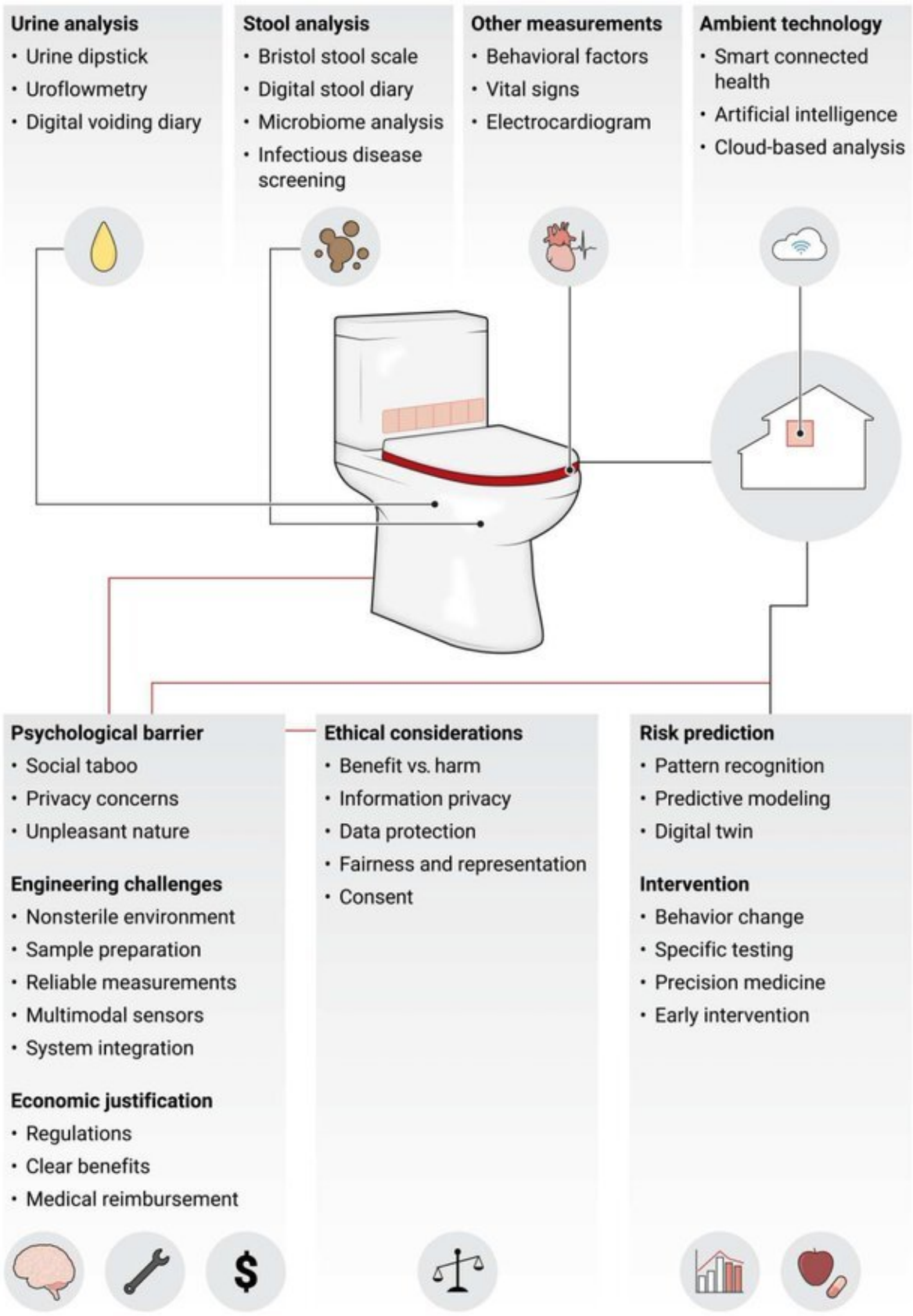
Human feces and urine contain a motherlode of health data: 'Smart toilets' detect daily fluctuations, serious disease

March 1 2023, by Delthia Ricks


Urine analysis
• Urine dipstick
• Uroflowmetry
• Digital voiding diary
Stool analysis
• Bristol stool scale
• Digital stool diary
• Microbiome analysis
• Infectious disease screening
Other measurements
• Behavioral factors
• Vital signs
• Electrocardiogram
Ambient technology
• Smart connected health
• Artificial intelligence
• Cloud-based analysis
Psychological barrier
• Social taboo
• Privacy concerns
• Unpleasant nature
Engineering challenges
• Nonsterile environment
• Sample preparation
• Reliable measurements
• Multimodal sensors
• System integration
Economic justification
• Regulations
• Clear benefits
• Medical reimbursement
Ethical considerations
• Benefit vs. harm
• Information privacy
• Data protection
• Fairness and representation
• Consent
Risk prediction
• Pattern recognition
• Predictive modeling
• Digital twin
Intervention
• Behavior change
• Specific testing
• Precision medicine
• Early intervention

Credit: *Science Translational Medicine* (2023). DOI: 10.1126/scitranslmed.abk3489

A disease-detecting toilet capable of a range of monitoring and surveillance activities could soon be reality, and while the device may test for everything from how fast your urine flows to reporting on your vital signs, some people may be a bit squeamish about daily health updates from the ubiquitous receptacle for smelly wastes.

The new spin on the loo is called a "smart toilet," and it is being developed at Stanford University in California. There, researchers are transforming the old porcelain throne into a high tech screening and monitoring device that incorporates artificial intelligence and is connected to cloud-based technology. Stanford scientists are testing the smart toilet in studies with participants who've volunteered to have their wastes scrutinized before they're flushed.

One of the prototype toilets is in the home of Stanford researcher, Dr. Seung-min Park, who, on the university's website, is credited with being the inventor of the Precision Health Toilet.

In addition to all of the health parameters that are screened by the smart toilet, the device also records each time number one and number two are deposited, giving the user a complete tally every 87 days. As a veritable home-based laboratory, the Stanford research team sees the smart toilet destined for bathrooms around the world.

Reporting in *Science Translational Medicine*, Park and colleagues describe the system as "passive monitoring," a non-invasive method, they

say, that is being designed to use artificial intelligence to extract vital health information from human poop and pee.

"We think that there's a psychological barrier. That's one of the most impeding factors for smart toilet development," Park said during a journal *Science* podcast, referring to paltry few advances in the use of smart toilets for broad-scale health monitoring.

"People just think that it's too dirty or it's unpleasant," he continued. "Even scientists believe that it's not a worthy subject to investigate. That's the reason why I started this project at the School of Medicine, because [health care professionals] are always dealing with a human substance, such as blood, and urine and stool every day. They're more open-minded dealing with human excreta."

Among health data drawn from the toilet, the smart model records urine color and fecal morphology. "That's all very important information for physicians," Park said during the podcast. "Actually, I talked to various gastrointestinal doctors [and] urology doctors and they're very eager to know those kinds of parameters."

The smart toilet looks like a standard model but is being designed to ultimately detect multiple signs of illness through the identification of specific biomarkers in urine and stool samples. With an early prototype in use and being tested among research participants, Park and his team are at work on an even more sophisticated version.

Stanford's smart toilets have the potential to detect an array of health data using computer vision and deep learning as the toilets conduct analyses of urine and stool. In the works is a smart toilet that screens for certain cancers, such as urological and colorectal malignancies. Going for screening in the not-too-distant future could mean a simple trip to the bathroom. And in the case of fecal analysis for colorectal cancer,

alleviating the need to send samples through the mail.

Other smart toilet targets include microbiome analysis as well as bacterial and viral disease screening and monitoring parameters such as temperature, heart rate and oxygenation.

Such technology could facilitate the daily collection of a wide range of health-related data, thus creating "a gateway to the 'digitalization' of health care in the home," Park and his colleagues write in *Science Translational Medicine*.

Human stool and urine contain a wealth of biological information, thus raising the profile of the lowly toilet to the 21st century's go-to apparatus for health monitoring and disease detection. The Stanford team developed a custom sensor that allows the toilet to do its jobs. Now, Park and his collaborators envision additional sensors that can make the smart toilet even smarter, transforming the average bathroom into a passive but sophisticated and flushable lab.

"We're just using the very first sensor [and] that is called an optical scanner," Park said, describing the inner-workings of his current prototype.

Via optical scanning, both urine and stool samples are captured on video and are then analyzed by algorithms that can distinguish healthy urodynamics—urine stream—from a flow that is unhealthy. Park, a physicist, is an instructor in urology at Stanford. The smart toilet analyzes urine flow rate, stream time and total volume. Stool consistencies are also analyzed.

"An optical scanner doesn't need any kind of reagent, the only thing it needs is electricity," Park added. "We are scanning the human excreta every time people defecated or urinated," he said of study participants.

With stream analysis, the toilet deploys urinalysis strips, or dipstick tests, to measure a host of molecular features. White blood cell count, levels of specific proteins and more can point to a spectrum of diseases, from infection to bladder cancer and kidney failure. It may even be possible with a future smart toilet to take a pregnancy test courtesy of built-in dipstick technology.

But as with any new technology that collects health information, there are concerns about privacy and ethics. On top of that are the taboos in many cultures cautioning against discussions of toileting habits. Moreover, the implementation of passive health monitoring presents several as-yet unresolved questions regarding data security and consent.

"There are myriad technological, behavioral, and ethical challenges in collecting data from the activity and products of human excretion," Park wrote on Twitter, referring to his invention. "Discussing toileting events, for example, remains socially unacceptable in many cultures.

"A smart toilet for health monitoring has been depicted in science fiction for decades," Park added. "But only a few commercial products can automate collection and analyze health information from human excreta."

The newly reported research builds on an an earlier study led by the late Dr. Sanjiv "Sam" Gambhir, also of Stanford, an early innovator in the smart toilet concept. In April 2020, Gambhir was the senior author of a paper published in *Nature Biomedical Engineering* involving 21 participants. Park served as senior research scientist on that report.

From the beginning of that project, the Stanford team wanted to make certain that the smart toilet could discern which member of a household was using the device. Being able to distinguish between users is important because of the individualized nature of the health data being

collected. That problem was solved by having the flush lever read fingerprints.

Beyond personal health, Park sees smart toilets playing roles in public health, especially when outbreaks occur. Municipal wastewater collection and analysis have become critical resources in COVID-19 tracking, and reliance on wastewater testing increased as cases of poliovirus emerged in New York and beyond last year.

Park sees a system of smart toilets—possibly hundreds of them—providing precise outbreak information sooner and in greater depth. "A wastewater study is just a collective, the lump sum of everyone's poop, right?"

"I think if we have a large network of smart toilet systems, it will be a very, very useful resource for public health because we [will] know where the outbreak started, and we can effectively contain that," Park said.

More information: T. Jessie Ge et al, Passive monitoring by smart toilets for precision health, *Science Translational Medicine* (2023). DOI: 10.1126/scitranslmed.abk3489