JAMES TEMPERTON ISABEL FRASER SCIENCE JUN 19, 2024 7:00 AM

How to Take the Perfect Soccer Penalty

To understand how to take a match-winning penalty, you've got to understand the physics behind the perfect kick.

Kai Havertz of Germany scores from the penalty spot in their opening Euro 2024 game against Scotland. PHOTOGRAPH: CLIVE MASON/GETTY IMAGES

SAVE

THE PENALTY WAS invented in England on February 14, 1891. It was the last minute of an FA Cup quarter-final between Notts County and Stoke City when a defender for County stopped a shot on the line with his hand. Stoke were awarded a free kick just centimeters from the goal-line, and the goalkeeper, as was perfectly legal at the time, stood right in front of the ball. The Stoke player, unable to do anything other than kick it straight at him, saw his shot blocked in farcical circumstances.

At a subsequent meeting of the International Football Association board in Glasgow on June 2, 1891, a motion for a new penalty-kick rule was suggested by the Irish FA. The board approved and, just like that, decades of anguish and joy were born. Sort of. The original rule stated that players could take a penalty "from any point 12 yards from the goal-line" and the keeper could advance at least 6 yards to save it. But, over time, that has been tweaked and finessed into what we know and love/hate today.

The likelihood of any penalty being scored is around 70 percent. At the 2022 World Cup, 22 of the 29 in-game penalties awarded were scored (76 percent). Until the beginning of this year's Euros, 88 penalties had been awarded in the competition, with 62 scored (70 percent). Penalty shootouts—introduced into the Euros in 1976 and the World Cup in 1978—also have roughly the same conversion rate. In World Cup shootouts, 222 penalties out of 320 have been successful (69 percent). In Euros shootouts, the conversion rate is a little higher: 178 out of 232 (77 percent).

But why must penalties be taken from 12 yards? Simple: That's what the FA decided in 1891. And it's likely never been changed, because scoring seven out of every 10 penalties gives a good mix of risk, reward, and drama.

Move the ball any closer or farther away and the odds start to tip too far one way or the other. As John Wesson points out in *The Science of Soccer*, taking into account air drag, a perfectly directed "penalty" hit at 80 mph into the top corner of the goal could, in theory, defeat a goalkeeper from 35 yards. Move 10 yards or closer to the goal and the likelihood of scoring rises steadily. At 3 yards, it is almost 100 percent.

Seemingly by fluke, 12 yards is pretty much the sweet spot: Enough penalties go in to reward skill and good placement, and enough penalties are saved to reward good guesswork, research, and agility by goalkeepers. Of those 88 in-game Euro penalties awarded before the 2024 tournament, only 18 were saved. England's Jordan Pickford is one goalkeeper who has used past behavior of penalty takers and their preferred goal placements to predict their future choices, keeping this data on his bottle for reference.

For a striker, relying on physics to score the perfect penalty is all about two things: speed and direction. At 80 mph, a goalkeeper has about one-third of a second to make a save. As this is similar to their reaction time, the only chance of it being saved is to guess correctly where it is going. And that's where placement comes in. Research carried out by the University of Bath in 2012 found a "diving envelope" that any given keeper can cover if they push off in any direction with maximum force. The probability of scoring inside the diving envelope is 50 percent. The probability of scoring outside the diving envelope is 80 percent.
The diving envelope covers 70 percent of the goal area, meaning a penalty taker has 30 percent of the goal to aim at to dramatically improve their odds of scoring. And if they hit it, they invariably score. For top penalty takers, having a top conversion rate is all about preparation. In his career, England's Harry Kane has taken 85 penalties and scored 74, a success rate of 87 percent. "I try to practice all different types of situations and make sure I'm ready for anything that comes," Kane has said. When the time comes, Kane already has a plan in place for how he is going to score a penalty. That clarity of mind, combined with great technique, increases his chances of scoring. "I'm ready for everything, whether it is a penalty, a set-piece," he has said.

So what does this all mean? If you want physics on your side, aim high and hit the ball hard. In this regard, one fairly recent rule change that was designed to help goalkeepers may have had the opposite effect. Until 1997, goalkeepers had to remain stationary in the center of the goal until a ball was struck. Since the rule change, they've been allowed to bounce along their line, dramatically changing the range of their diving envelope. This means they can potentially reach far more of one side of the goal, but leave the other side wide open. Clever penalty takers now use this to their advantage by subtly changing the speed of their run up to shift the goalkeeper's weight.

Research conducted by the University of Exeter, in 2009, tracked the eye movement of footballers when taking a penalty. Sports scientists gathered 14 university-level football players and fitted them with special glasses to track their eye movements. They were asked to attempt two types of penalty. First, the researchers asked them to try their best to score. In the second round, they were told their efforts would be recorded and shared with other players and that the best penalty taker would receive a £50 prize. This was designed to increase the pressure of taking the penalty—although it doesn't mimic the pressures of a real-world spot kick. The results showed that when anxious, footballers looked at the goalkeeper significantly earlier and for longer, making it more likely that a player would focus on the keeper and shoot more centrally. Penalty takers who focused too much on the goalkeeper saw their attempts saved 40 percent of time, compared to less anxious players who were able to ignore the goalkeeper, resulting in a lower save rate of 20 percent.

Physics is all well and good, but as the eye-tracking experiment shows, footballers are not robots. And under the most extreme pressure it turns out the brain plays even crueler tricks on you.

According to researchers from Bangor University, players consistently miss vital penalties by inadvertently making the exact error they are trying to avoid. The so-called "ironic error" effect is the result of players subconsciously assessing all the likely outcomes and then becoming overwhelmed. In a high-pressure situation like a Euro or World Cup penalty shootout, knowing that you *could* hit the post overrides the more statistically likely outcome: that you *should* score. Simply put: Under immense pressure to score a penalty, the mind is drawn ever close to focusing on how you could miss. The result? You miss. And football is no longer coming home.

This article was originally published by WIRED UK. *It has been updated for the 2024 Euros tournament.*

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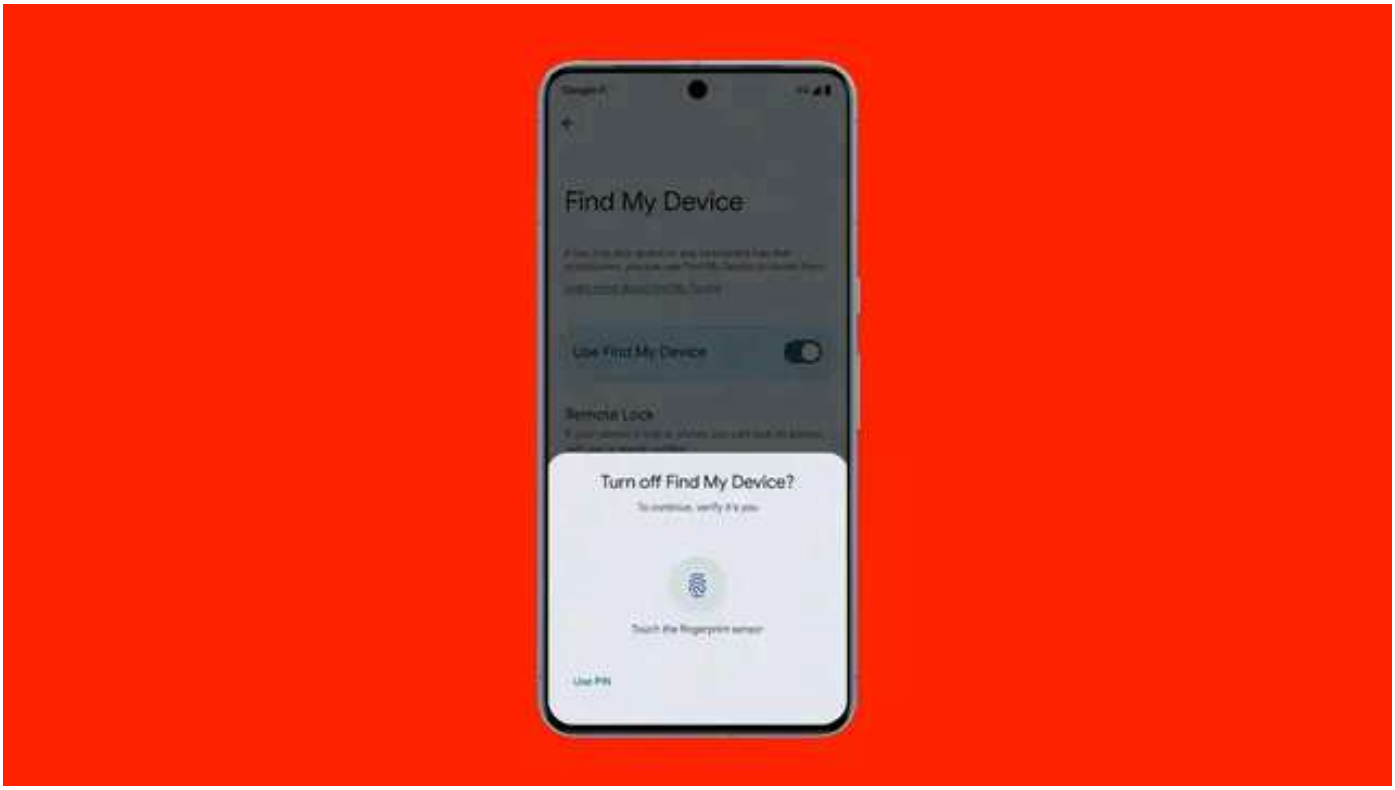

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