Welcome to the Huberman Lab Podcast,
where we discuss science and science-based tools
for everyday life.
I'm Andrew Huberman,
and I'm a professor of neurobiology and ophthalmology
at Stanford School of Medicine.
Today we are discussing mental training and visualization.
Mental training and visualization is a fascinating process
that has been shown over and over again
in now hundreds of studies
to improve our ability to learn anything.
When I say anything, I mean the ability to learn music,
the ability to learn and perform mathematics,
the ability to learn and perform motor skills in sport,
in dance, across essentially all domains.
The other incredible thing
about mental training and visualization
is that you'll soon see when you go into the literature,
that is the scientific studies
on mental training and visualization,
you quickly realize that it does not take a lot
of mental training and visualization
in order to get better at anything.
However, that mental training and visualization
has to be performed in a very specific way.
And today we will discuss exactly how to do
mental training and visualization
in the specific ways that allow it to complement
the actual performance of a motor or cognitive skill
to allow you to learn more quickly
and to consolidate that is to keep that information
in mind and body so that you can perform those cognitive task,
music task, motor tasks, et cetera,
for long periods of time
without ever forgetting how to do them.
All of mental training and visualization
relies on what I consider really the holy grail
of our brain and nervous system.
And that's neuroplasticity.
Neuroplasticity is our nervous system,
which of course includes the brain, the spinal cord
and all the connections between the brain and spinal cord
and the organs and tissues of the body

and then all the neural connections back
from the organs and tissues of the body
to the brain and spinal cord.
So the whole thing in both directions
has the ability to change in response to experience
in ways that are adaptive.
That is, that allows us to do things
that we could not do before.
And by doing those things
or by being able to perform those mental operations,
we can do better in the world that we live in.
We can perform new tasks, we can think new thoughts,
we can come up with novel solutions
to preexisting problems that before really vexed us
and that we couldn't overcome.
All of that is considered neuroplasticity.
So today what I'm going to cover
is a brief summary of what neuroplasticity is,
that is how it occurs in the brain and body.
This is extremely important to understand
if you're going to use mental training and visualization.
Then I'm going to talk about what happens
in our brain and body
when we do mental visualization in a dedicated way.
Many people have heard perhaps
that when you imagine something happening
that your brain doesn't know the difference
between that imagination of the thing happening
and the real thing happening.
Turns out that is not true.
It is simply not true.
However, there is somewhat of an equivalence
between a real experience and an imagined experience.
And we'll talk about the difference between those
and how that can be leveraged
in order to get the most out of mental training
and visualization.
Then I will cover exactly which types
of mental training and visualization work best
across all domains,
meaning for music learning, mathematics,
solving puzzles, motor learning, sports performance,
et cetera, et cetera,

to really allow you a template
in which you can plug in
or designate what you're going to do each day
for a brief period of time
in order to accelerate your learning
in whatever you choose.
And then I'm going to go into a bit of what happens
in the brains of different types of people.
These different types of people that I'm referring to
are people who have more or less of a natural ability
to imagine things and visualize them.
Because it turns out that we vary tremendously
from one individual to the next
in terms of our ability to mentally visualize
and imagine things
and our ability to get better at that over time.
And the good news is anyone can get better
at mental training and visualization
in ways that can serve them well.
I'll also briefly touch on the fact that certain people,
in particular people on the autism spectrum,
as well as people with synesthesias,
which is the combining of different perceptual experiences.
So you may be one of these people
or you may have heard of people that for instance,
when they think of a number,
they also just naturally,
spontaneously think of a color and vice versa.
We'll talk about how that relates to mental imagery
and visualization and the creative process
and problem solving in general.
And then finally, what I'll do
is I'll recap mental training and visualization
from the standpoint of how best to apply
mental training and visualization
according to specific challenges.
Things like challenges with public speaking
or challenges with sports performance
or challenges with test taking performance,
challenges with essentially anything
that will allow you to build
specific mental training and visualization practices
that are brief, that are supported by neuroscience studies

and that are highly effective.
Before we begin, I'd like to emphasize
that this podcast is separate
from my teaching and research roles at Stanford.
It is however, part of my desire and effort
to bring zero cost to consumer information
about science and science related tools
to the general public.
In keeping with that theme,
I'd like to thank the sponsors of today's podcast.
Our first sponsor is Element.
Element is an electrolyte drink
that has everything you need,
meaning sodium, magnesium and potassium,
but nothing that you don't, meaning no sugar.
And it has the sodium, magnesium and potassium
in the ideal ratios for hydrating
and providing electrolytes to the cells
and tissues of your body.
So I use Element in my water when I wake up.
I like to hydrate right away.
So I'll have an Element packet
in about 16 to 32 ounces of water when I wake up.
I tend to do the same while I exercise,
which I typically do in the morning,
sometimes in the afternoon,
and I'll drink another one throughout the day.
The great thing about Element is it also tastes terrific.
I particularly like the watermelon flavor,
but frankly, I like all the flavors
just mixed into, again, about 16 to 32 ounces of water.
If you'd like to try Element,
you can go to drinkelementlmnt.com slash Huberman
to claim a free Element sample pack with your purchase.
Again, that's drinkelementlmnt.com slash Huberman.
Today's episode is also brought to us by Maui Nui Venison,
which I can confidently say is the most nutrient dense
and delicious red meat available.
Maui Nui spent nearly a decade
building a USDA certified wild harvesting system
to help balance deer populations on the island of Maui.
The solution they built is extremely powerful
because it turns the proliferation of an invasive species

into a wide range of nutrient dense products
from butcher cuts, so venison steaks
and ground venison, et cetera,
to organ meats, bone broth, and jerky.
I really love all of their products.
So I love the venison steaks and the ground venison,
and their bone broth is fantastic.
It has an unmatched 25 grams of protein per 100 calories.
So it's very high density,
high quality protein per calorie.
So if you'd like to try Maui Nui Venison,
go to MauiNuiVenison.com slash Huberman
to get 20% off your first order.
Again, that's MauiNuiVenison.com slash Huberman
to get 20% off your first order.
Today's episode is also brought to us by Eight Sleep.
Eight Sleep makes smart mattress covers
with cooling, heating, and sleep tracking capacity.
I've talked many times before in this podcast
about the fact that sleep is the foundation
of mental health, physical health, and performance.
Now, one of the key features to getting a good night's sleep
is making sure that you get the temperature
of the environment you sleep in right.
That's because in order to fall asleep
and stay deeply asleep throughout the night,
your core body temperature needs to drop
by about one to three degrees.
Conversely, in order to wake up in the morning
feeling refreshed and ready to go,
your core body temperature needs to go up
by about one to three degrees.
Now, of course, you can adjust the temperature
of the room that you sleep in.
I do hope that people are doing that.
But adjusting the temperature of your mattress
and your direct sleeping environment is also key.
And with Eight Sleep, it makes it very easy
to program the temperature of that mattress
and sleep environment, not just throughout the night,
but for specific phases of the night.
I started sleeping on an Eight Sleep mattress cover
well over a year ago, and it's the best sleep

that I've ever had.
If you'd like to try Eight Sleep,
you can go to eightsleep.com slash huberman
and check out the PodPro cover
and save $150 at checkout.
Eight Sleep currently ships in the USA, Canada, UK,
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Again, that's eightsleep.com slash huberman
to save $150 at checkout.
Let's talk about mental training and visualization.
Now, perhaps surprisingly,
mental training and visualization has been studied
since the late 1800s.
There's actually a paper published in 1880 by Galton
called The Statistics of Mental Imagery.
So long ago, people were quantifying
and trying to understand how is it
that people come up with mental images
and how they can apply that
to learning things more quickly
and more stably over time.
Now, as I mentioned earlier,
mental training and visualization
relies on a process that we call neuroplasticity.
Neuroplasticity is a term that many people have heard
and encompasses many different things.
So broadly speaking,
neuroplasticity includes developmental plasticity,
which is the sort of plasticity that occurs
between about birth and age 25.
And that can be summarized very easily
as passive plasticity.
In other words, the sorts of changes
that happen in one's nervous system
simply by engaging in the world
and experiencing life as a child,
as a young adult, as an adolescent,
and as a 22, 23, 24 year old, et cetera.
Now, of course, of course, of course,
it is not the case that on your 25th birthday,
you close out passive developmental plasticity
and start engaging in the other type of neuroplasticity,
which is adult neuroplasticity.

It's a gradual tapering off of developmental plasticity
that occurs between age zero and 25.
And for some people might occur somewhere around 26,
for other people around 23.
When we say 25,
we're really just talking about the average age
in which passive plasticity tapers off.
However, starting fairly early in adolescence
and extending all the way out into one's 80s or 90s
or hundreds, should one live that long,
is the other form of neuroplasticity,
which is adult neuroplasticity.
Adult neuroplasticity is very different
than developmental plasticity
because it is the sort of plasticity
that one can direct
towards one's own specific desired learning.
So if we wanted to get a little bit technical here
for sake of clarity, not for sake of confusion,
we would say adult plasticity is really
about self-directed adaptive plasticity.
And the reason we call it that
as opposed to something else,
where simply adult plasticity
is that there are many different forms of neuroplasticity.
There is, for instance,
maladaptive neuroplasticity that occurs
if one gets a really hard head hit and concussion,
there will be changes to the brain and nervous system,
but those changes to the brain and nervous system
do not allow it to perform better.
In fact, it often impairs the brain
and nervous system's ability to function
and therefore is maladaptive.
So I don't want to get overly wordy
with a number of different terms here,
but I do think it's important to understand
that we have developmental plasticity,
again, in which the brain and nervous system changes
simply in response to experiencing specific things
for better or worse.
And there's adult self-directed adaptive plasticity
in which one can direct specific changes

in terms of learning things cognitively
or learning things in terms of motor function,
so sport, dance, et cetera, or a combination of the two.
Now, just to really clarify what I mean
by developmental versus self-directed adaptive plasticity,
I mentioned that self-directed adaptive plasticity
actually can start in adolescence, right?
Even though there's ongoing developmental plasticity,
I mean, let's be really direct.
The brain of a 14-year-old is very different
than the brain of that same individual
when that person is 21
because there's ongoing developmental plasticity.
However, starting at about adolescence,
we can all start to decide what it is that we want to learn
and engage in self-directed adaptive plasticity.
Now, the way to engage self-directed adaptive plasticity,
regardless of whether or not you're a 13-year-old,
14-year-old, or you're a 90-year-old,
or anywhere in between, is that it requires two things.
The first thing it requires is focused,
dedicated attention to the thing that you're trying to learn.
That's the first step.
And that actually triggers a number of different chemical
and electrical processes in the brain
that are often associated with agitation and frustration.
Believe it or not, the agitation and frustration
is a reflection of the release of specific chemicals,
in particular, norepinephrine and epinephrine,
also called noradrenaline and adrenaline
in the brain and body, that creates this discomfort
and this heightened level of alertness and attention
that many of us don't like and tend to back away from,
but it is exactly that chemical,
or I should say neurochemical milieu,
which signals to the neurons, the nerve cells,
in the brain and elsewhere in the body
that something needs to change.
Because if you think about it,
if you can do something perfectly,
or if you try and do something
and it doesn't cause any neurochemical change
in your brain and body,

well, then there's no reason for your brain
and its connections with the body
to change in any particular way.
Okay, so you need focused, dedicated attention
to the thing that you're trying to learn.
It's often accompanied by agitation, frustration, et cetera.
So that's perfectly normal.
In fact, that's a signal that things are going right,
meaning they're headed towards learning,
but there's a second component that's really required
for self-directed adaptive plasticity
and that's periods of deep rest,
in particular, a good night's sleep,
in particular, on the night that follows
that focused attention to the thing you're trying to learn.
There are now hundreds of studies
in both animal models and in humans,
showing that it is really during sleep
and other states of deep relaxation,
things like meditation and non-sleep deep rest,
which I've talked about before on this podcast,
but really during our main night of sleep,
that the rewiring of neural connections,
that is the actual neuroplasticity takes place.
So the verb neuroplasticity,
the rearrangement of connections between neurons,
really occurs during sleep,
in particular, on the first night,
following an attempt to learn something
through this focused attention.
Now, developmental plasticity, which is passive,
also requires good sleep.
It's slightly different, or frankly, it's a lot different
in terms of the underlying mechanisms
than self-directed adaptive plasticity,
but because today we're mainly talking about
how to learn faster through mental training
and visualization, and that really maps more closely
onto self-directed adaptive plasticity,
just really want to emphasize this two-step process.
There has to be focused, dedicated attention,
and then there needs to be sleep,
and in particular, sleep on the first night

following that training.
Now, should you have the unfortunate experience
of getting woken up in the middle of the night,
following, trying to learn something,
or should you simply not be able to sleep
for whatever reason on the night
following a bout of learning, or an attempt to learn?
Do not despair, because it turns out
that there are what are called
second and third night effects also.
Once you sleep, you will learn those neuroplastic events,
the reordering of connections that we call synapses,
and the changes that occur in neural circuits
that reflects what we call
self-directed adaptive plasticity.
That still will occur, but ideally,
you got a great night's sleep on the first night
following, trying to learn, and the second night,
and the third, and so on, and so on.
Now, there are a few other things
that are critical to understand
about self-directed adaptive plasticity
that will become especially important
when thinking about protocols for developing
the ideal mental training and visualization process for you.
And that is that there are different forms of plasticity
that occur between neurons, although the two main forms
are what are called long-term potentiation
and long-term depression.
I just want to queue up right now
that the word depression is a very loaded word,
because the moment people hear the word depression,
they think, oh no, that's bad.
But in the case of neuroplasticity, long-term depression
is simply a change in the connections between neurons
and the excitability between neurons
that in many ways can be excellent
for learning things, in particular motor skills.
And we'll get into this in more detail in a little bit,
but it turns out that a lot of our ability
to get better at some sort of motor skill
involves this thing that we call long-term depression.
And that's because much of what is happening

when we learn a new motor skill
is that we are depressing or suppressing specific actions
in order to generate a very specific coordinated action.
Some of the best examples of long-term depression
can actually be borrowed from developmental plasticity.
So for instance, if you've ever sat across from an infant
who is trying to eat their meal,
so imagine a one and a half-year-old or a two-year-old
trying to eat some noodles or some soup
or any kind of baby-suitable food with a spoon
and they're holding the spoon
or they're trying to hold the spoon,
what you'll notice is that their motor movements
are terribly uncoordinated.
They often will take that spoon to their cheek
or to their eye or to their head.
We've all seen these very amusing photos of babies
with bowls of food on their head
or with food all over their face or just everywhere.
It appears that they're basically getting the food everywhere
except where it's supposed to go, which is in their mouth.
And that's because their motor movements
are not very well-coordinated at that age
and they're not very well-coordinated
not because they lack sufficient numbers
of neural connections synapses between neurons,
but rather because they have too many connections
between too many different neurons.
The neural circuits that control very dedicated,
coordinated movement are not there yet.
Instead, too many neurons are connected
to too many other neurons
and so they can't generate the precise movements
that are required in order to get that spoon to their mouth.
Now, over time, they get better
at moving the utensil to their mouth
such that hopefully by about age five or six,
they are eating in a relatively cleaner way
and hopefully by time they're 10 or 11 or 12,
they're getting the food into their mouth
and not all over their face.
People learn this to varying degrees.
All you have to do is go to a restaurant

and watch how people eat.
And you will see a vast variation
in people's coordinated movements with utensils,
but in general, there's a theme.
The younger the person,
the more uncoordinated their movement of utensils
and as they get older, the more coordinated.
Now, of course, in people that are very old,
they have challenges moving objects and their limbs
in very smooth ways.
And that has to do with a topic that we'll get into
when we talk about age-related cognitive decline
and motor-related dementias.
But for sake of today's discussion,
if you just want to think about what happens
with long-term depression and the development of a motor skill,
both as a baby, as an adolescent and as an adult,
when you're trying to learn a new motor skill,
is that you are eliminating incorrect movements.
And when you are eliminating incorrect movements
to arrive at only the correct movements
in a very reflexive and repeated way.
So think your golf swing, your tennis serve,
think serving a volleyball,
think a child learning to crawl and then walk,
think a child learning to eat with utensils,
an example I gave before.
What's happening in all of those cases
is that, yes, certain connections in the brain
are being strengthened or what we call potentiated.
They are undergoing long-term potentiation,
the so-called quote-unquote fire together,
mantra that was popularized by the great neurobiologist,
Dr. Carla Schatz, my colleague at Stanford.
But in addition to that long-term depression,
the quieting or the silencing of specific synapses,
that is connections between neurons,
is absolutely critical for motor skill learning.
So we have LTP, long-term potentiation,
and LTD, long-term depression,
is every bit as important as LTP, long-term potentiation,
for getting better at some sort of motor skill
and indeed at getting better at some sort of cognitive skill.

Now as we hear this, this should be intuitive to all of us.
If you look at somebody's attempt
to learn a particular dance step
or at somebody's attempt to do a tennis serve the first time,
it's all over the place.
Now it's not perhaps all over the place
in that they're doing a jumping jack
while trying to serve the tennis ball,
but they're generally arching the racket too widely
on one trial and then they're arching it too close
to their body on the next trial.
So if we were to draw a line over each one of those trials,
we would see that there were lines everywhere over time.
Whereas once they quote unquote perfect the tennis serve,
it's going to be line drawn directly over line,
drawn directly over line,
meaning the arc of that tennis serve
is going to be very restricted.
And that without question has reflected the removal
or the quieting of particular synapses,
connections between neurons in the brain and body
to allow that very narrow coordinated
and directed movement.
The same is true for learning anything
in the cognitive domain,
meaning if you are to learn a language,
it is not of course the case
that you know every word in that language
and then you simply remove certain words
and arrive at the correct sentence structure
that you're trying to achieve.
But rather you have to suppress your native language
or if you're a young child,
you have to suppress the generation
of just kind of random babbling sounds,
turns out babbling isn't random at all.
But the point is that you have to suppress
the enunciation of particular sounds
and direct the pronunciation of other sounds
in order to generate that new language
or your ability to speak at all.
Okay, so we can really think about neuroplasticity
as both a building up process

in which you increase connection,
so-called long-term potentiation
and a sculpting down or a removal of connections process
that we're going to call long-term depression.
Now I have to acknowledge that of course
there are other forms of neuroplasticity too.
I know there are probably some aficionados
listening to this who will be perhaps shouting back
at whatever device my voice is coming out of.
Wait, what about spike timing dependent plasticity
or what about paired pulse facilitation?
Yes, yes, and yes, there are multiple forms
of communication between neurons
that can strengthen those connections
or weaken those connections.
But for today's discussion,
we just broadly want to think about
long-term potentiation and long-term depression
because it captures the two most important themes
related to mental training and visualization,
which is that when we perform a given cognitive
or physical task in the real world,
so we actually try the dance step or the tennis serve,
or when we actually try a math problem
or we try and learn some specific knowledge
and write it down and remember it,
that is engaging particular neurons, right?
They're firing, they're releasing chemicals,
but it is also actively suppressing
the activity of other neurons.
And we are always completely unaware
of the ways in which our brain
is suppressing certain activity, okay?
So today we have to keep in mind
that where there is strengthening of connections,
there is also weakening of connections.
And when it comes to mental training and visualization,
and here's the really key point,
with mental training and visualization,
you are capturing both processes,
both the potentiation that is the building up
and strengthening of connections
and the weakening of the connections

that are inappropriate for the thing you're trying to learn.
And there are different aspects
of mental training and visualization protocols
that really harness the potentiation
versus the depression aspect.
And today we will cover mental training
and visualization protocols
that capture both the potentiation
and the depression aspect of neuroplasticity.
And in that way serve as an augment,
that is a compliment to the actual real world,
cognitive and physical training that you're doing,
because I'll just give this away right now.
Turns out that mental training and visualization
is not a replacement for real world cognitive
or motor behavior.
Again, mental training and visualization
cannot replace real world execution of cognitive tasks
or of motor tasks if you want to learn.
However, mental training and visualization
can and has been shown to be effective
for greatly enhancing the speed at which you learn
and the stability of that learning over time.
Okay, so let's take a second
and really think about what's happening
in the brain and body
when we do mental training or visualization.
In fact, we can do a little experiment right now
that is not unlike many of the classic experiments
looking at what's happening in the brain and body
through mental training and visualization
in which I just ask you to close your eyes
and imagine a yellow cube, okay?
And next to that yellow cube is a red rose.
And perhaps I also ask you to float
or fly up above the cube and the rose
and look at them from the top, top down.
And then I tell you to fly back around
and land behind those and look at them
from the perspective of behind that yellow cube
and that red rose, okay?
Now, what the data tell us is that most people
will be able to do that.

Most of you will be able to do that
to some degree or another.
Regardless of your attention span,
whether or not you have ADHD or not,
most of you will be able to do that
to some degree or another.
We also know from neuroimaging studies
in which people are placed
into a functional magnetic resonance imaging scanner
that during the sort of visualization you just did
or that I described,
that your visual cortex and associated areas
quote unquote, light up, they become very active
in similar but not identical ways
to how they would light up and be activated
were you to actually look at a yellow cube
and a red rose on a screen
and perhaps fly above them virtually of course
and land behind them virtually of course
or if you were to actually look at a yellow cube
and red rose in the real world,
right in front of you on a table,
then get up on your tippy toes
and look down at them from the top
and then walk around the table
and look at them from the other side.
So there is some degree of what we call
perceptual equivalence between real world experiences,
digital experiences and imagined,
meaning with our eyes closed,
just in our mind's eye experiences.
This is true not just of vision
and what we call the visual domain
but also the auditory domain, okay?
So for instance, I could play for you a short motif
of a song, let's just pick something
that I think most people know, goodness,
I'm a terrible musician and even worse singer,
but let's just take the opening
to ACDC's Back in Black, right?
I think I can do that when it's like
dun, dun, dun, dun, dun, okay, got it.
That's the actual sound,

although admittedly a dreadful version
of the great ACDC song Back in Black.
But now I ask you to close your eyes
or you could keep them open
and just imagine that dun, dun, dun, dun, dun, okay?
Or for instance, I place you in a quiet room
so you could close your eyes
and ask you to imagine the opening
to ACDC's Black in Black
but ask you to pause it halfway through.
What you would find again is that most people,
somewhere between 90 and 95% of people
would be able to do all the sorts of things
that I described, right?
Cube and Rose, ACDC Back in Black.
Even a somatosensory task.
I imagine what it's like to touch felt
or to touch chinchilla hair or something like that.
A chinchilla's hair, ideally a live chinchilla sitting still.
Those little critters move really, really fast
but they have very, very soft hair.
High hair density, so soft.
Okay, most people can do that.
About five to 15% of people are less able to do that
and there's a small percentage of people
in that five to 15%
that simply cannot do it at all,
that just cannot visualize well.
We'll talk later about these people.
They have what's called aphantasia
and an ability to mentally visualize
but most people are actually pretty good
at visualizing things when they are told what to visualize
and this is a really key point
and if what they are told to visualize is very simple
and the whole visualization is quite brief.
Lasting on the order of about 15 seconds
to generate the visualization in the auditory
or in the visual aspect of one's mind's eye or ear,
if you will, and if it's repeated over and over.
What's far harder for everybody to do
and in fact what most people simply cannot do
is imagine long extended scenes and stories in their mind

that go on for minutes and minutes
that involve a lot of different sensory stimuli.
This is a really key point.
In fact, as we start to home in
on ideal mental training and visualization protocols,
I'd like to establish this as the first principle
of mental training and visualization
which is that if you are going to use
mental training and visualization to its best effect
in order to engage neuroplasticity and learning,
you need to keep those visualizations quite brief,
really on the order of about 15 to 20 seconds or so
and pretty darn sparse, meaning not including
a lot of elaborate visualization,
not including a lot of sequences of motor steps.
What I mean are motor sequences,
if you're trying to learn something
in terms of physical movement
or visual sequences or auditory sequences,
if you're trying to learn things in terms of music
or dance, et cetera,
that can be completed and repeated in 15 seconds or less.
Now, later I'll give you a couple of specific examples
but if you want to use mental training and visualization,
understand this is the key first principle.
They have to be very short visualizations
that you can repeat over and over and over again
with a high degree of accuracy.
So you don't want to embark
on a mental training and visualization paradigm
in which it involves a lot of elaborate stimuli
and you have to think really hard and work really hard
even if you're in that category of people
who can do mental visualization pretty naturally and easily.
Now, if you're somebody who can't do mental visualization,
in fact, if you're somebody who has full blown
aphantasia or the inability to mentally visualize,
well, then it's especially important
that you make those mental trainings and visualizations
really brief and very, very simple.
I'd like to take a quick break
and acknowledge one of our sponsors, Athletic Greens.
Athletic Greens, now called AG1,

is a vitamin mineral probiotic drink
that covers all of your foundational nutritional needs.
I've been taking Athletic Greens since 2012
so I'm delighted that they're sponsoring the podcast.
The reason I started taking Athletic Greens
and the reason I still take Athletic Greens
once or usually twice a day
is that it gets to be the probiotics
that I need for gut health.
Our gut is very important.
It's populated by gut microbiota
that communicate with the brain, the immune system,
and basically all the biological systems of our body
to strongly impact our immediate and long-term health.
And those probiotics in Athletic Greens are optimal
and vital for microbiotic health.
In addition, Athletic Greens contains a number of adaptogens,
vitamins, and minerals that make sure
that all of my foundational nutritional needs are met
and it tastes great.
If you'd like to try Athletic Greens,
you can go to athleticgreens.com slash huberman
and they'll give you five free travel packs
that make it really easy to mix up Athletic Greens
while you're on the road and the car on the plane, et cetera.
And they'll give you a year supply of vitamin D3K2.
Again, that's athleticgreens.com slash huberman
to get the five free travel packs
and the year supply of vitamin D3K2.
Now, in order to develop
the best mental training and visualization protocols for you,
let's go a little bit deeper into what the research says
about mental visualization.
Now, the classic work on mental visualization
really hinges on a number of different researchers
and their work, but in particular, Roger Shepard,
who did this work at Stanford,
and Stephen Costlin, who's now at Harvard.
Of course, others in the field,
but it's really the work of Shepard and Costlin
to lay the foundation for our understanding
of what happens in the brain
when we mentally visualize something.

Shepard did these incredible experiments
in which he had students mentally visualize simple objects
like a square, like a triangle.
And he measured how long it took them to do that.
Now, of course, at the time when he did these experiments,
there were no sophisticated brain imaging devices
and machines like fMRI.
However, everything I'm about to describe
has been later confirmed using things like fMRI.
What Shepard did and what he found is that
if people were told to visualize very simple objects,
they did it pretty quickly.
However, if they were told to visualize more complex objects,
or importantly, to rotate those objects in their mind's eye,
well, then it took longer
for them to perform those mental visualizations.
Now, many of you might think, duh,
if I have to just imagine a triangle or a cube,
that's going to be very easy and very fast,
whereas if I have to rotate that triangle or a cube
in my mind's eye, that's going to take more time.
And indeed, that is somewhat of a duh, except,
and this is so very important,
except that what Shepard and his colleagues found
is that how long it takes somebody to generate
and rotate a given visual image scales directly
with the complexity of that image.
In fact, Kozlin did some experiments,
I think illustrate this even better.
And here's the experiment.
I love this experiment.
I think you'll love it too,
because it illustrates something so fundamentally important
about how our brains work,
not just for sake of mental training and visualization,
but just how our brains work at all.
He showed people a picture of a map.
So a map drawn on a piece of paper.
This was a map of an island.
It included things like a loading dock for some boats.
It had a location for getting food on the island,
it had some trees,
it had some other small landmarks drawn out.

And people looked at this and memorized it.
Or in other experiments,
they just had people imagine this island
and the location of these different landmarks on the island.
So it didn't really matter which.
But then he had people imagine moving or walking
from one location on the island to another.
So they'd say, okay, you're at the loading dock,
now move to the restaurant.
Okay, you're at the restaurant,
now move to the palm tree.
You're on the North Shore of the island,
now go around the side of the island clockwise
to arrive at the bay on the Southwest corner,
this sort of thing.
What Coslin found was absolutely incredible.
What he found was that the amount of time
that it takes people to move from one location on the map
to another, scaled linearly, directly
with the actual physical location
between those objects on the map.
So for those of you that can understand
or into the importance of what Shepard and Coslin showed,
great.
I'm guessing, however, that for most people out there,
you're still grasping it like, okay, interesting,
how things happen in the real world,
dictates how they happen in our mind's eye.
But I wanna make sure that I really nail home
the importance of this for everybody.
The importance of this is that when we look
at something in the real world,
so if I look at the pen in front of me,
I'm holding up my pen, for those of you that are listening,
I'm just holding up my pen in front of me.
I move it to the right and back and forth.
What's happening is I'm activating
or I'm triggering the electrical activity of neurons,
which we can think of kind of as pixels in my eye, okay?
So it's, you know, leftward to rightward motion
for me and back and forth.
And those are getting activated
and they're sending signals up to my visual cortex.

And that information is processed at a given speed.
What the visualization experiments
that Shepard and Coslin and others did show
is that the processing speed of imagined experiences
is exactly the same as the processing speed
of real experiences.
And the spatial relationship between imagined
and real experiences is exactly the same as well.
Put simply, when we imagine something in our mind's eye
or mind's ear, we are imagining the real thing happening.
And when I say the real thing,
it's not the obvious real thing.
Of course, if you're imagining something,
that's the thing you're imagining.
What I mean is that your brain at the level of neurons
is behaving exactly the same way.
And this needn't have been the case, okay?
There could have been a result, for instance,
that if people were asked to visualize a cube
and rotate it from, you know, flip it from top to bottom,
okay, so put the top that's upward on a table,
now down on the table and so forth,
or to migrate around the island, you know,
counterclockwise going from, you know,
the northern coast all the way down to the southern coast,
clockwise and then back up to the northern coast,
that they could have just done it really quickly,
like all in one second, but that's not what happens.
They always match the speed at which they do things
in their mind's eye to the same speed
that they do them in the real world.
So in telling you this, what I'm saying is that
mental visualization at the neural level
is identical to real world events.
So when you've heard that when we imagine something,
it's identical in terms of our brain's experience of it
and our body's experience of it,
as when we actually experience something,
that is true at the neural level.
However, when it comes to learning and improving performance
in the cognitive or physical domain, they are not equivalent.
So this is the second principle
of mental training and visualization.

As you recall, the first principle
of mental training and visualization
was that in order to make it effective,
it needs to be very brief and very simple
and repeated over and over again.
The second principle of mental training and visualization
is that while yes, mental training and visualization
recaptures the same patterns of neural firing
in the exact same ways as real world behavior and thinking,
it is not as effective as real world behavior and thinking.
In other words, if you want to learn something,
the ideal situation is to combine real training
in the physical world with mental training.
And I'll talk about exactly how to do that
and in what ratios a little bit later.
Now, there's a really incredible set of experiments
that illustrate why it is that mental training
and visualization can be extremely effective,
but that it's always going to be most effective
when combined with real world training and experiences.
The experiments that I'm talking about
involve the use of what are called
bistable images or impossible figures.
Now, some of you are probably familiar
with impossible figures.
These are figures or objects that when you look at them,
they have these odd features,
like you're not sure where they stop
and where they start or where they end.
One good example would be the so-called mobius strip.
The mobius strip is literally a strip or a line
that is contiguous, it goes up and it loops around
and then it curves around and then it goes back
and it just continues and continues.
And when you look at it,
you can never really tell where it starts
and where it stops because it doesn't have any
of the features that allow you to see what's the front
and what's the back in any kind of stable way.
Another example of an impossible figure
would be a little set of cubes
that look like they're coming out toward you,
maybe with a little bend in them,

going up at a right angle, perhaps.
But then if you look at it a little bit longer,
that little piece that's facing up looks like it's in front
and you can't really tell what's in front and what's in back.
And so it's called an impossible figure
because you don't really know how to frame it in your mind
to tell what's closer to you and what's further apart.
Bistable images are somewhat similar,
although different in the sense
that they typically are simple silhouettes.
So for instance, the faces, vases by stable image
is perhaps the most famous of these
where you look at this image, it's very simple
and it looks like two vases.
But then you look at it a little bit longer
and you realize that you're looking at the side angle
or the profile of two faces looking at one another.
And when you see those two faces looking at one another,
you can't see the vases at the same time.
But then if you decide to see the vases again,
you can see the vases again, but the faces disappear.
So it's by stable meaning that you can't see the faces
and vases at the same time.
And impossible figures and by stable images
are capturing the fact that your visual cortex
and some of the associated areas
that compute visual scenes in your world
are essentially trying to recreate
whatever it is that's out in front of them.
And that's effectively what your visual system does.
It's very good at recreating visual images
in your brain, in your mind's eye.
So if you think about it, even with your eyes open,
your brain is just creating an abstract representation
of what it thinks is out there,
but that when it comes to assigning an identity
to something like, oh, that's a face or oh, that's a vase,
that is constrained by different neural circuits,
by different areas of the brain.
And somehow those circuits can't be coactive.
We cannot see the faces and the vases
at exactly the same time.
We can switch back and forth really quickly,

just as we can switch back and forth really quickly.
When we're looking at the impossible figure
and think, okay, that's the front of it, that's the back.
No, wait, that's the back, that's the front.
And it's going back and forth,
but we can't see them both at the same time.
No one can see them both at the same time.
We know this from brain imaging studies.
Now, impossible figures in bistable images can be seen.
You could look them up right now on your phone or computer,
or I could show you pictures of them
on paper right in front of you.
And you can do these sorts of perceptual experiments
of telling people, look at the face, look at the vase,
look at the front of the cube,
and I'll make it at the back of the cube.
And they can do this somewhat deliberately.
However, and this is, I think, so very interesting
to understanding how mental training and visualization
does and does not support real world learning.
If you try to imagine a bistable image, you can't do it.
In fact, no one can do it until they do something else.
Okay, so for those of you that are saying, wait,
I can do it, I can do faces, vases in my mind's eye.
I promise you that the neuroimaging
disputes your belief, okay?
And supports the idea that we can see real world
bistable images, we can see real world impossible figures,
but when we try and imagine those in our mind's eye,
we simply can't do it.
We can't do the perceptual shift in our mind's eye.
We can't switch back and forth between faces and vases.
However, and I just have to chuckle
because I think these experiments are so clever.
If I have you trace or draw
with a pen, on a piece of paper, an impossible figure,
or the faces, vases, bistable image,
and then I ask you to imagine that bistable image
or impossible figure and to switch back and forth,
you are able to do it.
So what that illustrates is that it's the combination
of imagined and real world experiences,
real motor movements, real perceptual experiences

combined with motor movements, combined with what you imagine
in your mind's eye, that really gives you the most depth
and flexibility over your mental visualization.
And in doing so, we can really stamp down
a third principle of mental training and visualization,
which is that your mental training
and visualization will be far more effective
if you are performing the exact same or very similar
mental and physical tasks in the real world, okay?
So first principle is mental training
and visualization needs to be simple and brief and repeated.
Second is that mental training and visualization
is not a replacement for real world motor training
or cognitive training, it's an augment,
it's an addition that can really help.
And the third principle of mental training
and visualization is that you need to combine
mental training and visualization with real world behaviors
and experiences that are very, very similar.
Now as a brief, but I think really relevant aside,
one of the things that also makes mental training
and visualization more effective is when we assign
cognitive labels to what's going on when we visualize.
So what I mean is that people are much better
at manipulating faces and vases in their mind's eye,
of course, only once they've drawn them out physically
with their hand, as I mentioned before.
Then they are manipulating abstract objects
like impossible figures, in part because
by labeling them faces and vases,
people are able to capture a lot of other neural machinery
that's related to faces and vases.
In fact, we have entire brain areas on both sides
of the brain devoted to the processing of faces,
they're called fusiform face area.
We have other areas in our brain that are involved
in processing of 3D objects,
but faces are of particular value.
There's a value to understanding what a face is
as opposed to a non-face,
and there's a value to understanding
what a particular face is.
In fact, the simplest way to put this

is that the human brain is, in many ways,
a face recognition and expression
of faces recognition machine.
Of course, there's other things,
but it is exceptionally good at that.
Unless you're in a profession
in which the relationships between 3D objects
and your ability to manipulate them
is exceedingly important,
you're not going to have a lot of neural real estate
specifically devoted to that.
Some people will be better at it, some people will be worse,
but when it comes to faces,
unless you have a condition like propethicgnosia,
which is an inability to recognize, say, famous faces
and distinguish them from non-famous faces,
or if you have some sort of face recognition deficit,
which about anywhere from one,
perhaps to 3% of people out there have,
because they're just terrible at recognizing faces.
And by the way, there's about half a percent of people
out there that are what are called super recognizers
that can recognize faces in a large crowd.
They can recognize specific faces
even from just partial profiles.
By the way, these people are extremely valuable
to security agencies and security agencies
are very good at finding these people.
Machines are quickly getting better
or at least as good as super recognizers,
but the best super recognizers are still better
than the best AI and machine algorithms out there.
But the point is that in your mind's eye,
you are better able to manipulate specific objects
or to see things more clearly and with more specificity
when it has a label that you recognize
from your real world experience,
as opposed to abstract or fictional labels.
Again, stamping home the idea
that what you experience in the real world
really serves to support your mental imagery
and therefore the key importance of experiencing
and doing things in the real world

and supporting that with mental training and visualization
and not just relying on mental training and visualization.
And the tangent here that's a little bit of fun,
and I don't think we've ever talked about before
on this podcast is that of UFOs, unidentified flying objects.
You know, there's a lot of people out there
who think that they've seen UFOs.
I guess technically they have
because a UFO is an identified flying object.
And if it's unidentified, at least to them,
then it is indeed a UFO.
I guess the question is whether or not,
or the dispute rather, is whether or not
those UFOs are actually flown by aliens
or controlled by aliens.
I think that's where the dispute lies.
But you can imagine how if somebody sees an object
in their environment and decides, ah, that's a UFO, okay?
Remember these faces, vases, or these impossible figures?
If they say, oh, that thing is a UFO
as opposed to something else.
They see, in other words, the face, not the vase.
Well, that stamps it down as a memory
in their visual system and related systems.
And then in their mind's eye, they are seeing the UFO.
They're not seeing the other thing
that it could possibly be, okay?
So it stamped down a very specific memory.
So the point here is that mental training
and visualization relies on not just the physical contours
and the exact spatial profiles and the speed of movement
of particular things that we experience in the real world.
It also heavily depends on the cognitive labels
and the decisions we make about the things that we see.
And this will become very important as we build up
toward our fourth principle of mental training
and visualization, which is that our cognitive labels,
that is what we decide is happening
when we do mental training and visualization,
turns out to be very important.
Now, this is not simply to say that you can decide,
okay, I want to learn how to play piano.
And so I'm going to tell myself

that a particular chord I imagine in my mind's eye
is identical to the real world chord
just because I decide it is.
The brain doesn't work that way.
It's not possible to just lie to yourself
and learn better as a consequence of the lies
you tell yourself.
However, what this tells us is that it is very, very important
that your mental training and visualization
accurately recapitulate the real world training
that you're doing.
So we are going to stamp down a fourth principle
of effective mental training and visualization
based on what we know from the scientific literature
is that your mental training and visualization
should assign labels to what you're doing
that can be matched to real world training and experiences.
Now, these can be somewhat abstract.
So for instance, if you're trying to learn
a particular aspect of the golf swing, okay?
So let's say that you're working on your golf swing.
Seems to be there are a lot of people out there
working on their golf swing
and you're going to do some mental training
and visualization in order to improve your golf swing.
We already know, again, let's just march through them
that your mental training and visualization
needs to be brief and simple.
It needs to be the same or in fact, it will be,
we can say the same as your real world golf swing.
In other words, it will take you exactly the same amount
of time to perform that golf swing in your mind's eye
as it would in the real world.
Incredible, right?
Again, something that maybe is taking a little bit of time
to sink in, but once it does, you're gonna be like,
wow, the brain is really an incredible machine.
And that third principle that you still have to do
golf swings in the real world
in addition to the mental training of golf swings.
And fourth, that if you want that mental training
and visualization to really improve your golf swing,
you're going to have to name or apply an identity

to the specific golf swing or aspect of the golf swing
that you're practicing.
So this could be abstract.
You could call it mental training and visualization
of golf swing 1A and you could imagine in your mind's eye,
you know, the perfect golf swing over and over
and over and over.
But then when you're in the real world,
you're also going to have to call that either out loud
or just to yourself golf swing 1A, okay?
As opposed to a putt, which might be 1B.
So naming and giving an identity to a real world skill
and applying the same name or identity
to the mental version of that, the visualization of that,
can enhance the mental training and visualization
in significant ways.
So when we apply identities or names
to these mental trainings and visualizations,
and again, provide that they are brief and repeated
and so on, we greatly enhance the amount of neural machinery
in the brain and body that we are able to recruit
when we go to perform those real world golf swings
and golf putts and here just replace golf swing
and golf putt with anything that you're trying to learn,
you're able to recruit a lot more neural machinery
and greatly increase the probability of proper execution.
So before we go any further,
I wanna share with you a couple of incredible aspects
of mental visualization that really can be harnessed
and applied toward mental training and visualization.
Some of these were done by Roger Shepard
and his graduate students in postdocs,
some were done by Steve Costlin and by others.
What these experiments really show
is that mental training and visualization
is capturing many, many of the exact same features
of real world behavior and perceptions,
not all of them, but many of them.
So for instance, if I tell you to close your eyes
and imagine a ceiling that has tiles
that are black and white checkered tiles,
one black tile, one white tile, for instance,
we know based on experiments

where we measure eye movements behind closed eyelids
that people tend to move their eyes up
when they are imagining things above them,
such as a ceiling.
Whereas if I tell you to imagine things down on the floor
like you're taking a hike
and you're looking for rattlesnakes,
actually just recently I experienced
because it's spring here in California,
rattlesnake along a hiking trail,
it's really quite beautiful,
although I have to confess I enjoyed keeping my distance.
I don't like snakes very much.
I don't dislike snakes,
but I prefer not to interact with them unless I have to.
If I have you imagine that rattlesnake,
depending on your relationship or thoughts about rattlesnakes,
number of things will happen in your brain, of course,
activation of the limbic system or not, for instance.
But what I know is that regardless of how you feel
about snakes, most of you will move your eyes down
when imagining a snake.
It might be subtle, it might be fast,
but statistically that result shows up
as opposed to when I imagine
where I ask you to imagine something above you,
tend to move your eyes up.
In addition to that, if I tell you, for instance,
to imagine an elephant and a mouse next to one another,
you presumably have some real world understanding
about the relative sizes of elephants versus mice.
Elephants generally are bigger than mice.
Thank goodness.
Mice are smaller than elephants.
If I ask you to tell me about the details
of that mouse's face,
so for instance, can you see its whiskers?
The processing time required for you to do that
is much longer than the processing time required
if I say, tell me what the position
of that elephant's trunk is.
Now, why would that be so, okay?
The position of the elephant's trunk

wasn't something that I told you.
It wasn't dictated by me.
It's in your mind's eye.
Maybe you don't even know
and you have to go searching for it.
But what we do know is that if I tell you to look
at a small object in your mind's eye
versus a larger object,
so for instance, the mouse versus the elephant,
it takes longer for you to do that.
In other words, just as with the map experiment,
the distance between things on a map
is conserved in your mind's eye
as a linear relationship.
It takes longer to go far distances
between things on a map in your mind
than it does to go shorter distances.
It's also the case that it takes you longer
to look at the details of a small object
versus a large object because why?
Because you are zooming in in your mind's eye.
Again, all of which speaks to the equivalence
of mental imagery with real world imagery and perception.
And as I mentioned earlier,
and as we'll see in a moment,
this also extends into the motor domain.
It takes you longer to perform complex motor sequences
in your mind's eye than it does simple motor sequences,
just as it would in the real world.
And if you're saying, of course, of course, of course,
well then great, then we've really underscored the point,
which is that when you imagine things,
it is not exactly the same,
but it is very, very much the same
as actually doing or perceiving those things
in the real world.
And the fifth principle
of effective mental training and visualization
is this notion of equivalence of mental imagery
versus real world perception and behavior.
These are the experiments, as you recall,
where if people are told to look for clouds
in their mental visualization, they tend to look up,

or if they're looking for something on the floor,
they tend to look down, even behind closed eyelids.
Now, this can be applied toward building
an especially effective mental training
and visualization protocol.
If you deliberately move your eyes in the direction
of the thing or things that you are trying
to recapitulate in your mind, in your visualization, that is.
You don't necessarily have to include this step,
but mental training and visualization
is going to be more effective if you do,
because with consciously generated eye movements,
again, even behind closed eyelids,
you are bringing about more of the neural circuitry
that one would experience if you were to perform
that particular cognitive task or motor task
in the real world, which, as I mentioned before,
in principle number three, you need to be doing anyway,
separately from your mental training and visualization.
So what we're talking about here is thus far,
five principles of mental training and visualization
that are well-established
from the scientific research literature.
In fact, I haven't mentioned this quite yet,
and I'll refer to some other references,
but there's a wonderful systematic review
of a large number of studies
that have looked at mental training and visualization,
what's effective, what's less effective,
across a bunch of different disciplines
that include education, medicine, music, psychology,
and sports.
We will provide a link to this paper
in the show note captions,
but the title of the paper is Best Practice for Motor Imagery,
a systematic literature review
on motor imagery training elements
in five different disciplines.
As the title suggests,
it's mainly for motor imagery training,
but it extends into music,
which of course involves motor training and execution,
but as well as education.

This review establishes a number
of different important things.
I'm going to read off some of the key
or highlight takeaways.
For instance, I described principle one
of effective mental training and visualization,
which is that the visualization be brief
and it be simple and it be repeated.
May ask how many times that very brief
five to 15 second exercise of going through some routine
should be repeated.
Well, different studies have used different ranges
of let's call them repetitions
in a given training session,
but the number that seems to be most effective
is somewhere between 50 and 75 repeats per session.
That brings about the question of how long one should rest
between each repeat.
This gets a little tricky
depending on what you're trying to do.
Remember that we have this threshold of about 15 seconds
for completion of the entire motor sequence.
Let's say what you're trying to do,
like a golf swing takes you five seconds
to imagine in your mind's eye,
from the point where you,
let's just say have the ball on the tee,
you bring the golf club up,
you might reposition your feet just a little bit,
you know, that kind of little wiggle that golf golfers do,
and then the swing.
If that whole thing takes five seconds in your mind's eye
and roughly five seconds in the real world,
well, then you'd be able to repeat it, of course,
three times in 15 seconds.
That would be one repetition,
even though you're doing it three times.
So it's one 15 second epoch,
as it's sometimes called, EPOCH epoch.
And then you would rest for
an approximately equivalent amount of time,
15 seconds or so, and then repeat.
And rest 15 seconds or so, and then repeat.

Rest 15 seconds, and then repeat.
Again, three golf swings within that 15 seconds,
rest 15 seconds.
Truth told, these epochs and these rest periods
do not need to be exact.
You could imagine, for instance,
that you get three repetitions of the swing within 14 seconds.
Well, then do you do another one
or do you wait until the end of that 15 seconds?
I encourage you not to obsess too much
about those sorts of points.
Rather, you want to do as many repeats as you can
in about a 15 second epoch,
and then rest for about two seconds.
And then rest for about 15 seconds,
and then repeat for a total of 50 to 75 repetitions,
which might not sound like a lot to some of you,
might sound like an awful lot to others of you.
To me, it sounds like a lot.
50 repetitions of something
and where you're trying to concentrate in your mind's eye
on getting something accomplished over and over
over again in exactly the same way might seem like a lot.
We know, based on the learning literature,
that your ability to successfully perform something
in the real world will lend itself
to better performance of that thing
in the imagined world within your mind's eye.
That's also one of these sort of does.
But if you're trying to get better at something
that you've never performed before,
you really should know that the mental training
and visualization is probably not the best augment
to that real world training
until you're able to perform it successfully
in the real world at least some of the time.
Mental training and visualization can be effective,
however, at increasing the accuracy or the frequency
at which you can do that real world behavior.
So if normally you're only getting the correct swing
or you're only hitting the golf ball correctly,
say 10% of the time mental training and visualization
can really help bring that number up.

But it is important that you are able
to successfully complete that motor task in the real world.
Similarly, for performance of cognitive tasks,
so say for instance, speaking a new language,
you might ask, well, gosh, what in the landscape
of speaking a new language can be restricted
to five to 15 seconds where I could repeat it anywhere
from one to three times in a given epoch and then rest
and then keep repeating 50 to 75 times?
Well, there I would encourage you to pick something
that you are able to do perhaps very slowly.
So to speak a particular sentence,
but with some challenge in getting the accent
and the enunciation right,
but you've completed it successfully before
and you wanna get more smooth
and more fluid with it.
Likewise, for playing piano or guitar,
again, you have to translate to the specific cognitive
and or motor activity that you are seeking to improve at,
but those epochs lasting five to 15 seconds
are really the cornerstone
of an effective mental training and visualization practice
and the repeated nature of it,
50 to 75 repetitions in a given session
is also another cornerstone
of an effective mental training and visualization practice.
So says this review and some of the other papers
that I'm going to get to in a few moments.
Now, one of the other key components
of a successful mental training and visualization practice
is how often you perform
that mental training and visualization practice.
And again, a number of different studies
have looked at this through a number of different lenses,
meaning anywhere from two to eight times per week,
it does appear that performing these sessions
anywhere from three to five times per week
is going to be effective.
We could perhaps even say most effective
because most of the, let's just call it the strongest data,
really point to repeating these 50 to 75 trials
of the same thing three to five times per week.

So you can come up with a number
that's reasonable for you to do consistently.
And you might ask, do you have to continue
to perform the mental training and visualization forever?
And the good news is the answer to that question is no,
it does seem that once you have what's called
consolidated the motor performance
or the cognitive performance of something,
it can be further supported or reinforced,
that is consolidated in the neural circuits
that are responsible for performing
that mental or physical task.
So in other words, once you are performing
that cognitive or motor task in a way that's satisfactory
or perhaps just improved, perhaps you're not 100%
but it's improved in the real world,
you don't need to continue to do mental training
and visualization to maintain that real world performance.
So that's a good thing.
In fact, the ideal situation would be
then to pick a different sequence
or thing that you're trying to learn
and do mental training and visualization for that.
I perhaps might have misspoke there,
although I don't want to edit this out.
I misspoke in the sense that again,
I said for the thing that you're trying to learn,
remember mental training and visualization
is going to be most effective for building up
the number of accurate trials
or that your ability to do something
with a greater frequency of something
that you're already capable of doing
or have done at least once in the real world.
This is not to say that mental training
and visualization can't be used to acquire new skills.
It can in principle, but it has been shown
to be most effective for enhancing the speed
and the accuracy of skills
that one has already demonstrated
some degree of proficiency at in the real world.
I think that's important to point out
because we often hear mental training and visualization

and this equivalence of perceptual and motor experiences
in our mind's eye to the real world.
And we think, oh, all we have to do is imagine doing something
and we will get better at it.
And unfortunately, that's not the case.
The good news is, however,
if you can do something once,
even very slowly in the real world,
and then you bring it to the mental imagery
and visualization domain,
you can get much faster at it
in a way that really does translate back to the real world.
I'd like to just take a brief moment
and thank one of our podcast sponsors,
which is Inside Tracker.
Inside Tracker is a personalized nutrition platform
that analyzes data from your blood and DNA
to help you better understand your body
and help you reach your health goals.
I've long been a believer in getting regular blood work done
for the simple reason that blood work is the only way
that you can monitor the markers
such as hormone markers, lipids, metabolic factors, et cetera,
the impact your immediate and long-term health.
One major challenge with blood work, however,
is that most of the time it does not come back
with any information about what to do
in order to move the values
for hormones, metabolic factors, lipids, et cetera
into the ranges that you want.
With Inside Tracker, changing those values
becomes very straightforward
because it has a personalized dashboard that you can use
to address the nutrition-based, behavior-based,
supplement-based approaches that you can use
in order to move those values into the ranges
that are optimal for you, your vitality,
and your longevity.
Inside Tracker now includes a measurement
of apolipoprotein B, so-called APOB,
in their ultimate plan.
APOB is a key marker of cardiovascular health,
and therefore there's extreme value

to knowing your APOB levels.
If you'd like to try Inside Tracker,
you can go to insidetracker.com slash huberman
to get 20% off any of Inside Tracker's plans.
Again, that's insidetracker.com slash huberman
to get 20% off.
Now, if you recall principle number three,
or what I'm calling principle number three
of effective mental training and visualization,
which was that you have to be able to perform
the thing that you're trying to get better at
through visualization and imagery in the real world.
That should raise the question of what is the ratio
of real-world training versus mental training
that's going to be most effective?
Well, here there's some really interesting data,
not just in the review that I mentioned,
but in a couple of the other papers
that we're gonna talk about in a few minutes.
But what I've done is I've synthesized the information
across those papers, and they really all point
to the fact that real-world training
is more effective than mental training,
and mental training is more effective than no training.
Now, the mental training more effective
than no training is kind of a duh,
except that there are people, for instance,
people who are injured, who are trying to maintain
or replenish some motor skill or ability
to move in a particular way,
or who have had traumatic brain injury
and are trying to recreate experiences
in a way that's safe for them
while in a somewhat restricted format.
So, for instance, if you've damaged a limb
or you're experiencing chronic pain,
and you need to take a layoff or some physical activity,
there are now many studies looking at stroke patients,
at patients that have been in accidents, TBI,
also people who are suffering
from more conventional limb and connective tissue injuries,
that if they do mental training,
it obviously is not going to put them at risk

of doing those same movements
as it would in the real world, right?
But that it can actually accelerate
or at least maintain skill performance.
So this is pretty exciting, if you think about it.
What this means, and the reason it underscores
this mental training is better than no training,
is that should you find yourself
in the unfortunate circumstance
of being injured or unable to perform a given behavior,
imagining the sequence of behavior
that you'd like to maintain or even build up over time,
provided you've done that motor sequence before
in the real world.
Well, the mental training and visualization
can really help keep that online
or even help you improve over time.
In fact, I have a colleague in the psychology department
at Stanford who told me an anecdote,
and admittedly it's just an anecdote of a student
who was recruited to Stanford,
both for their academic prowess,
but also for their abilities in tennis
and was injured in their first year,
and at first thought this was devastating,
but did a cognitive reframe around the idea
that what's called extended layoff from actual tennis
was going to afford them the ability
to do more mental training than they would otherwise,
even though they were quite sad
to not be able to do actual physical training for tennis.
And when they came back from that injury,
they did indeed manage to improve
beyond the initial non-injured state
they were in before the injury, which is pretty remarkable,
but as this colleague pointed out to me,
they were very careful to include
a lot of mental training and visualization
during that quote unquote layoff period.
So again, mental training better than no training,
physical training better than mental training,
but when we say physical training better
than mental training, what we're really talking about

is when you allocate a certain amount of training hours
for a given skill per week.
Okay, so how would this look?
What these studies have done is they've said,
okay, if people have the option
of doing the real world training for 10 hours a week,
versus mental training for 10 hours a week,
which group performs better?
It turns out it's the ones that do the physical training
for 10 hours per week.
However, we also know that combinations
of physical training and mental training
can bring about results that are greater
than either one of those alone.
How would that work?
Well, I wish I could tell you that if you did nine hours
of physical training per week, plus one hour of mental training,
that your performance would be better
than if you did 10 hours of physical training.
And that's not the case.
Okay, this is why we can reliably say
physical real world training,
and again, this could be in the cognitive domain,
is always going to be more effective
on an hour by hour basis compared to mental training.
So if you can do real world training,
and perhaps we should be calling it real world
as opposed to physical, but if you can do real world training
compared to purely mental training,
that's going to be the best use of your time.
This is really important.
It doesn't underscore everything that we're talking about
because here's the really cool thing.
If you do 10 hours per week of real world physical training,
again, could be running, could be music, could be math,
could be whatever it is you're trying to learn,
shooting basketballs, hitting golf balls,
and you add one hour or even half an hour of mental training
to that real world training,
well then the results are significantly greater
than you would experience with physical training alone.
And of course they would be greater
than you could achieve with mental training alone

because we already established
that real world training is more powerful
in learning skills and retaining skills
than is mental training.
Okay, if any of that was confusing,
let me just say it one more time just to be ultra clear.
If you have the option to do real world training
for a cognitive and or motor skill versus mental training,
always go with real world training.
However, if you can add to a maximum amount
of real world training by doing some mental training
and you follow the principles that we've been discussing here
which are gleaned from the scientific literature,
well then you are going to get significantly greater results
in terms of speed, accuracy, and consistency of performance
of those real world behaviors and cognitive abilities.
And of course, if you are unable to do physical training
for whatever reason, injury, travel,
whatever the case may be,
well then doing mental training is still far
significantly greater than doing no training at all.
Okay, so total layoffs it turns out are a bad thing
if you want to get better at something
and indeed if you want to retain certain skills
both cognitive and motor.
Now a couple of other things to keep in mind
as you're thinking about how to build up skills
through a combination of physical and mental training.
Well, remember back to the beginning of the episode
where we talked about neuroplasticity
and the fact that self-directed adaptive plasticity
which is really what we're talking about here
in this entire episode,
things that you're trying to learn in a deliberate way.
That is as you recall a two-part process
requires focused attention,
both when you're doing it in the real world
and when you're doing mental training
and it requires rest and sleep.
And in fact, you would be very wise
to try and get a good night's sleep
both on the days when you do physical training,
again also called real world training

and mental training.
You may also be asking,
can you do them on the same day?
And this gets into some nuance in the literature
but by my read of the literature,
here's the takeaway.
If you are doing the maximum amount of physical training
that you can do according to your schedule,
preventing injury and all those sorts
of important constraints
and you're going to add mental training and imagery,
it doesn't really matter when you do it.
You could do it immediately after your physical training,
you could do it on a separate day
but you do wanna place it at a time
in which you can try and get good sleep that night.
So for instance, believe it or not,
studies have been done where people are doing mental training
at times when they should be sleeping,
that is going to offset some of the degradation
and performance that you would normally see
but it's generally a bad idea.
You should do your real world training
and your mental training whenever it is that you can
and then you should try and get as much quality sleep
as you possibly can on the night
following that physical and or mental training.
This is true of pretty much every night of your life.
If I had my way, that is if I had a magic wand
which obviously I don't,
I would ensure that I and everyone else in the world
get sufficient amounts of quality sleep every single night
but that's just not realistic.
There are going to be times
where that's simply not gonna happen for whatever reason
and I always say if you're not going to get
sufficient amounts of quality sleep for whatever reason,
try and make it for a fun reason or a good reason
but I think getting sufficient amounts of quality sleep
80% of the nights of your life is a reasonable goal
and one that's worth striving toward
and we have lots of episodes now
or three really on mastering sleep,

on perfecting your sleep and episode,
a guest episode with the great Matthew Walker
who wrote the book, Why We Sleep,
an incredibly important book.
All of those as well as our toolkit for sleep
describe ways to improve your sleep.
So you can refer to those episodes
if you're having challenges with sleep
and want to improve on sleep
and things like non-sleep deep breaths
which can support your ability to sleep
and your ability to learn.
So sleep is still vitally important
not just for ensuring neuroplasticity occurs
following real world training
but also following mental training
and again when you place that mental training
is not so critical.
At least it doesn't appear to be based on the literature.
So if anyone out there has knowledge
of any peer reviewed studies
stating that mental training should be done
either before or after or some hours away
from real world training, please send that to me
or put it in the comments on YouTube
and I'll see it there
because I do read all the comments
but I'm not aware of any such data or analysis.
And by the way, if you are interested
in understanding the relationship
between motor skill acquisition and retention
and this first night phenomenon
of sleep the first night after training
versus sleep on the second night, et cetera.
There's a really wonderful paper
that was published by none other
than the great Matthew Walker
when I believe he was a graduate student.
Maybe he was a postdoc when he did this
in Robert Stickgold's lab at Harvard.
The title of the paper is Sleep and Time Course
of Motor Skill Learning.
This is a paper published in 2003.

Still an incredibly important paper.
I will provide a link to it in the show note captions.
It really highlights some of the key aspects
of when people sleep and how critical sleep is
on the night following and the nights following
that training in order to really consolidate
certain types of learning
and what phases of sleep relate
to the consolidation of motor learning, et cetera.
A really wonderful paper and of course
but just one of Matthew and Robert Stickgold's
incredible papers on sleep and learning.
Remember at the beginning of the episode
when I mentioned that many people are good
at mental training and visualization
but some people are not.
Well, sex differences have been explored
and age related differences have been explored
in terms of people's ability to mentally visualize
and train up specific skills.
And while initially there were some sex differences
identified, really the bulk of the subsequent literature
that is the majority of quality peer reviewed studies
on this aspect of mental training and visualization
pointed to the fact that there are no significant differences
between males and females in terms of their ability
to mentally visualize, nor their ability
to use that mental visualization
toward improving cognitive or motor skills.
That point was covered in some detail
in the review I mentioned earlier.
Best practice for motor imagery,
a systematic literature review on motor energy,
training elements in five different disciplines.
This review also looked at age related effects
and perhaps the only thing that really popped out
from this literature review
in terms of age dependent differences
that point to changes in protocols that you might make
is that for individuals 65 or older,
a combination of physical and mental training
may actually allow them to gain
and consolidate skills better

than were they to do physical training alone.
Now, whether or not that's due to some lower upper limit
of physical training that they can do because of their age
or whether or not that's something specific to do
with older versus younger neural circuits isn't clear,
but what this review also makes clear
is that for the vast majority of people out there,
so teens, people in their 20s and their 40s and so on,
physical training more effective than mental training,
we said that before,
combination of physical and mental training more effective
than physical training alone provided the mental training
is on top of the maximum amount of physical training
that one could do and of course mental training
more effective than no training at all.
Okay, so we talked about sets and reps.
We talked about five to 15 second epochs
with about 15 second breaks in between
or rest between sets if you will,
repeated for 50 to 75 trials,
done three to five times per week.
Some of the conditions of keeping it really simple,
the importance of being able to actually perform
those sequences in the real world and so on.
What we haven't discussed is first person versus third person
and eyes open versus eyes closed.
What are we really talking about here?
Well, first person, mental training and visualization
would be where you are imagining doing something
and you are seeing yourself doing something
from the inside out as opposed from the outside in.
Imagine for instance wearing a head cam or a body cam
and doing something with your hands
or being in virtual reality and having the sense
that whatever you see in front of you
and that's moving and that you're doing, that's you.
So what I mean by this is a mental training
or visualization protocol.
For instance, if you were at the piano or at a guitar
where you're actually looking down at
or sensing the feeling of your hands
but you're not actually moving your hands, okay?
As opposed to seeing yourself from outside of your body.

So looking at yourself, say standing next to you
or from across the room, you're looking at yourself
playing the piano or playing a guitar
or swinging a golf club or doing a tennis serve, okay?
First person versus third person.
And what the data tell us is that first person,
mental training and visualization
is generally more effective than third person,
mental training and visualization,
which perhaps raises another chorus of does out there.
But it needn't have been the case, right?
I mean, you could imagine that seeing yourself doing something
and doing it perfectly,
because you've done it perfectly once before, hopefully,
would allow you to build up that skill more quickly
because you have that third person perspective
where you can really see every aspect
and every element of what you're trying to perform.
Well, it turns out that the first person,
mental training and visualization
is significantly more effective
than that third person mental training and visualization.
So if what you're trying to learn lends itself well
to this first person mental experiencing of self
as you perform the cognitive and or motor skill,
I suggest you do that as opposed to the third person version.
Now, what if what you're trying to learn
doesn't lend itself well to first person visualization?
For instance, what if you're trying to learn
specific cognitive skill
that doesn't involve any overt motor behavior to be observed?
Well, in that case, it's very clear
that closing your eyes ideally
and trying to perform that specific cognitive task
or the statement or the uttering of a particular sentence
in another language or doing some sort of computation
or problem solving of some sort in your head.
Well, that itself of course is first person
because it's inside your own body as opposed to
and I don't know that anyone would actually do this
but looking at yourself from a third person perspective
in your mind's eye and seeing yourself
perform that cognitive challenge,

whatever that challenge may happen to be.
Okay, now we have to address eyes open versus eyes closed.
And this is where the literature gets pretty interesting.
I always thought for some reason, I don't know why
but I presumed that mental training and visualization
should always be done eyes closed.
But it turns out that's not how a lot of studies
of mental training and visualization have been done.
And in fact, many of them have arrived
at really impressive protocols
which are essentially the protocols
that I've distilled out
and I'm listing out during today's episode.
Having people either watch videos of themselves
performing a given skill
and imagining themselves in that role
and again, it's them.
So again, during the mental training and visualization
they're watching a movie of themselves.
So they're somewhat in the third person perspective.
I guess we could technically say
they are in the third person perspective
but they're watching themself.
So in doing that, we know based on neuroimaging studies
that when we watch videos of ourselves doing things
we experience that more from a first person perspective
than if we watch videos of other people doing things.
Use your imagination here folks.
So if you're somebody for instance
who's trying to get better at a particular skill
this could be not just sport but also public speaking
watching videos of yourself doing that can be very effective
but of course we have to come back
to the first principle
of effective mental training and visualization
which is that whatever it is that we're trying to build up
or consolidate as a skill needs to be brief and repeated.
So what we're really talking about here
is watching a video of ourselves on loop
or listening to a audio or audio video recording
of ourselves on loop for whatever aspect
that we're trying to build up or improve upon.
Now for people that for instance are trying to get better

at dealing with public speaking
and there isn't a particular skill
or utterance of particular sentences
or words that they're trying to accomplish
but rather they're trying to learn to be more relaxed
or to articulate better in the public speaking scenario.
There would be one of the few instances
in which I suggest more general theme
and not exact recapitulation of some specific words
that you're going to say.
Perhaps it could be a sequence of you walking out
onto stage toward the podium or out from the podium
and facing the audience and looking in multiple directions
up and down to see people in every corner of the room
and just repeating that on loop in your mind's eye
or watching yourself do that on video
and making yourself calm in your internal state
as you're doing that.
This is more of mental autonomic training
because what you're really trying to do
is control your autonomic nervous system,
the nervous system aspect that controls how alert
or calm you are as opposed to a specific skill.
However, you could also translate this to dance steps
or to motor sequences for playing an instrument and so on.
So the point here is that it's not as if there is zero
utility to third person mental training and visualization.
There can be, but first person mental training
and visualization is going to be more effective
as I mentioned before.
And if you're going to use third person
mental training and visualization,
ideally you would be looking at yourself either on video
or listening to yourself and audio and or video.
That is going to be more effective than closing your eyes
and trying to imagine yourself from a third person
perspective in your mind's eye.
Okay, so just to make it really simple,
first person better than third person visualization,
if you're going to go with third person visualization,
try and go with real third person visualization
where you're actually seeing and or hearing yourself
on a screen.

And again, this was somewhat of a surprise to me.
I always thought that mental training and visualization
was done with eyes closed.
I thought, okay, close your eyes.
You imagine this, you imagine that.
That's actually not the case for many, many studies,
some of which are considered real hallmark studies
within the field of mental training and visualization
and the different neural circuits that it recruits.
And along those lines is a really interesting study.
It came out not that long ago.
This was just a summer of 2022.
I'd like to discuss in a little bit of detail
because it really hammers home a number of the principles
that we've talked about.
The title of the article is mental practice modulates
functional connectivity between the cerebellum
and the primary motor cortex.
Going to tell you the essential features of this study.
First of all, primary motor cortex,
sometimes called M1 is a relatively small
but vitally important strip of neurons
in or near the front of your brain.
The neurons there are called upper motor neurons.
They communicate through a set of neural connections
with what are called lower motor neurons.
The lower motor neurons sit
in what's called the ventral horn of the spinal cord.
So along the spinal cord, you have sensory inputs
coming from skin and muscle
and what's called proprioceptive feedback
that tells you where your limbs are
in relation to each other and to yourself and so on.
You also have motor neurons that live in the spinal cord.
They're actually the ones that send little wires
that we call axons out to the muscles,
release the acetylcholine onto those muscles
and allow those muscles to contract.
Lower motor neurons are the ones
that actually generate movement.
However, they are largely responsible
for reflexive movements or already learned movements
and they require some input

from things like central pattern generators
and some other circuits
within the spinal cord and brainstem.
But it's those M1 primary motor cortex neurons
that are called upper motor neurons
because they control lower motor neurons
through directed action, okay?
So when I say primary motor cortex,
I'm really talking about those upper motor neurons, M1.
The cerebellum is an area in the back of your brain.
If you were to look at a brain,
you'd see two lobes back there that are highly foliated.
Foliated means that lots of folds
and lots of bumps and grooves back there
and actually means mini brain.
It looks like a kind of a mini brain
stuffed in the back of the brain.
In certain animals, the cerebellum is much larger
than the rest of the brain in humans.
The cerebellum is relatively small
compared to the rest of the so-called neocortex,
the outer shell, the human brain.
The cerebellum is involved in balance.
It's also involved in eye movements.
It's also involved in timing and motor learning.
And the key thing to understand
is that the cerebellum communicates
with the primary motor cortex
and it can do so through what's called inhibition.
It has outputs that inhibit the activity of neurons
in the motor cortex and elsewhere
and that has a profound influence
on the execution of motor behavior
and the learning of particular motor behaviors.
Now, I don't wanna get into too much detail around all this
but what you need to know is that
the cerebellum communicates with M1 primary motor cortex.
M1 is primary motor cortex.
Those are the upper motor neurons that control
the lower motor neurons and are going to control
physical behavior and execution of physical movements.
The communication between cerebellum
and primary motor cortex is inhibitory

although it can activate motor cortex too.
And this gets into a little bit of technical detail
but there can be inhibition of inhibition.
So if you take something that's a break
and you inhibit that break,
what you end up with is more excitation, okay?
So the takeaway here that's key
and everyone should be able to understand
even though you may or may not be following
this whole cerebellum primary motor cortex thing
is that when we gain a new skill
or we get more proficient at a skill,
so faster and more accurate,
there tends to be more net excitation
of the cerebellum to motor cortex communication.
And that is accomplished by reducing inhibition.
So that's where it gets a little bit confusing to some
but in this paper, what they did
is they explored people's ability to improve
on a very specific but very simple motor sequence.
It's one that you're already familiar with.
It's that tapping sequence that I talked about before
where the thumb is digit one, index finger number two,
middle finger number three,
ring finger number four and pinky finger number five
and it's a one, two, one, three, one, four, one, five,
one, two, one, three, one, four, one, five.
And they had people actually perform this
and they measured their speed and accuracy
and then they had them do a practice session
that was either an intentional task.
So one group just looked at an attentional cue
and had to maintain focus on that attentional cue
and another group did mental practice.
They basically did 50 imagined trials.
So just in their mind's eye of this one, two, one, three,
one, four, one, five on repeat, 50 trials,
much in the same way as what I referenced
as the ideal protocol earlier, 50 rounds of that.
Then they got tested again on the motor task in the real world
and there were also recordings of the cerebellar
to primary motor cortex communication.
So there were a bunch of different results in the study

I think are interesting but the ones that are most important
are that, quote, we found that mental practice
enhanced both the speed and accuracy
of this one, two, one, three, one, four, one, five
performance in the real world
when people did these 50 imagined trials.
There are many results out there, different papers
that parallel and essentially say the same thing
as what is said in this paper.
And remember, there've been studies of mental training
dating back to the 1880s.
But what this paper really does,
it looks at the neural machinery
and the changes in the neural machinery.
And what they found using transcranial magnetic stimulation
both in the context of stimulating
but also recording activity and connectivity
between cerebellum and primary motor cortex
is that mental training enhanced the net excitation
of cerebellum to motor cortex communication.
That is it reduced the inhibition in a way
that allowed motor cortex to generate these movements
with more accuracy and more speed.
What's also interesting about this paper
is that it showed that the improvement
in performance of this task was not related
to activation of the motor pathways themselves.
So it's not the case that the cerebellum activation
or inhibition changed the patterns of excitation
going directly to the spinal cord
because those pathways actually exist
through a couple of intermediate stations.
What it really showed is that when people do mental training
and here you could say, okay, 50 trials,
that's a lot of trials,
it's not actually that many trials.
It's pretty fast learning if you think about
do a task in the real world,
do 50 trials of the imagined task,
do the trial in the real world again,
significant improvement in speed and accuracy
through now what are becoming
to be established neural circuit connections

between cerebellum and primary motor cortex.
So this study is one of several
but not a tremendous number of studies out there
that are starting to really pinpoint
the underlying neural circuits
that allow mental training and visualization
to really improve motor skill performance.
But again, and please hear me on this in this study
and in the vast majority of other studies
that have shown significant improvement
in motor performance in the real world
by use of mental training and visualization,
there was an ability of each and everyone in the study
to perform the specific motor sequence in the real world
that then they were able to enhance
with mental training and visualization.
Now thus far we've been talking mostly
about performance of motor sequences
and one of the things to really understand
about performance of motor sequences
both in the real world and in the imagined context
is that it involves the doing
is what we call a go action
and not doing certain things.
What do I mean by not doing?
Well, for many tasks out there,
even ones as simple as the one, two, one, three, one, four,
one, five tasks that we talked about a moment ago,
there is the need not just to tap those fingers
in the correct sequence as quickly as possible
but also to be accurate about it to not do one, three, one, four
or one, three and four at the same time.
So there's both a go component, an action component
and a withhold action component.
And the ability to withhold action
is strongly constrained by the time domain.
In other words, the faster that we need
to perform a given motor sequence,
the more likely we are to perform incorrect components
of the motor sequence as well, okay?
So one of the key things
about mental training and visualization
that's really remarkable is that it can also be used

and has been shown to improve not just go aspects
of motor performance and cognitive performance
but also no go aspects of motor performance
and skill learning.
Now the go no go thing is something I've discussed before
on this podcast in reference to the so-called basal ganglia.
Basal ganglia are subcortical.
So they're below that bumpy surface of the human brain
that we're most accustomed to seeing
when we look at it from the outside.
And the basal ganglia are strongly involved
in go versus no go type tasks and learning.
Now, there are only a few studies
that have really looked at the learning
and the improvement of no go components of motor learning
but these no go components are really, really important.
In fact, if we were to look at what's involved
at improvement in a golf swing or shooting free throws
or getting better at piano or getting better at math
or language speaking, I think it's fair to say
that at least half and probably as much as 75%
of motor learning is about restricting
inappropriate movements or utterances or thoughts
if what you're trying to learn is purely cognitive.
I think that's an important point
that brings us back to our initial learning
when we come into this world, that developmental plasticity
which as you recall, we have a lot of interconnected aspects
of our brain and nervous system early in life.
Remember the example of the kid trying to eat
and getting a spoon of food and bowl on their head, et cetera.
And then over time getting more accurate
at bringing food to their mouth and eating in a clean way,
things that most but not all people accomplish
at some point in the course of their lifetime.
Well, there haven't been many
but there have been a few very interesting studies
looking at how mental training and visualization
can improve the no go aspect of motor learning.
And I think this is important to highlight
because it really mirrors what's done in the real world
as opposed to just the finger tapping type things
which are mostly go tasks.

Again, there's a little bit of a no go component there
but there are specific tasks
that people have developed for the laboratory
that really closely mimic action learning
and cognitive learning in the real world.
And one of the more important of those
is what's called the stop signal task.
Now the stop signal task is something
that I'll explain to you.
I'll also provide a link in the show note caption
so you can try it.
It's actually a lot of fun to try this
because it really gives you a sense
of just how challenging some of these laboratory tasks are.
Let me just describe it for a moment.
The stop signal task was really developed
and popularized by Gordon Logan and William Cowan.
Gordon Logan is at Vanderbilt University
and has done a lot of really important work.
But one of the important aspects of his work
is looking at motor performance and skill acquisition
and the development of the stop signal task.
I'll describe the stop signal task for you now
in broad contour.
You or another research subject
would sit in front of a screen.
There are two keys on that keyboard
or two keys among the other keys on that keyboard.
One which is designated left.
The other which is designated right.
And then on the screen, you'd be presented for instance
with a left facing or a right facing arrow.
So in the initial trial, what would happen is
that arrow would pop up on the screen
and your job is to press the left key
when the right facing arrow is presented,
you press the right key.
Okay, pretty straightforward.
But there's a limited amount of time
in which you can do this.
And the idea is that you're going to need to do this
within approximately 500 milliseconds
of the presentation of that arrow

or else it's going to tell you that you missed that trial.
Now, of course, if you press the wrong key,
so if the arrow goes left and you press the right key,
then you would be told you got that one wrong, okay?
So this is a reaction time test
and not one that's particularly novel.
What's novel and what Logan and Cowan developed
was that in the stop signal task,
every once in a while, not every trial,
but every once in a while, that arrow is presented.
And then with some delay ranging from anywhere
from 100 milliseconds to maybe 350 milliseconds,
there would be a red circle
or a red X also presented, which is a stop signal.
And your job is to not press the key
that corresponds to the direction of arrow,
in fact, not press any key at all.
Now, you can imagine how if the stop signal shows up
with a longer delay after the presentation of the arrow,
there's a higher probability
that you will have already generated
the key pressing movement, okay?
So at the link that we provided in the show note caption,
you can actually do these two tasks.
And what you'll find is that you and most people
will be able to do this arrow to reaction time pressing
of the left to right key somewhere in the neighborhood
between 300 milliseconds
and maybe as long as 500 millisecond delay,
you'll get an average of how quickly you respond.
And then of course, if you choose to,
and I would hope you would choose to go on
and do the stop signal task,
you will be told trial by trial,
whether or not you are hitting the right keys,
because if you are, you'll be allowed to progress
to the next trial.
Or if you are told to stop,
that is you get the stop signal and you press the key anyway,
you'll be told that you made an error
because you did not stop.
Now, again, with very short delays
between the presentation of the arrow and the stop signal,

you are going to be much better at inhibiting
or preventing yourself from the behavior
at the no go aspect of motor execution that is.
What you will find is that if the stop signal
is presented very shortly after,
let's say 100 milliseconds,
which is a very, very brief amount of time,
after the presentation of the arrow,
there's a good chance that you're going to be able
to withhold the key pressing behavior.
However, if the delay is anywhere from 200 to 350 milliseconds
after the presentation of the arrow,
chances are that you're going to press the button
even when you shouldn't have on at least some of those trials.
And if you try and game the system
and wait a certain amount of time
after the presentation of each arrow,
there will also be times in which the stop signal
does not appear and you fail to hit the button
in the appropriate amount of time.
So it's a fun little task, it doesn't cost anything
or set maybe a couple of minutes of your time.
And if you do have time to go to it,
I think it will give you a much deeper flavor
for the sorts of experiments that we're talking about here
and that you'll find that these stop signals
are actually pretty hard to generate
when you're trying to learn some new motor behavior.
And that actually illustrates a bigger point here.
If today you sense that we've been talking about studies
of tapping fingers and stopping button presses
and that those examples are highly artificial
and don't really translate to the real world,
well, keep in mind that the tasks
that are used in these studies really target
the specific neural circuits,
that is the same neural circuits
that you would use for the performance
of essentially any motor task.
Now, of course, other motor tasks
like ones where you involve your feet or cognitive tasks
where you have to think really hard
about specific information and search for that information

and assemble it in particular ways,
of course, involve other neurons and neural circuits
that we haven't discussed today.
But the core components of these go and no go task
or the stop signal task really capture
the core elements of most all of cognitive
and or motor learning in some way
that's fundamentally important, okay?
So they have real world relevance.
The paper that I'd like to just briefly describe to you
is entitled Motor Imagery Combined with Physical Training
Improves Response and Abition in the Stop Signal Task, okay?
So that title is a little bit wordy,
but now you know what the stop signal task is.
And what this paper essentially found was that
if people did physical training,
so the sort of experiment that I just described
versus mental training where they sat eyes open
and imagine their responses to those arrows
and stop signals,
but they didn't actually generate any key presses
versus a combination of the physical training.
So the actual pressing of the buttons
or withholding pressing of the buttons
as the case may be, plus mental training
over the course of about five days,
using the contour described of the key principles
of mental training and performance that we've talked about.
I'll get to the specifics in a moment,
but it really obeyed most all of what we've talked about,
if not all of it.
So repetition, simple, repeated over about five days
and so on and so forth.
What they found was that the mental training
and physical training groups,
so mental and real world training groups
perform significantly better
in the stop signal reaction time.
That is they were able to withhold action
when they needed to withhold action.
More frequently and with more accuracy
vended either the physical training
or mental training groups alone.

So this actually spits in the face of what we said earlier,
which is that physical training is always better
than mental training
and mental training is always better than no training.
And it's important to point out here
that both the physical training
and the mental training groups
experience significant improvements
in their reaction time and accuracy
at the stop signal task.
But in the case of this study,
which is exploring the withholding
of inappropriate behaviors,
the combination of mental training and physical training
outperformed either physical or mental training alone.
So while earlier we said
that if you have a certain amount of time
in order to train something up,
physical training is always going to be better
than mental training.
Well, here we have somewhat of an exception
where if the thing you're trying to learn
involves withholding mistakes
as opposed to trying to generate the right behaviors per se,
well, then you are probably better off
doing a combination of mental training
and physical training.
Let me state that a little bit differently.
If you're finding that you're screwing up something,
not because you can't initiate
that particular motor behavior,
but you're doing the wrong thing at the wrong time,
you're not able to withhold a particular action,
well, then in that case,
mental training in combination with physical training
becomes especially important.
So for you coaches, for you students out there,
keep that in mind.
When trying to learn how to withhold
particular action sequences
because they're not serving you well in the real world,
using a combination of real world training
and physical training is actually better for you

on an hour per hour basis than is physical training alone.
A couple of key details about this study
should you decide to implement these protocols.
In this study, they did approximately 30 trials
of the thing that they were trying to get better at.
Now they did those in the real world.
So in this case, the stop signal task
involved actually pressing those buttons,
and then they had a test phase of about 144 go trials
and about 48 stop trials.
So this is important.
If you are a coach or you're a student
or you're just gonna self-direct this kind of learning
in your self-directed adaptive plasticity,
it's important that you mix in both go and no go trials.
It wasn't always the case
that there was a stop signal generated.
The other thing that was really impressive about the study
is that the changes occurred very quickly.
So the training was performed five times over five days.
So once a day for five days,
again, back to this three to five times per week principle.
And the improvements were really significant in some cases.
In fact, if you decide to peruse this paper,
you can go to table two,
you can see in some cases a near doubling
in the reduction in reaction time
through a combination of mental and physical training
compared to physical training alone
or mental training alone.
Again, however, both physical training
and mental training groups alone
saw significant improvements,
but the combination of mental training
and physical training was far greater
than you saw with either one of those alone.
So that's all nicely quantified for you in this paper.
So again, I really like this paper.
Despite it not involving a huge number of subjects,
I think it is a key paper
because it really points to such an important element
of motor learning and training,
which is this action withholding component,

this no-go component that here is captured so nicely
in the stop signal task.
So before we round up our discussion
about motor training and visualization,
I wanted to just briefly touch on some of the studies
that have explored why certain individuals
are better or worse at motor training and visualization
and what that might correlate with.
At the beginning of today's episode,
I briefly mentioned affentasia,
which is this phenomenon where some people just simply
can't or seem to have extreme challenge
generating visual imagery.
In a number of studies exploring how affentagics,
as they're sometimes called, although nowadays
it's not considered polite, if you will,
to refer to people according to their condition.
So for instance, propasagnosia is a condition
in which people are unable to recognize particular faces.
And in the past, these people were referred to
as propasagnosics, as if their condition defined them.
Nowadays, it's not considered polite to do that.
Rather, we say the person has propasagnosia
or suffers from propasagnosia,
although the word suffer then also
has become a little bit touchy.
I'm going to do my best to just try
and be as clear as possible here
and explain that people who have affentasia
can have affentasia to varying degrees
so they can either have a complete absence of ability
to generate mental imagery,
or they have a poor or kind of rudimentary ability
to generate visual imagery in their mind's eye.
It was thought that people who have affentasia
are not capable of what's called synesthesia.
Synesthesias are when people have perceptual blending,
and this is not while under the influence
of any kind of psychedelic or other kind of drug,
perceptual blending of an atypical kind or rare kind.
I actually have some friends,
two friends that have different forms of synesthesia.
One associates different keys on the piano

or musical notes with specific colors
in a very, very one-to-one specific way.
So they'll tell you that E-flat on the piano
is a particular tone in their mind of amber hue, okay?
And that I forget what other key is associated
with a particular shade of red and so on and so forth.
Are these people better at piano?
Are they more perceptive of colors in their environment?
Not necessarily so.
This is just a perceptual blending.
It doesn't necessarily lend itself to any improved ability.
Now you could imagine why people would hypothesize
that people who have affentasia,
especially its extreme form,
would not be capable of or have synesthesias.
It turns out that's not the case.
There are a couple of really interesting papers.
Again, we will link these in the show note captions.
One is entitled,
What is the relationship between affentasia,
synesthesia, and autism?
And the other one is affentasia,
the science of visual imagery extremes.
And I really like to review affentasia,
the science of visual imagery extremes
for those of you that are interested
in understanding affentasia with more depth.
The study addressing the relationship
between affentasia, synesthesia, and autism
found that affentasia is indeed linked
to weak visual imagery,
but that affentasia can also be synesthesics.
And vice versa.
What was also interesting about this study
is they addressed the question of whether or not
people who have affentasia,
that is a challenge or inability to generate
mental or visual imagery,
tend to have features associated with autism
or residing somewhere on the autism spectrum.
And I'm not trying to use ambiguous language here,
but the whole set of language and nomenclature
around autism and autism spectrum

is also undergoing revision now,
because we are now coming to understand
that autism and nowadays,
it's generally not considered correct
to call people autistics in that sense,
but autism is considered one set
of positions along a spectrum
that includes things like aspirators, et cetera,
but that may also include other aspects
of cognition and even personality.
So these are starting to be viewed
not just as a spectrum or one continuum
ranging from non-autistic to autistic,
but a lot of variation and subtlety in between
and even crossing over with other aspects
of personality, psychology, and neuroscience.
So I'm not trying to be vague here.
I'm trying to be accurate,
rather by saying the whole description
and categorization of autistic, non-autistic, et cetera,
is undergoing vast revision right now.
But the important point I think from this paper
is that indeed it was found that people who have affentasia
tend to exhibit more of the features
that are associated with the autism spectrum.
Now, how those things relate to one another
in terms of their clinical relevance isn't clear.
And of course, it is entirely unclear
as to what's the chicken and what's the egg there.
So you could imagine, no pun intended, for instance,
that people that are on the autism spectrum
might be less proficient at generating visual imagery
because they are exceedingly proficient at other things.
You could also imagine that people are placed
on to the autism spectrum as it's sometimes referred to
or are associated with particular features
on the autism spectrum because in a causal way
of the affentasia, and of course,
it's extremely important to highlight
that not all people that consider themselves
or that people consider autistic
or that are on the autism spectrum
or Asperger's or any variation thereof

necessarily have affentasia.
Just as it is that not all people
that are on the autism spectrum
completely lack or even lack what's called theory of mind,
which is the ability to sort of empathize
and as describe feelings and motivations of others
when viewing the actions and perceived feelings of others.
So what I just described,
hopefully doesn't come across as just a bunch of word soup.
What I'm trying to pinpoint is that there does seem
to be a relationship between one's ability
to generate visual imagery and certain constellations
of cognitive and emotional perception and behavior
and vice versa, okay?
In a future episode, I promise to cover synesthesia
and autism and some of the related cognitive
and motor aspects of autism and things like Asperger's.
I'm going to feature an expert guest
or actually several expert guests in this area
because it is a rapidly evolving
and somewhat controversial field.
Meanwhile, I think it's important to at least consider
how mental training and visualization might relate
to certain aspects of cognition
and our ability to visualize things,
not just in terms of other people's behavior,
which is one of the common ways that people probe
for autism and Asperger's versus non-autistic
and non-Asperger's and so on,
the so-called theory of mind task
and in fact, asking whether or not children or adults
can really get in the mind of others.
That's a typical task developed by Simon Baron Cohen,
but also whether or not children and adults
are capable of generating mental imagery
in a really vivid way
or whether or not they have minor
or even extreme challenge in doing so.
And perhaps the most direct way to explain
why I included this aspect of the discussion
of mental training and visualization
as it relates to different cognitive phenotypes
or neurocognitive phenotypes,

such as autism, Asperger's, et cetera,
is because if you think about motor skill execution
or cognitive skill execution
and the relationship between mental training
and visualization and motor skills or cognitive skills,
that's all pretty straightforward
when you're talking about finger tapping
and go-no-go tasks and learning piano
and things of that sort.
But in many, many ways, our learning of social cognition,
our learning of how to behave in certain circumstances,
what's considered normal or atypical,
neurotypical and neuroatypical, if you will.
A lot of that is not just generated from the inside out,
but it also involves observation and visualization
of what are considered appropriate and inappropriate,
definitely placed in quotes, by the way, folks.
I'm not placing judgment, I'm just saying appropriate
and inappropriate for a given context behavior.
In other words, social learning and social cognition
is every bit as much a learned behavior
and pattern of cognitive and motor patterns,
as is tapping fingers or withholding key presses
in a go-no-go task.
It's just that it transmits into a domain
that involves smiling versus frowning,
versus asking a question, versus staying silent,
versus sitting still, versus fidgeting what's appropriate
and when, what's inappropriate and when.
All of that is what we call social cognition
and it has direct parallels
to everything we've been talking about up until this point.
So today we did a deep dive,
which is often the case on this podcast,
into mental training and visualization.
During the course of the episode,
I tried to lay down one by one the key components
of an effective mental training and visualization practice,
everything ranging from making sure
that the practice involve brief epochs,
repeats of specific sequences of motor
and or cognitive behavior,
that those be relatively simple so that you can imagine them,

even if you're somebody who is not good
at doing mental training and visualization.
And I should mention that if you do mental training
and visualization repeatedly over time,
you get better at mental training and visualization.
There's a, what's called meta-plasticity here.
So it's not just about engaging neuroplasticity
of particular circuits,
it's also about getting better at engaging plasticity.
So plasticity of plasticity.
I also described the key importance
of being able to actually execute specific movements
and cognitive tasks in the real world,
if you want the mental training and visualization
to be especially effective.
And we talked about the importance of naming things,
we talked about the importance of creating,
not just one, but many parallels
between real world training
and mental training and visualization.
And really on the whole, what we established was
that cognitive and or motor learning
really is something that you should do in the real world
as much as possible,
but if you can't do to injury or whatever conditions,
using mental training is a reasonable substitute,
but not a complete substitute.
And if you can't do real world training
for whatever reason, injury or otherwise,
that mental training is going to be better
than no training at all.
And of course, we established that at least for
withholding action in order to get better at a skill,
a combination of physical training
and mental training is going to be best,
but that if you're trying to learn a new skill
and you're having challenges with performing that skill
because of an inability to do the skill in the first place
or on a consistent basis,
well then on an hour by hour basis,
you're best off investing your time
into the physical training,
only incorporating mental training and visualization

if you are able to do that on top of the maximum amount
of real world training that you're capable of doing.
And of course, we talked about the actual neural circuits
and a bit about how the actual neuroplasticity occurs.
Early in the episode, I mentioned long-term depression.
Well, in describing the improvements in no-go tasks,
those stop signal tasks,
a lot of what's observed during those tasks is improvement
or rather an increase in long-term depression
of specific neural connections.
So my hope is that in learning about those basic neural
circuits and plasticity mechanisms,
and in learning about the critical importance of focus
and attention during learning, both real world and imagined,
as well as the importance of sleep and deep rest
for really consolidating learning
and the different tools, the various steps or principles
of effective mental training and visualization
that you now have a fairly coherent
or maybe even a very coherent picture
of how to develop the best mental training
and visualization protocols for you.
I realize that everyone has different goals,
everyone has different time constraints.
If you are somebody that's interested in developing
a mental training and visualization protocol,
so if you're a coach or teacher or simply a learner
or you're trying to self-direct your own adaptive plasticity,
I wanna emphasize that the key components
that we discussed today are essential to include,
but I wouldn't obsess about whether or not
a given epoch is 15 or 20 seconds or even 25 seconds.
I wouldn't obsess over whether or not
you got 30 repetitions in and then your mind drifted
or whether or not you could do the full 50 to 75
or whether or not even in your mind's eye
you made some errors.
What's been shown over and over again in this literature
is that performing mental training and visualization
repeatedly and in a very restricted way
that makes it easier to perform those trials
over and over and over again
and with a high degree of accuracy.

Almost always, really we can fairly say
in essentially every study where it's been explored
has led to improvements in real world performance
of both cognitive and or physical tasks.
So if you're trying to learn anything at all,
I do encourage you to explore motor training
and visualization because basically all the studies out there,
in fact, I couldn't find one exception
where some degree of improvement wasn't observed
when people use motor training and visualization
on a consistent basis,
even just the three to five times per week,
these simple repeats over and over.
So I don't want to over complicate
or make it sound like mental training and visualization
has to be performed in a very precise way
or that it has to be done perfectly each and every time
quite to the contrary.
What is clear is that mental training and visualization
is a very effective way to improve real world performance.
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Not so much on today's episode,
but on many previous episodes of the Huberman Lab podcast,
we discuss supplements.
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many people derive tremendous benefit from them
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And at all those places, I cover content,
some of which overlaps with the content
of the Huberman Lab podcast,
but much of which is distinct from content
on the Huberman Lab podcast.
So again, it's Huberman Lab on all social media platforms.
Also, I know many of you are interested
in summaries of podcasts and what we call toolkits,
which describe ideal toolkits and protocols for sleep,
or ideal toolkit and protocols for neuroplasticity,
or for deliberate cold exposure, et cetera.
For that reason, we've established what's called
the Neural Network Newsletter.
This is a completely zero-cost newsletter
that you can sign up for by going to HubermanLab.com.
Go to the menu, scroll down to newsletter,
and you sign up by providing your email.
We do not share your email with anybody.
And there are also some sample PDFs
of existing Huberman Lab podcast protocols,
again, ranging from neuroplasticity to sleep,
and other topics that we've covered
in brief one to three-page summaries.
Thank you once again for joining me for today's discussion,
all about the science and effective implementation
of mental training and visualization.
And last, but certainly not least,
thank you for your interest in science.