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Editorial

Refocusing Surgical Resident Education Amidst the COVID-19 Crisis: A Mental Imagery-Based Transfer Learning Model for Virtual Teaching of Operative Fundamentals

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Editorial

Surgical education has always been reliant on hands-on training. The rise of the virtual learning environment ushered in by the unprecedented COVID-19 pandemic has thus provided a challenge for surgical residents. Several academic programs around the country have made changes to their didactic curriculum [1,2]. At our neurosurgical residency program, to facilitate continued operative education in a virtual learning environment, we experimented with a novel chief resident-led teaching curriculum. We focused on operative fundamentals via a virtual didactic experience. Its novelty was nestled in the approach. We informally combined two different learning frameworks - mental imagery and transfer learning-to produce an effective modality for virtual teaching of operative fundamentals.

In the context of surgery, mental imagery asks the learner to think deeply about surgical steps and maneuvers without watching or physically performing them. Prior studies have shown that mental imagery enhances motor learning and skill acquisition by activating specific motor circuits involved in the completion of the imagined task [3,4]. Mental imagery is, of course, not new in surgical training. The ritual of "talking through" a case is practically a sine qua non in a resident's operative training paradigm. While useful, these "talk throughs" have several important practical limitations: 1) they commonly occur the night before a surgery, the morning of a case, or even at the scrub sink, 2) they may only focus on certain parts of the surgery, and 3) they are dependent on the resident learner's current knowledge set. The solution for the first two limitations is simple: time. With a dedicated block, a "talk through" transforms from rushed "pearls" to a holistic didactic. The third limitation however presents a challenge for efficiently learning new content with mental imagery alone, since it is difficult for a learner to imagine content they have not consistently seen. However, in a virtual learning environment, it is important to be able to learn new information while not being able to practically experience it. Our solution to this challenge arises from the Artificial Intelligence (AI) literature.

Transfer Learning (TL) is a concept in AI that describes the process of extracting relevant knowledge from a previously learned Source Task (ST) and applying it to a novel Target Task (TT) [5,6]. The transferred relevant knowledge enables the TT to be learned at a more efficient rate [7]. As a neural network is trained, the necessary features for discriminating information are fine-tuned. For instance, a fully-trained neural network used in self-driving automobiles enables the rapid, accurate distinction between a stop sign and a yield sign. The neural network learns that primary distinctions between the two are of shape and color; these features therefore have large weights associated with them. If the neural network needs to learn something more complex, such as a "Do Not Enter" sign, it would pair shape/color with the specific pattern inside the sign. If this "Do Not Enter" sign were being learned from scratch, it may take thousands of iterations of images to reliably classify that sign given brand new rules. If the neural network starts instead by using weights of prior training, it would immediately be able to identify this sign as different than the stop or yield signs it has been trained to detect. It would then take a relatively small amount of additional training to learn the distinguishing pattern of the new sign. This process is TL, and it co-opts fine-tuned feature weights created by a ST (distinguishing stop sign vs. yield sign) to quickly learn a TT (identifying a "Do Not Enter" sign).

Applying these principles to surgical education, a ST could be a surgery that is known to a resident, while a TT is a more advanced surgical approach. Leveraging transfer learning would allow the resident learner to understand the new operative fundamentals more efficiently via immediate modification of previous knowledge. To achieve this, as directed by the AI literature, fine-tuned feature weights that can connect the ST to the TT must be identified. In the surgical education domain, the fine-tuned feature weights come from the chief resident.

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Considering limitation three described above, "talk throughs" are dependent on the resident learner's current feature weights in order to effectively learn new features. An attending surgeon has a different set of feature weights developed over a career that helps distinguish key moments during a surgery. Teachable insights based on these weights may not be effective for a more junior resident learner. However, since chief residents have recently transitioned from the junior level, they are able to use their own weights to enable targeted knowledge transfer.

Our experimental didactics began in early March, as increasing numbers of elective surgical procedures were canceled, and were scheduled as three 90-minute sessions every week. We used the Blue Jeans virtual environment. Since the goal was providing a substitute for the gold standard of intra operative learning, the focus was purely on operative fundamentals. As such, sessions were structured as chief resident (PGY-7)-led step-by-step interactive walkthroughs of common neurosurgical pathologies and relevant surgical procedures.

An example is the case of a 58-year-old woman with a sphenoid wing meningioma. The surgical approach for this case, a pterional craniotomy, is considered a fundamental neurosurgical procedure. Understanding this approach relies on advanced topics that may be difficult to contextualize for a more junior resident who has not assisted in many of these cases. For example, the dissection of the temporalis muscle, part of the initial exposure for the approach, is a particular step that itself has at least three different approaches. Similar multifaceted surgical decision-making points exist throughout the case.

The PGY-7 would present the case and then have a junior resident use mental imagery to describe each step of the operation. Positioning, cranial pinning, incision planning, and operative maneuvers would then be reviewed sequentially by having that resident discuss both major, overarching considerations and patient-specific considerations for every step. Though more difficult, the use of mental imagery enabled the effective internalization of known content. We utilized transfer learning to help promote effective knowledge transfer of unknown content.

The chief resident functioned as the fine-tuned feature weights for transfer learning of novel information. Compared to the pterional craniotomy, a decompressive hemicraniectomy is a more frequently performed neurosurgical procedure in junior residency. In the TL model for pterional craniotomy, bony removal comprising a decompressive hemicraniectomy functions as a ST while the bony removal during pterional craniotomy functions as the TT. The chief resident prompts the resident learner through operative steps while referencing the decompressive hemicraniectomy, thereby using the resident learner's prior knowledge to morph the image of the ST into the TT (Figure 1).

Mental imagery-based TL in this manner has several benefits within the context of surgical education. As discussed, it enhances a natural method of learning for surgical residents. Our teaching sessions capitalize on this familiarity while also providing a protected session to delve into the key points of an operation. Another key benefit is that these sessions can be used to discuss common procedures, such as the pterional craniotomy discussed above. Weekly didactic sessions with attending surgeons more often focus on complex cases that provide teaching points that may not focus on operative fundamentals important for junior resident learners. The chief resident, due to proximity in training to the resident learner and as a relative expert in common procedures, has a strong grasp of available ST. The novelty of our mental imagery-based TL sessions is therefore the focus on operative fundamentals for common procedures, during the COVID-19 pandemic, the teaching of operative fundamentals is precisely the component of education most affected. The novelty of our mental imagery-based TL sessions is therefore the focus on operative fundamentals for common procedures, providing an effective method for internalization of known content and learning of new content.

Our TL model has inherent durability. As apparent in the AI literature, TL enhances the speed at which novel information can be learned. In an environment with growing concerns over work hours and changes in gradations of autonomy, TL principles are especially useful for providing a mechanism to more rapidly and efficiently learn new operative fundamentals. As virtual learning continues its meteoric rise in the COVID-19 era, teaching methods that require minimal preparatory work while retaining significant learner impact are invaluable. Given the ease with which we were able to perform these teaching sessions virtually, we believe they have longstanding utility.

To conclude, we restructured our surgical resident education during the COVID-19 pandemic to formalize virtual teaching of operative fundamentals. We utilized a mental imagery-based TL paradigm as a novel didactic format for achieving this. We found that mental imagery provided an effective method for internalization of known content, while transfer learning directed by the chief resident also enabled the rapid learning of new content for resident learners. Despite starting as a virtual learning exercise during COVID-19, we believe mental imagery-based operative TL may continue to be an impactful adjunct to surgical education well into the post-pandemic era.

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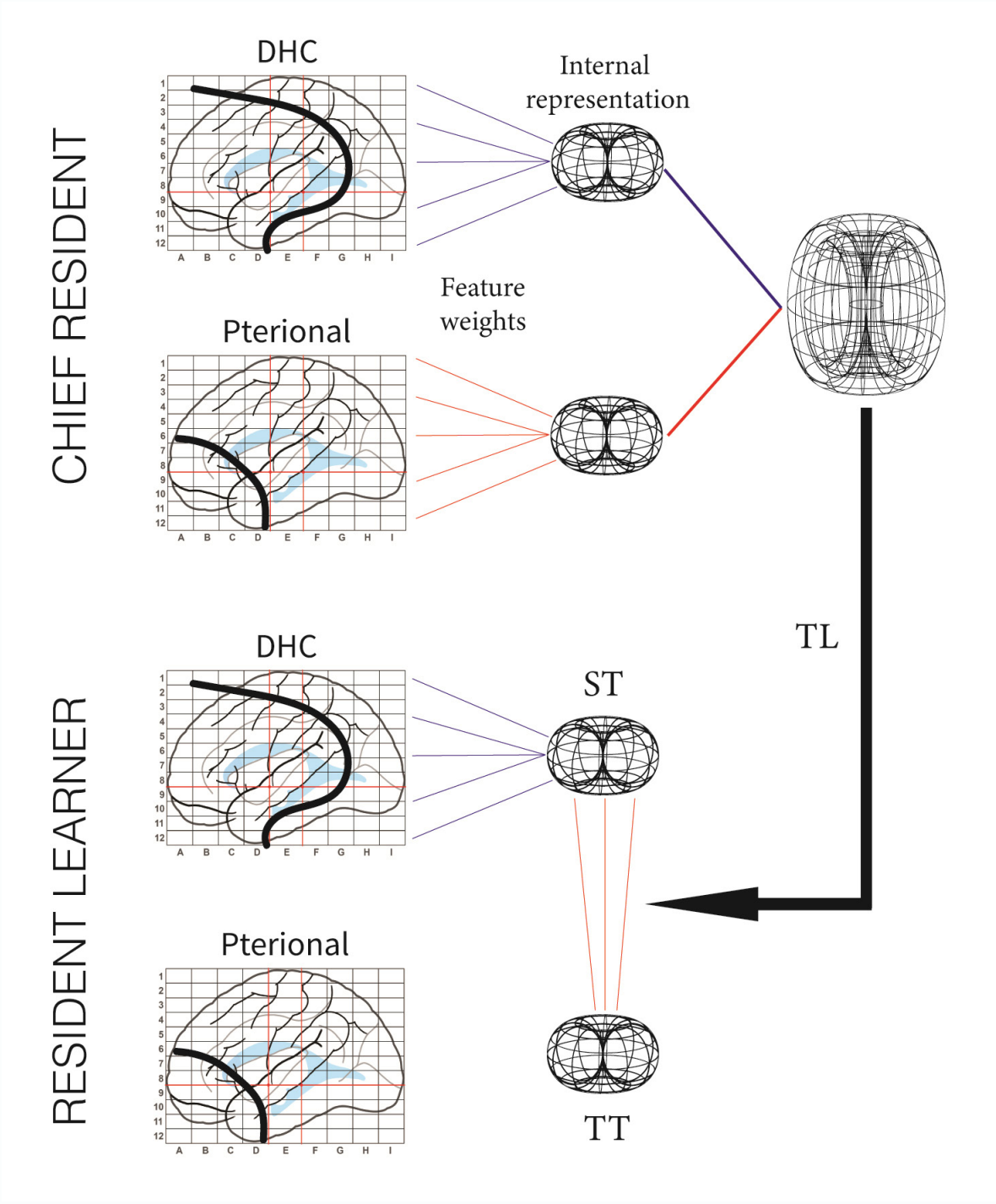

Figure 1: A schematic of the mental imagery-based Transfer Learning (TL) paradigm. The two surgeries, Decompressive Hemicraniectomy (DHC) and pterional craniotomy (pterional), are shown. The thick black line represents the scalp incision for each procedure, highlighting how the surgical approaches have some overlap but have major differences. In this example, the Chief Resident (CR) has ample experience performing both procedures, and over time has extracted the key feature weights for both procedures into different internal representations. The Resident Learner (RL) has previously performed and extracted relevant feature weights for the Decompressive Hemicraniectomy (DHC), but not yet for the pterional. Thus the DHC serves as the Source Task (ST), while learning the novel pterional approach serves as the goal, or Transfer Task (TT). Using Transfer Learning (TL), the feature weights of the DHC (ST) can rapidly enable learning of the pterional approach (TT) by iteratively fine-tuning the RL's weights using the feature set of the CR.