and disadvantages, it undoubtedly provides valuable, reproducible training for OP-CAB.

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Commentary: Getting to Carnegie Hall

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CENTRAL MESSAGE

Research in technical skills training should account for the various aspects of cognitive load. Study designs may not be able to control or adjust for some confounding aspects.

In 1878, the Russian composer Pytor Ilyich Tchaikovksy completed composition of his *Violin Concerto in D Major* (Op. 35). For the first 3 years, the concerto was not publically performed because the Czar's court violinist Leopold Auer reportedly declared it unplayable. Since then, it has become not only a standard in the repertoire of professional violinists but also among the most frequently performed violin concertos.[1] This radical transformation may be tied to late 19th century pedagogical advancements in violin playing. Although Auer did eventually perform and teach the concerto, of the 3 contemporary violin treatise authors with the greatest influence on modern pedagogy, Auer focused the least on technical aspects.[2]

In human technical skills performance, skills that do not primarily rely on physiology (eg, strength and flexibility) or adjunctive technology must look even more to a systematic method of training. In cardiac surgery, opportunities for technical skill training have traditionally occurred in an apprenticeship model, with experience gained during actual patient care. Increasing patient risk profiles and scrutiny of outcomes has led to investigations of simulation as an adjunctive method of training.[3] This has challenges of fidelity, reproducibility, cost, and efficacy. Hence, widespread standardized simulation remains in evolution more than a decade after its role in cardiothoracic surgical training was envisioned.[4]

Wu and colleagues[5] report their findings of a randomized study of trainees who were novices to coronary artery bypass grafting (CABG), comparing training on a beating heart model with a nonbeating model. Participants were tested on both models after 3 months of training. Significant findings were that those who trained on beating heart models improved to a greater degree in use of needle holder

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and forceps, needle angles, and completion time; there were no differences in the other aspects of coronary anastomosis.

The most interesting aspect of this study is the initiation of novice training with the more complex, high-fidelity model. The empirical evidence that complex high-fidelity simulation improves skills acquisition or transfer has previously been weak, or even contrary.[6] Rather, the paradigm for complex tasks has been to simplify conditions and to isolate focus on individual core skills. Nonsurgical examples of this paradigm include sports drills and musical études (the French word for *studies*), designed to provide practice material for perfecting a particular skill. In fact, Wu and colleagues[5] refer to this concept when describing training as graduated. This concept is rooted in the cognitive load theory. Human cognition is viewed as a natural information processing system in which there is a limit to the number of information elements that can be processed at any given time (ie, limited working memory).[7] For novices, this creates a bottleneck to long-term learning. The quality of instructional design can be improved by decreasing nonessential aspects of the task (external load) and titrating essential aspects to the learner's developmental stage (internal load). In this framework, the finding by Wu and colleagues[5] that the high-fidelity trainer cohort had significantly greater improvements in some domains may seem counterintuitive.

There are a few study limitations that may explain this. First is the ambiguity surrounding the novice to CABG group. It is unknown to what extent trainees had experience with general surgical skills or vascular anastomoses before the study. Second, in addition to the learner, the setting and instructor influence aspects of cognitive load during learning. In fact, instructor engagement was the only factor positively associated with the third component of cognitive learning—germane load—that refers to the processes that lead to actual learning.[8] It is highly possible that instructors may have been more engaged with the newer, high-fidelity training model due to its novelty. Such confounding would be difficult to control or adjust for. Finally, to be clear, the model should not be interpreted as technical training for off-pump CABG; skill in maneuvering and positioning the heart for revascularization of vessels other than the left anterior descending artery were part of neither instruction nor assessment. Although it may be tempting to rush to apply this novel teaching method, some caution is needed in interpreting the results. Particularly for the early stages of practice, further research is needed before we can define the optimal instructive techniques in technical skills competency.

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