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New research rethinks how we grab and hold onto objects

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New research shows the most important factor in determining how hard you grip an object, like a glass, isn't what you know about it but what you don't. Credit: Jeremy Brooks/Flickr

It's been a long day. You open your fridge and grab a nice, cold beer. A pretty simple task, right? Wrong. While you're debating between an IPA and a lager, your nervous system is calculating a complex problem: how hard to grasp the can.

We never know exactly how heavy or slippery an object will be until we grab it; we need a way of predicting those things so that objects don't slip out of our hands. For years, researchers thought that grip force—how hard we grab an object—parallels the expected load force—the weight—of the object.

Now, researchers at the Harvard John A. Paulson School of Engineering and Applied Science (SEAS) have shown that the most important factor in determining grip force isn't what you can estimate about the object but rather what you can't. Maurice Smith, the Gordon McKay Professor of Bioengineering, and postdoctoral fellow Alkis Hadjiosif have shown that the amount of variability associated with estimating an object's physical dynamics, such as its weight, is the most important factor in determining grip force. They described their findings in the *Journal of Neuroscience*.

Take the can of cold beer. When you grab it, the minimum grip force required depends on the weight of the beer and the friction coefficient between its surface and your fingers. On top of that minimal force, your nervous system implicitly factors in a safety margin to protect against miscalculations, such as if the can is heavier or more slippery than you may have expected.Previous research assumed this safety margin was a fixed fraction of the minimum required grip force, like the safety factors widely used in engineering design, but Smith and his team wondered if this was the most effective approach.

"Wouldn't it be more efficient for the motor system to reduce the safety margin when variability or uncertainty was low and increase it when variability was high," Smith asked. "This line of thinking leads to the idea that the safety margin should be determined not by the nervous system's estimate of the minimum required force but by its estimate of the uncertainty about that force. As it turns out, that's exactly what happens."

"It turns out that by making the safety margin proportional to variability, it's possible to maintain control over the probability of failure in a uniform manner in both high and low uncertainty environments. This achieves a fixed statistical confidence against failures like slip," added Hadjiosif.

If you're grabbing a clear glass of beer that you're familiar with, the amount of uncertainty is low. You know the weight of the glass itself, how slippery it is, what's in it, how much and whether or not it's sloshing around. From this, your motor system can make a pretty precise estimate about the glass's dynamics and safely use a grip force just above the minimum required force, with only a small safety margin.

But if you're grabbing an opaque cup or an object you're unfamiliar with, the higher uncertainty about required grip force would necessitate a stronger grasp with a higher safety margin to minimize the chance of slip.

Dynamical variability in the environment also comes into play. You hold your beer more tightly standing in a crowded bar, where someone might bump into you and your beer, than sitting in your living room at home.

Understanding the mechanisms behind grip force control could result in a better understanding of how neurological disorders affect the neural calculations that underlie this control.

"We are still in our in the infancy in understanding how the nervous system goes about making many of the calculations it needs. For example, we don't know how neurons compute estimates of variability and uncertainty. Grip force control may be a good model system for answering that question," said Smith.

Smith and Hadjiosif observed that grip forces are three times more sensitive to the standard deviation of the load force than to the expected load force.

This sensitivity leads to some interesting behaviors.

"The high sensitivity that grip forces display to variability makes the surprising prediction that handling an unexpectedly light object leads to stronger rather than weaker grip forces, at least transiently," said Smith.

Let's say your friend hands you a box that you expect to be full of rocks, but is actually full of cotton balls. Experiencing this surprise has two very different effects. It decreases your expectation about how heavy the box is for the next time you hold it, but it also increases future uncertainty and therefore increases the safety margin you use for that box.

"Although the reduced weight expectation would tend to appropriately decrease the grip force your nervous system produces, the increased uncertainty about the load estimate would widen the safety margin, inappropriately increasing the grip force," said Hadjiosif. "We show that because the grip forces are considerably more sensitive to uncertainty than expected load, the widening of the safety margin overrides the effect of the reduced weight expectation, resulting in grip forces that are actually higher the second time you lift an unexpectedly light object."

In these situations, only after uncertainty is decreased by repeated lifts, would grip forces be reduced to suit the lighter-than-expected object.

"As far as we know, this is the first time that a motor learning system has been observed where responses to a stimulus veer systematically in the wrong direction at first," said Hadjiosif.

More information: "Flexible Control of Safety Margins for Action Based on Environmental Variability." *Journal of Neuroscience*, 17 June 2015, 35(24): 9106-9121; DOI: 10.1523/JNEUROSCI.1883-14.2015

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