Why Is Safe Science Good Science?

Camilla M. Kao,[a] Che-I Kao,[b] and Russell Furr[c]

[a] School of Engineering, Stanford University, Shriram Center, 443 Via Ortega, Stanford, CA 94305, USA (E-mail: ckao.science@gmail.com; tel: 713 397 6490)
[b] Houston, TX 77081, USA (E-mail: ckao.science@gmail.com)
[c] Environmental Health & Safety, Stanford University, Environmental Safety Facility, 480 Oak Road, Stanford, CA 94305, USA (E-mail: rfurr@stanford.edu; tel: 650 721 2582)

Greater Control = Reduced Uncertainty = Safety + Quality

- **Better statistics** of the experimental data (reproducibility, sensitivity, coverage, etc.)
- **Other improved properties** of the experiment (yield, purity, viability, sample sizes, cost, etc.)
- **Innovation** --- considering safety issues is a hands-on activity analogous to prototyping in design thinking and creative limitation in the arts
- **Reduced risk**

In science, safety can seem unfashionable. Satisfying safety requirements can slow the pace of research, make it cumbersome, or cost significant amounts of money. The logic of rules can seem unclear. Compliance can feel like a negative incentive. So besides the obvious benefit that safety keeps one safe, why do some scientists preach that “safe science is good science”? Understanding the principles that underlie this maxim might help to create a strong positive incentive to incorporate safety into the pursuit of groundbreaking science.

Many highly experienced researchers say anecdotally that doing an experiment safely causes a scientist to do it well. Safe science does not *guarantee* good science --- a safe experiment can be scientifically meaningless. But usually safe science seems to be “good” science. Why would this be the case? What does safety have to do with the quality of an experiment and with other sought-after outcomes?

First, being safe in the laboratory can improve the statistical quality of one's data. An experiment can have better sensitivity, reproducibility, coverage, etcetera. This relationship exists because being safe induces a researcher to have **greater control** over an experiment, which reduces the **uncertainty** that characterizes the experiment. For example, writing a detailed protocol will lessen the uncertainty surrounding one's physical actions, helping the researcher to avoid mistakes that could be dangerous. **Safety** is increased (which is the same thing as reducing risk). But a detailed protocol will also enable the researcher to conduct the experiment in exactly the same way in the future, making repeated trials more accurate and precise. **Statistics** will improve, e.g., "error bars" will be smaller.

Second, a relationship between safety and quality exists because greater control over an experiment improves **countless other properties**. Examples include the yield and purity of a product, the viability of living cells, the sizes of samples (e.g., smaller sizes being desirable), and cost (e.g., lower being better).

The third relationship is between safety and **innovation**. When considering issues about safety, one obtains new ideas about how to conduct an experiment. New ideas lead to innovation. This process is analogous to **prototyping** in design thinking, where physically building something brings one to points where decisions need to be made and new ideas emerge. **Creative limitation** (1) has the same effect in the arts. In poetry and screenwriting, for example, the artificial barriers of rhymes and genres, respectively, force an artist to make decisions that are unrelated to the art's content. New ideas form and the art takes unexpected turns. Like prototyping and creative limitation then, the hands-on nature of **considering safety** is a decision-making process that can foster innovation in research.

Recently chemists at Eli Lilly reported a continuous manufacturing process that demonstrated how safety and innovation can go hand-in-hand (2). As one of many advantages of the new process, safer operating conditions permitted the chemists to run this reaction step **faster**:

> The flow process included a step involving hydrazine—a compound used in rocket fuel—that would have been too dangerous to run in a batch reactor. Because flow chemistry uses a small amount of the reagent continuously instead of a large amount all at once in a batch process, the chemists could run the step safely at **high temperature and pressure** [bold emphasis ours] (3).

Let us return to the original question, "Why is safe science good science?" Greater control over one's experiment reduces the uncertainty that characterizes the experiment. Less uncertainty improves both safety (by reducing risk) and the quality of the experiment (better statistics and other improved properties). Considering safety issues is a hands-on activity that spawns innovation.

If you are a researcher, this point should be clear: Safety is good for your science!

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