The Degrees of Freedom Problem (and Why a Good Teacher Is Worth Their Weight in Gold)

Description

At first glance, throwing a crumpled up ball of paper into a trash can seems like a pretty simple task. Hold with fingers, and flick forward with wrist and elbow. How hard can that be?

But when you get serious about developing your trashketball skills, it becomes apparent that the throw is not so simple.

Unlike, say, a trashketball-playing robot with fixed joints that is perfectly calibrated to make a basket by moving in exactly the same way every time, our joints and limbs are flexible and can move in many different directions and planes of motion. As a result, we can get the paper ball into the trash can in many different ways. By varying the angle of our wrist. The angle of our elbow. The speed of the throw. The release point and trajectory. Our stance relative to the target. Heck, there's probably a near-infinite range of variations and combinations of such factors that would end in the same successful result.

But not all of these variations are equally good. Some will be more efficient (take less energy or effort to achieve the same goal), while others may result in greater consistency, accuracy, and a higher percentage of makes.

Which brings us to one of the main challenges in learning a complex skill – the "**degrees of freedom problem"** (a.k.a. the motor equivalence problem). With so many possible combinations that can end in the same result, is it enough just to know if we made the shot or not? Or is there something more we need to maximize our learning?

After all, just because we make a shot doesn't mean that we did so in the most effective way. Maybe we simply got lucky, and made the shot despite using a low-percentage technique. Or perhaps we really did stumble onto the most effective way to throw paper into a trash can…

Speed, pressure, and point of contact

My childhood teacher's favorite mantra was "Speed. Pressure. Point of Contact." I remember her joking that she ought to make t-shirts for everyone in the studio with these words printed on the front.

If you're a string player, you'll recognize these as the three main variables which affect sound production. For instance, if you want to play louder, you can apply more bow weight to the string, but may have to speed up the bow to avoid crunching. Which might result in running out of bow, so you could slow down the bow, keep the weight the same, but move closer to the bridge to compensate in a different way.

This formula was burned into my brain from the time I was 9 or 10. And it saved me a ton of time and frustration. Any time I didn't like the sound I was getting, I was able to do a lot of troubleshooting on my own. Rather than experimenting aimlessly in dozens or hundreds of non-relevant areas, I knew exactly where to look; it helped reduce the complexity of sound production from a gazillion different things, to three key factors.

So, going back to the question of whether it's enough to know if something sounded good or not, I'd say that sure, these results are an important piece of the puzzle, but for best results, we need more. If we want to learn more efficiently, it helps to have some idea what the key variables governing success are for the task at hand, whether it's shifting to a high position, playing double stops in tune, or playing fingered octaves.

Target practice

A recent study studied this by having 23 participants engage in a computer-based target shooting challenge.

Once strapped in front of a screen, participants were instructed to hold a robotic arm, and when an arced target area appeared on screen, make a quick pushing movement to land their cursor in the middle of the target zone. Imagine playing air hockey on a pizza slice-shaped table, where your goal is to get the puck to land on the crust, and you've got the idea.

The game was set up to make it look like the *distance* of one's pushing motion was the key factor in achieving success, while the direction in which one pushed didn't matter. But in actuality, the direction *did* matter. Unbeknownst to most of the participants (except five, who were explicitly told that the direction of their push might have an impact on their success), there was a small sliver of the target zone which resulted in a higher chance of success than anywhere else along the "crust".

The 18 participants who weren't told about the importance of direction, had no idea which movement factors (e.g. speed, arm posture, initial acceleration, grip strength, etc.) would help them land in the target area, and just had to figure it out for themselves.[1]

Awareness enhances learning

Despite going through the same number of practice repetitions, the unaware participants' scores didn't improve with practice. As far as they were concerned, success/failure was somewhat random – they never figured out how to increase the likelihood of a successful result.

The participants who were (or became) aware of the importance of direction showed a much larger learning effect, getting increasingly closer to the secret high-probability-of-success area of the target zone with practice.[2]

Simply knowing when they hit the target or not didn't help the unaware participants achieve successful outcomes more often. Only when they knew exactly what movement direction to vary did they start changing their behavior in a way that increased the likelihood of success.

Take action

There's certainly something to be said for experimentation and exploration in the practice room.

But this exploration seems to be most productive if we *already know what variables to manipulate*. Because if we're lost, stumbling around in the dark, and have no idea which factors are important and which ones aren't, it's probably going to be an awful long time before we figure out which is which.

Sort of like trying to reverse engineer a recipe. It's one thing if we know what the ingredients are and just need to figure out how much cilantro vs. pepper vs. cayenne we need, and how long to simmer, bake, or sauté the ingredients. But if we have no idea what spices are in the dish, or what the key ingredients are, it's going to take us an awful lot of blind trial and error to stumble across the right combination.

And that's where our teachers (and more experienced colleagues) can be so invaluable. As my teacher once did many years ago, reducing the number of variables in the equation to just the key ones that give us the most bang for our buck can save us from a lot of teeth-gnashing and exasperated grumbling. Not to mention help us be more independent learners and improve faster!

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