Charting a path to powered exoskeletons

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Exoskeletons are devices that are worn for protection or support—like a suit of armor or a helmet. Those and other passive devices have been around for millennia, but today's researchers are developing powered exoskeleton systems that, in the future, could take humans to new levels of strength and endurance.

By providing additional power, they could improve the endurance of soldiers on the battlefield or help workers perform tasks more easily and safely. They could also help injured and disabled people regain their independence.

But to make next-gen exoskeletons work, we'll need to rethink our ideas about how wearable systems interact with the humans who use them. Associate Professor Leia Stirling is doing just that in the U-M Department of Industrial Operations and Engineering. Formerly with the MIT aeronautics department, Stirling's human factors work at U-M is shedding new light on how powered exoskeletons change the way their wearers think and move. Stirling's latest paper is titled "Static, Dynamic, and Cognitive Fit of Exosystems for the Human Operator." We sat down with her recently to learn more about her work.

We've all seen plenty of exoskeletons in movies like Iron Man and RoboCop. Are those the kinds of systems you're working on?

Not exactly–I think full-body exoskeletons are still a long way off. In the meantime, though, there are more limited powered exoskeleton applications that can assist people with specific movements, like adding support and power to an ankle or a knee. Those are the low-hanging fruit, and we are starting to see these systems commercially. But there's a lot of work to be done before they become practical for widespread use.

Why are even single-joint powered exoskeletons so much more complex than passive systems?

When we add power to even a simple exoskeleton, we need to start thinking about it less like a piece of clothing and more like a very small vehicle. When I put on an exoskeleton, I'm inside it and it's actively moving me. So we need to think about it from a human perspective—how can the user drive that vehicle most efficiently and safely?

That's a departure from the past, where exoskeleton researchers mostly focused on the mechanics of the devices. And it means that human factors researchers like me need to be working with mechanical engineers to get these machines to the next level.

How do you know that powered systems affect the wearer differently than the braces and other devices we've had for years?

All systems can affect the way we move and powered systems are no exception. For example, not long ago, we did a study where participants wore a simple powered exoskeleton—one that provided extra power for the ankle as they pushed their foot off the ground while walking. We turned it on, and we found that different participants used that boost very differently as they adapted to the system. Some took longer steps, some took shorter steps, some stayed the same. Some went back to their normal gait patterns after we turned the power off, some didn't.

The study showed that even a small change alters the feedback loop that enables us to navigate our environment. These changes can occur both consciously and unconsciously. We need to understand how these powered systems affect our perception, cognition, and motor process and how we can design the exoskeletons to appropriately adapt to individual users.

How do you measure whether a powered exoskeleton "fits" its wearer?

We've actually rethought the idea of "fit" in a recent paper we published. We've broken it down into three separate aspects.

The first is "static fit"—this is what we're used to, as in how well does this device fit the size and shape of my body when I'm not moving.

The second dimension is "dynamic fit," i.e. how well the device moves with me. Is it restricting my movement, and does it fit properly during the entire range of movement I'll need to perform for a set of tasks?

The third dimension, and the one that we're least accustomed to, is "cognitive fit." This dimension measures how a device that I'm wearing changes the way I think about movement, both consciously and unconsciously. How am I interpreting the feedback I get from the device? And how can the makers of a device adapt its feedback to the cognitive processes of different users?

Powered exoskeleton devices inherently provide tactile feedback because of the way they apply forces to the body during motion. But we're also looking at how we can design in explicit feedback to help users build confidence in the devices and make them easier to use efficiently.

If we now need to consider these new factors, does that mean we're losing ground on the road to new kinds of exoskeleton systems?

On the contrary, identifying these additional dimensions is all part of the process of building new kinds of machines. Exoskeletons really are interdisciplinary systems, so designing them requires a unique set of skills. This research provides a framework to make that happen.

In fact, one of the reasons why I came to Michigan was that there were all these people thinking about exoskeletons from all these different perspectives. I'm really excited to be in a place where there are all these people looking at it from different angles who can work together.

More information: Leia Stirling et al. Static, Dynamic, and Cognitive Fit of Exosystems for the Human Operator, *Human Factors: The Journal of the Human Factors and Ergonomics Society* (2020). DOI: 10.1177/0018720819896898

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