Cognitive Training Recommendations

TIMING CONTROL

Goal: Train better timing decisions to improve contact and hard contact rates.

Background: Timing a reaction to intercept a moving ball relies not only on the physical and mechanical execution of the swing, but importantly on split-second timing systems in the brain. These timing decisions in the brain tell the body "when" to swing, and if these decisions are off by even a few tens of milliseconds, the swing can be too early or too late. It is an incredible human feat that the brain can make adjustments in timing on the order of single digit to a few tens of milliseconds to achieve solid contact. There is strong scientific evidence that timing decisions can be improved with practice. S2 has also demonstrated that 4-8 weeks of consistent timing drill work in elite youth baseball players utilizing a combination of front toss, pitching machine, and live pitching formats, leads to statistically significant improvements in contact and hard contact rates on a realistic, challenging in-cage timing test.

Key Principles and Strategies for Training Timing:

1. A round of BP using a constant velocity is useful for training timing to that particular velocity. If each round focuses on a different velocity, this forces the hitter to adapt and learn timing associated with each unique velocity. This can be a useful way to lay down memory representations for different velocities and the swing initiation timing associated with each velocity. Working a different pitch speed in each round is just a starting point for training the timing decision system to adjust to different velocities. The big drawback is that timing is strongly influenced by the sequence of velocities across successive pitches. Working just one velocity in a round does not prepare or train the hitter to make pitch-by-pitch adjustments to different velocities. Additionally, working a constant velocity across an entire round, even if changing the velocity for each round, still allows the brain to quickly get into auto-pilot mode because the timing demands aren't changing pitch-by-pitch.

2. The next progression is to force the timing system to adjust on a pitch-by-pitch basis. In this next progression, we describe a predictable timing format. In a predictable format, the hitter knows in advance whether the velocity of the next pitch will be faster or slower, which means the next swing will need to start sooner or be delayed. There are a couple of ways to do this:

    a. Plate drills are examples of predictable timing drills, where the hitter steps closer or backwards with respect to the pitching source, and takes a few swings after each step before moving again. Assuming the pitch source is throwing a constant velocity, when the hitter steps closer to the pitcher, the swing decision must be made sooner, but when the hitter steps backwards (away) from the pitcher, the swing decision must be delayed. Moving forward and backwards trains the timing system to make these adjustments on a pitch-by-pitch basis. It is also straightforward to make the timing adjustment more difficult by mixing up the size and the direction of each step.

b. One limitation of plate drills is that moving toward and away from the pitching source can alter the visual depth, angle, and other characteristics in a way that doesn't exactly match what happens in a game. This doesn't diminish the value of plate drills as there is still plenty of overlap to the baseball context to facilitate near transfer, but the next progression should involve the hitter making timing adjustments from a fixed distance with the pitching source responsible for changing velocities on a pitch-by-pitch basis. To keep the drill predictable, the pitcher can simply call out the speed of the next pitch (fast, medium, slow) or use an easily predictable order of speeds (fastball-fastball-offspeed-offspeed, etc.). Again, the intent here is to force the hitter to train timing adjustments on a pitch-by-pitch basis.

3. Ultimately, a hitter must train to make split-second timing adjustments when the pitch velocity is unpredictable, or even more challenging, when the hitter expects one velocity and is fooled by seeing a slower or faster velocity. Here are a couple of ways to structure these drills:

    a. Simply eliminating telling the hitter what velocity is coming next and mixing different pitch velocities in a round converts the drill to an unpredictable timing drill. It is critical to add these unpredictable timing drills to BP to help the hitter practice making pitch-by-pitch adjustments in timing. One potent factor to make these drills more or less challenging is to mix up the probabilities or percentages of certain velocities in a round of pitches. For example, if a hitter takes a round of 16 pitches, and 75% (12 pitches) are at a faster velocity and just 25% (4 pitches) are at a slower velocity, this forces the hitter to prepare for the more frequent faster timing, but makes it more challenging to delay timing when the much rarer offspeed is thrown. Reversing these percentages (75% offspeed, 25% faster velocity) does the opposite, putting the timing decision system in a readiness state for delaying the swing to deal with the frequent offspeed, but making it more difficult to speed up the timing decision to catch up with the much rarer faster velocity. Mixing up the percentages of certain velocities like this is a powerful way to work changes in velocity in both directions and alter the difficulty. Other ways to make the drill more challenging are to introduce 3 or more different velocities into the drill or mix up the size of the velocity differences, working smaller differences and larger differences in velocities between pitches.

    b. One of the biggest challenges to a hitter's timing system is when the hitter is fooled by the pitch velocity. Creating drills to simulate being fooled is a powerful way to train extreme adjustments in timing decisions. One strategy is to use different percentages of pitch velocities (as explained above) to set up higher expectations of one velocity so that the rare velocity is less expected and more likely to fool the timing system. An alternative strategy is to deliberately violate a hitter's expectations, what we call VEX (violating expectancies) drills. A simple way to do this is to tell the hitter or have the hitter tell the pitcher what pitch speed to throw, and most of the time, say 80-90% of the time, throw the expected pitch speed. However, on 10-20% of pitches, throw a slower or faster velocity than the

one said by the pitcher or the hitter. Violating the expectation of a pitch speed puts considerable demands on the timing system to adjust on-the-fly.

TRAJECTORY PREDICTION

Goal: Train better predictions about the trajectory of the pitch to improve the accuracy of ball/strike and pitch location decisions.

Background: Determining pitch location involves a predictive decision. Because the angular velocity of the ball exceeds the smooth pursuit capabilities of the eyes, the hitter must rapidly gather information (spin pattern, velocity, exit trajectory) about the pitch and use that information to guide a predictive saccade and bat delivery to where the ball is expected to cross the hitting zone. The accurate visual prediction of the ball's arrival at the plate facilitates accurate eye-bat coordination. It is obviously easier to predict the path of a linear pitch (e.g., fastball with no movement) than that of a reasonably consistent curvilinear pitch (e.g., curveball, slider, etc.) or that of an inconsistent curvilinear pitch (e.g., think Mariano Rivera's cutter that had a highly consistent path half way to the plate but sprayed in all directions as it crossed the hitting zone). To build better trajectory judgment skills, hitters need to focus on predictions. The prediction space can be quite basic, such as simply predicting strikes versus balls, but building a better trajectory prediction map of the hitting zone will require very intentional work to develop more refined predictions of specific and tighter zones. Prediction skills can be trained, but require a combination of repetition and feedback so that the hitter can adjust and fine tune predictive models about pitch trajectories.

Key Principles and Strategies for Training Trajectory:

1. The key concept in training better trajectory is training better prediction. A good initial strategy is to have a hitter call out the location of a pitch before it crosses the hitting zone. A key piece about "call out" drills is that immediate feedback about the true pitch location should be given after each pitch, either verbally by the pitcher or an observer, or digitally by a tracking display. The immediate feedback allows the hitter to reinforce the prediction accuracy or make adjustments to the visual prediction error so that he can build a more accurate trajectory prediction model. This is a drill that can be accomplished using front toss, pitching machine, and standing in on pitcher bullpen sessions to simulate game pitch velocities. Variations of the "call out" drill can be used, with simpler versions requiring a simple ball/strike prediction, and more complex versions involving carving up the hitting zone in/out or up/down into 2-4 zones (we've seen as many as 7 zones each reflecting the width of a ball from inside black to outside black of the plate – 7 balls roughly cover the plate) and having the hitter call out the predicted zone. We tend to discourage too many zones because every additional option slows decision speed (simple brain principle that more response options and load in working memory equals slower decision speed), plus most hitters seem to look for pitches in zones that reflect roughly a 3 ball diameter (e.g., looking for balls in the 3-4-5 zone), so keeping zones to 2-4 is a reasonable balance between carving up into functional zones and not overloading with too many options. The drill can be used to train predictions in/out and up/down in isolation and then progress to more complex combinations of each. The drill can also be used to train trajectory predictions for linear as well as curvilinear ball paths.

Couple of final thoughts. We've seen a variation of the "call out" drill where the hitter calls out the location of the pitch after it crosses the hitting zone. The problem with this version is that the hitter now relies on a memory system rather than a prediction system for reporting the pitch location. It is an obvious tell when hitters look down at where they think the pitch crossed the hitting zone and try to recreate the location from memory. Having the hitter call out pitch location before it crosses the hitting zone forces a prediction. This is a subtle, but critical difference. While we also are big fans of keeping the swing involved in drills, but in this instance, vocally calling out the pitch isolates the prediction process. We will progress to adding the swing in the subsequent strategies. In fact, it might be advantageous to use "action" words for the call out rather than descriptive "nouns", for example saying "hit" instead of strike and "take" instead of ball. Might sound silly, but saying an action word engages motor circuitry related to that action ("take" would prime action inhibition), whereas stating nouns does not activate motor circuitry in the same way - might as well prime the action system for going or taking in the drill.

2. The prediction of the ball's trajectory is critical not only for deciding whether to swing but also deciding where to swing. "Eyes closed" drills can be a very effective way to train where to swing based on a predicted trajectory. The basic idea is to simulate the process of building the predictive decision about the ball's trajectory, close your eyes, and hit the ball hard by swinging to the predicted location. This is probably best using front toss format to minimize injury potential. The hitter sees the ball out of the hand, reads the trajectory of the pitch, closes his eyes, and then hits the ball. If you closely watch the focus of the eyes at ball contact in real games, it is immediately clear that there is a lot of variability between where the eyes appear fixated at contact and where the ball is making contact. In other words, the eyes move to the predicted path close to (but predominantly out in front) of the contact point. Closing your eyes after visually processing the pitch trajectory forces the hitter to create and trust the prediction.

   Just a quick note about a variation of this drill that we've seen, but actually does the opposite with respect to when the eyes are closed. We've heard of a drill where the hitter starts with eyes closed and as the pitcher releases the ball, the pitcher makes a sound that signals the hitter to open his eyes and hit the ball. For the purpose of trajectory prediction, this version really isn't working the same system. Plus, not knowing where the ball is upon opening eyes forces the hitter to have to engage a visual search process to locate the ball in space. This is more of a visual search task than a trajectory prediction task. This version may be a reasonable strategy for working on late adjustments, but does not get at trajectory decisions. We've also seen a slight variation of the eyes closed drill that introduces an occluder into the drill, such as a pitcher throwing a pitch into a net positioned between the pitcher and hitter, and then the hitter hitting a ball off of a tee. The problem with this approach is that the likelihood of the thrown ball trajectory crossing the hitting zone at the exact positioning of the ball on the tee is highly improbable, thus does not help the brain link a specific trajectory to where it actually crosses the hitting zone. Occlusion drills can be used to develop better trajectory prediction, but require a temporal occlusion where you see a limited amount of a ball's trajectory, predict where the pitch would have crossed the

hitting zone, and then receive immediate feedback on whether the prediction was correct or not. In fact, the eyes closed drill is essentially a temporal occlusion drill.

3. Hitters frequently adopt an approach that might look for certain types of pitches, certain locations of pitches, or some combination of a type of pitch in certain locations. Obviously, the approach depends on several factors (pitcher's arsenal, pitcher's tendencies, count, RISP, hitter's strengths, etc.). Ultimately, a hitter has an advantage when he can cognitively load up a "trajectory zone" mind set (e.g., low strikes on the outside third of the plate) and prime the brain to more quickly and automatically recognize specific trajectories for that zone. To achieve these trajectory zone mindsets, the hitter needs to train hitting zones around the strike zone and build tighter linkages between specific trajectories and hitting zones. Working trajectory zones around the strike zone builds these maps. The "call out", "eyes closed", and regular BP formats can be used for these drills. The key concept is to identify a target trajectory zone, and only call out or swing at pitches in that zone across a round of pitches. Because the hitter is making a swing/no swing decision in this drill, it is unavoidable that the drill engages motor control systems (e.g., impulse control, stopping control) that regulate taking (no swing) decisions. This is okay as both trajectory and motor control processes independently contribute to chase rates, so incorporating both processes further helps link taking processes to unwanted trajectories.

   In terms of setting up the progression structure of these drills, we recommend starting with rounds of pitches where the percentage of pitches to the target trajectory zone is much higher than the percentage of pitches out of the trajectory zone. In fact, it may be a good idea to do a first round with all pitches hitting the desired trajectory zone. In this initial phase, the hitter is building a map or database linking trajectory predictions to where the ball will cross the hitting zone. Slowly add more pitches out of the trajectory zone across subsequent rounds or sessions as the hitter achieves more success. Ultimately, the toughest challenge will involve a round of pitches where the majority of pitches are out of the zone and a few random pitches hit the target zone. Obviously, start with zones that match a hitter's most frequent approach preferences or strengths and progress down the priority list. Additionally, this drill progression can be used for linear and curvilinear pitch types. Again, use feedback about the accuracy of the hitter's decision on each pitch so that the hitter can fine tune his internal trajectory prediction model. The objective here is to build these trajectory zone mindsets so that when a hitter loads a zone, his brain becomes highly tuned to those specific trajectories.

TAKE DECISIONS

Goal: Train better skill at taking pitches you don't want to swing at.

Background: An important concept when attacking take decisions is understanding that the go and inhibition systems in the brain are distinct, independent systems. If a hitter only trains the go (swing) system, the hitter is neglecting the other key piece of hitting, taking pitches you don't want to swing at. To be complete, hitters should train both systems so that they are effective at going when they need to go and effective at shutting down or stopping when they need to take. There is ample scientific evidence that the inhibition system in the brain can be trained to improve skill at preventing or stopping unwanted actions, especially when worked on in the performance context. There are two general effects that unfold when training take decisions. As the hitter trains to take a specific pitch, he develops and strengths the association between that pitch and a stopping decision so that every time he sees that pitch the brain automatically wants to shut down. Additionally, with focused inhibition training, the strength of the impulse to swing at that pitch weakens over time. So in effect, the pitch doesn't activate the go system as potently and the inhibition system engages more effectively to shut down the swing. S2 has investigated the effects of a 4 week training program designed to reduce chasing at competitive, high balls among elite youth baseball players. In a highly challenging in-cage test of chasing, the 28 hitters as a group reduced chase rates from 54% to 13%, with individuals averaging a baseline reduction of chasing to the tune of 77% reduction. There are several drill strategies to work the inhibition system in more generic and specific ways to put the hitter in a control mode. Below we lay out a progression that trains taking broader categories of pitches (balls out of the strike zone, all breaking balls, etc.) as well as taking a specific pitch (e.g., high fastballs up and out of the strike zone).

Key Principles and Strategies for Training Take Decisions:

1. Before introducing a framework for training the take system to a specific pitch, let's first introduce an all-purpose take drill format that can be used to introduce hitters to taking drills more generally or used as a primer or warm up to get hitters in a mindset of being selective. This drill framework isn't anything new or sophisticated, but brings some level of intentionality to working on taking and switching a hitter's mindset from BP focused on swinging (go-only decisions) to a mindset of being selective. Throwing an accidental ball or two in a round of BP is unlikely to provide enough reps and structure to train the inhibition system. Thus, the concept for take drills is to intentionally and systematically introduce pitches that the hitter should take into the round of BP. In a first round, the simple and familiar instruction given to the hitter is to hit the strikes and layoff the balls. The pitcher (front toss, machine, live BP) should intentionally throw a percentage of

balls out of the strike zone mixed with pitches for strikes. Nothing new so far, but here are some variations to increase the difficulty of the drill:

a. Alter the ratio of strike to ball percentages – simply varying the percentage of strikes and balls in a round can shift the hitter into swing mode vs. a more controlled mode. A higher percentage of strikes (e.g., 75%) to balls (25%) puts the hitter in swing mode, whereas a lower percentage of strikes (25%) to balls (75%) forces the hitter to take more than swing. Working hitters using different percentages (probabilities) of strikes to balls is an effective way to make the drill more difficult and to teach the concepts of modes (swing vs. control) that can be important for specific counts, situations, and pitchers who vary their probabilities of serving up strikes and balls. As a rule of thumb, here is good 3 round strikes-to-ball percentage ratio progression – 25:75, 50:50, 75:25.

b. Tighten the difficulty of ball/strike judgments – other ways to make the drill more difficult are to reduce the time to make the judgment by progressing faster velocities or to tighten the difference or distance between pitches judged as balls versus strikes. For example, start with ball/strike judgments that are easier to distinguish (obvious ball vs obvious strike) and then progress to tighter differences, such as balls/strikes that share space early, or balls that are just off the black vs. strikes that are just inside the black. Start mixing these more difficult to judge pitches with the probabilities in part a to make another difficult progression.

c. A hitter's approach further defines pitch selectivity. A hitter's approach may target certain strikes defined by pitch type or location, but lay off of other pitches that may be balls or strikes outside of the desired approach zone. Fine tuning the ball/strike concept to working pitches in and out of an approach zone is another way to progress the basic drill.

2. The basic premise for training to take a specific pitch is to begin linking the visual representation of that pitch to a rapid, automatic inhibition decision. For the purpose of this drill progression, let's start with a hypothetical hitter who tends to chase high, competitive fastballs that are up and out of the strike zone. We'll focus training on the take system to lay off of this particular pitch, but the principles and progression can be applied to any specific or general pitch type/location. These drills can be done with front toss, machine, or live pitching formats, and we'd recommend using multiple formats to increase transfer effects. We break the framework down into three phases:

a. Phase 1: In this first progression, mark half of a bucket of balls with nickel-sized red dots on 2-3 of the open sides. We are going to use the color red because it is often linked to a stop sign, so the color is already highly associated with inhibition. Instruct the hitter to not swing at any baseball that has a red dot, but to swing at all baseballs without a red dot. In the initial round, throw 75% of the pitches with the red dot balls and 25% of the pitches with balls without the red dot. Here is the key training component – throw all of the red dot balls up and out of the strike zone (keep them competitive, but high balls), but throw all of the baseballs

without dots for strikes. While the hitter is directing intense focus to determining the presence or absence of the red dot, the fact that all of the red dot pitches are the targeted take pitch (high fastball up and out of the zone), inhibiting the swing to red dots will indirectly associate inhibition to the high ball out of the zone. This is a great way to begin associating the specific pitch to an inhibition signal. Note that the high percentage of take pitches in this early phase is intended to produce a high number of repetitions to build the linkage between high ball and take decision.

b. Phase 2; The next phase of training incrementally makes the drill more challenging. Sticking with the same structure in part 2 (red dot/no dot baseballs), the subtle but potent shift involves changing the percentages of take pitches to strikes. Instead of throwing most of the pitches for balls up and out of the strike zone (i.e., 75% of baseballs with red dots to just 25% no dot balls for strikes), change the percentage of baseballs with and without red dots to 50%-50%. Continue to throw the red dot baseballs for balls up and out of the strike zone. Shifting the percentages in this direction will now put the hitter in more of a swing mode because he's seeing and hitting more strikes. This is one of several strategies that can push a hitter into a swing mode. The concept here is that when the brain gets into a go mode (swing mode), there is a tradeoff with the inhibition or control mode. Athletes understand that pressing for speed, strength, aggression always comes with a tradeoff loss of control and more vulnerability for making errors and impulsive decisions. Shifting into swing mode increases a hitter's vulnerability to biting on first impulses to swing, so this should feel harder to lay off of the red dot balls compared to the first phase with a higher percentage of take balls. Extending this concept, the next shift in progression would be to further shift the percentages of pitches so that the no dot strike pitches are thrown 75% of pitches in a round to just 25% of the red dot take pitches. In this round, the hitter is really put into swing mode, thus making the rare take pitch harder to lay off. Working these percentages in a progressive way starts to train better control as the difficulty of taking increases. Again, using the red dot as the take pitch is continuing to lay down reps that associate the ball up and out of the strike down zone with a take inhibition decision.

c. Phase 3: For this phase, we want to repeat phases 1 and 2 but only using baseballs without the red dot. At this point in the progression, the indirect association to take high fastballs should be well established, so removing the red dots starts reinforcing the inhibition association through intentional takes. The instructions should be modified to take the "take" pitch and hit strikes.

d. Phase 4: For this final phase, the goal is to incorporate the take pitch into more challenging drills formats like those described in 1a and 1b, thus making it harder to distinguish the take pitch from hittable pitches. The intent here is to continue shaping the inhibition system to shut down to that pitch when it is embedded in a variety of contexts, counts, and pitch types.