete the following outline in your response. You do not need to write actual code, however if writing pseudo code helps you describe your application, you may do so.

**Problem Statement:** Identify the problem/problems that your software application will solve.

* I have been reading a lot on basketball literature. There is a sizeable amount of research on the effect of distance on our shot kinematics but not as much on how the presence of a defender impacts our kinematics as well. Rojas and colleagues around 2000 found that when a defender is present the shot accuracy decreased, there was an increase in ball release angle, increase in ball release height and an increase in jump time. With the increase in jump height, ball release angle, etc. when a defender is present suggests that we are altering our lower extremity biomechanics in some way in order to produce those movements. There is also research suggesting that how we produce force during a jump shot is comparable to a counter movement jump (start in a squat and jumping up) so I would also like to see if how we load differently when a defender is contesting a shot. Therefore, my software application will solve how our lower extremity kinematics alter when a defender is contesting a shot while also giving insight on how the outputted force is changed too.

**Programming Language/Packages:** Which language/platform did you choose and why? What are a few example packages you would use given your selection and why?

* I chose to use Python over Matlab for my analysis. I personally prefer Python’s flexibility when coding and that it feels that I can solve a problem in several different ways to get similar results (i.e. deciding to store data in a list versus a dictionary). Also, I personally work best when I can visualize a flow of the data and Python’s ability to interact with strings, float numbers, etc. allows me to visualize best with certain object oriented approaches. Being able to do so also helps me continue to learn and understand the power and manipulation of functions. Not to mention, error handling is easier for me in Python. Another important component that made me choose Python is the number of open-source packages available for data handling, data analysis and data visualization. The packages I would primarily use are pandas, numpy and matplotlib. Pandas allows me to work with data in a labeled 2-by-2 data structure and is able to handle any type of data which gives me the flexibility to how I would want to use the data. Pandas also allows me to target specific rows and columns specifically which eases splicing apart the data, especially when working with csv data sets that contain C3D data. Numpy has function within pandas but it is also useful when handling more complex calculations, mathematical sequences and can help work around some limitations to certain function’s parameters. Lastly, matplotlib to still have the data visualization power seen within Matlab and because I am most familiar with Matlab’s format/customization. It also lets me continue to follow an object oriented approach which helps me plot on specific axes.

**Inputs:** What are the inputs into your software? Describe the file data types.

* I would personally input the file as an excel because the excel’s organization allows for easier organization by Pandas. However, I would likely set up the software to handle both excel files and csv files since both are able to store different data types. Majority of the data types will be float numbers from the motion capture data, however the names of the columns will be the marker names in a string data type. Going about it in this way will allow me to take entire pandas series and perform some form of transformation or manipulation on them.

**Features:** What are the main features of this application? Why are these important?

* The main features of this application are importing all of the files in a given directory, calculate joint angles, joint velocities, force calculations, data visualization of the previously mentioned calculations and a report for the lower extremity. I think it is important to calculate the joint angles, velocities and forces on the lower extremity because it can give insight on the mechanics that are caused by a contested shot. We know that there is a higher jump release angle in a jump shot when a defender is present, which means there is likely a change in how fast we are going through our movement and how much force is being produced. It is also important to be able to visualize the data to help us gain understanding on our findings and to communicate those findings to other people. Then a report is also useful for the user to understand what measurements are coming out of it and allows us to give a concise summary of our findings.

**Functions:** What are some of the main functions that you would need to create?

* The first function I would probably create is an importing function that loops through a directory and transforms the data into a pandas dataframe. This would allow me to pick and choose who I want to analyze or who I want to compare. Likely stored in a dictionary, not everyone properly labels their files so an unordered storage is best for me.
* The second function would be angle calculator. The function would take in the markers at the joints to create segments and determine the joint angle off those segments using basic trigonometry. Learned that ideally not having to do this from a marker cluster not at the joint is easiest.
* I would have a function that would handle all of the force calculations (peak force, force distribution, rate of force production, etc.)
* Then I would need a comparer function that could automate both of the calculation focused functions. This function would create the report since all of the information for the specific subject would be contained in one spot at that moment
* Then most likely a function that exports my report so that it can be sent and seen by other people. Also helps with readability not trying to read command shell lines.

**Plotting:** What data visualizations would you create and why?

* I would create a visualization of the angles over time of the movement. I would put the angles in terms of percentage of movement instead of frames so it would let me draw conclusions easier. It is important to visualize these especially because sometimes a movement may cause the data the flip-flop between degrees axes.
* I would also create a visualization based off of the force plate data. Lets us know potential timings when synced up with our motion capture findings.
* Each visualization would likely have event lines based on real-time video analysis to give more context

**Outputs:** What are some potential outputs from your software?

* Have kind of mentioned them before but some outputs are joint angle calculations for the lower extremity, joint velocities for the lower extremity, various force calculations and visualizations of the data.
* The calculations will be exported as an excel sheet and sheets will be added for each report created.

**Verification and Validation:** Define each and describe how you will incorporate these into your implementation plan.

* I would base the verification of my software on findings seen within the literature.
* My implementation plan would begin with focusing on being able to import my data in effectively as soon as possible, then work on creating each individual function and checking within each function is giving me expected results (i.e, can’t have 250 degrees of extension for the knee). Then I would be working on my visualizations of the data once confident the functions are working relativlely well. Then comes coordinating all of the pieces together and making sure I get my correct output. Lastly, I would focus on testing which would essentially be me trying to break my own code and run it through various situations to ensure it is working properly. Then after using some trial data to make sure it is working, I would apply the code to all of my subjects and go over the report, visualizations and comparisons in order to draw conclusions on the lower extremity biomechanics.