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REVIEW

A literature review on observational learning for medical motor skills and anesthesia teaching

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Abstract Motor skill practice is very important to improve performance of medical procedures and could be enhanced by observational practice. Observational learning could be particularly important in the medical field considering that patients' safety prevails over students' training. The mechanism of observational learning is based on the mirror neuron system, originally discovered in the monkey pre-motor cortex. Today we know that humans have a similar system, and its role is to understand and reproduce the observed actions of others. Many studies conclude that humans are able to plan and to make movements based on visual information by mapping a representation of observed actions, especially when the motor system is committed to do it. Moreover most researchers considered observational learning effective for complex skills, such as medical procedures. Additionally, observational learning could play a relevant role during anesthesia training since the learner works in pairs most of the time (dyad practice). Some teaching approaches should be taken into consideration: an implicit engagement of the observer motor system is required, immediate feedback seems to have an important effect, and a combination of observational and physical practice could be better than physical practice alone. In an environment where effectiveness and efficacy are essential, observational learning seems to fit well.

Keywords Observational learning · Dyad practice · Motor skills · Medical procedures · Anesthesia

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Introduction

Many medical procedures are known as ‘open skills’ in that they require physicians to adapt to unpredictable and ever-changing environments (e.g. orotracheal intubation and surgical suture). Motor skill practice thus becomes very important to improve performance of these medical procedures. Understanding the underlying mechanisms responsible for these motor actions plays an important role in developing even better training and learning systems for the skills.

Fine motor movements, like those used during complex medical procedures, stem from representations within the central nervous system (cortex and subcortex) such as action representation in perception, in motor control, and in motor learning (Elliott et al. 2011). According to Elliott et al., the exclusive attention to one object requires an organization of perceptual motor environments to limit receptivity by narrowing the range of stimuli. In order to facilitate the intended action, the representation in perception minimizes unwanted actions and distractions. The representation in motor control is organized to improve speed, accuracy, and energy consumption. Although errors are necessary to determine ideal performance, the final goal is to discover the optimal movement control. Elliott et al. also mentioned two components of the action representation in motor control: recall memory and recognition memory. These components are responsible for the relationship between the initial body conditions, the sensory consequences of the movement, and what movements are necessary to reach the desired outcome.

Motor skill learning can be enhanced by several factors, such as specificity of learning, variability of practice (Wulf and Schmidt 1997), knowledge of results, immediate feedback (Salmoni et al. 1984), and observational practice (Wulf et al. 2010). Observational learning, from a neuroscientific point of view, is based on the ‘mirror neuron system’ (Rizzolatti and Craighero 2004). Whenever we observe someone doing something, we activate the same neural connections that would trigger if we were to perform that same action ourselves (Di Pellegrino et al. 1992). Thus, by watching other individuals perform, we are able to generate representations and gain knowledge of specific actions.

Observational practice could be particularly important in the medical field considering that patients’ safety prevails over students’ training. Observational learning (specifically the dyad practice) is very prevalent during anesthesia training since the learner is assigned to a particular anesthesiologist each day, forcing them to work in pairs most of the time.

The goal of this review is to briefly explain the mechanisms of observational learning and its possible uses in medical motor skill education. Furthermore, investigation into the various ways observational learning can be utilized in the anesthesia setting will be conducted.

The mechanisms of observational learning

The mirror neuron system consists of visuomotor neurons, originally discovered in the monkey pre-motor cortex (Rizzolatti and Craighero 2004). These neurons were found to be responsible for the monkey’s own motor actions, but some of the same neural connections were also activated whenever the money observed the experimenters performing actions of their own (Di Pellegrino et al. 1992). Today we know (through neurophysiological and brain-imagining evidence) that humans have a similar system, and its role is to understand and reproduce the observed actions of others (Rizzolatti and Craighero 2004).

The first evidence of the existence of mirror neurons in humans was provided by Gastaut and Bert (1954). They observed similar EEG recordings during subjects’ active movements and while subjects were watching others' movements. These results were reproduced and confirmed by Cochin et al. (1999). Transcranial magnetic stimulation (TMS) studies have shown two important differences between monkey and human mirror neuron systems. Intransitive movements (a movement not directed towards an object) activate mirror neurons in humans but do not in monkeys, and movements *forming* an action are also coded by the system in humans, whereas only movements directly making up the action are coded for in monkeys (Patuzzo et al. 2003; Maeda et al. 2002). In addition to EEG findings, studies using magnetic resonance imaging (MRI) techniques show that neuronal circuits responsible for imitation and action observation are the same (Nishitani and Hari 2000; Iacoboni et al. 1999). All these studies, combined with many others (Watkins et al. 2003; Buccino et al. 2001) conclude that humans are able to plan and to make movements based on visual information by mapping a representation of observed actions.

Mattar and Gribble (2005) tested a different and interesting question: can observed information tell us *how* to perform certain movements, rather than just tell us which movements to make? The authors used a robotic device to generate novel forces to disturb the trajectory of the limb. The idea was to see whether observing another individual learning how to deal with the new forces could affect one's performance. The subjects held the end of the robot device and first performed movements in a null field, and then while watching a video showing another person learning. The subjects were randomly assigned to one of three groups: to observe someone learning a clockwise force field, a counter-clockwise force field, or to observe nothing. Surface electrodes were used to record muscle activation. From their findings they concluded that observers learned how to move more precisely in a new environment by watching another person learning. In addition, the authors tested whether observational learning was a conscious strategy. A group was asked to solve a mathematical problem while watching the video. Later the group was asked to perform rhythmic arm movements while watching the video. Then the subjects were asked whether they were aware of the forces they performed. Mattar et al. concluded that motor learning by observing is not a conscious act, it is not affected by a mathematics problem, it is reduced by an unrelated movement task, and an implicit engagement of motor system is required. In other words, the human motor system is able to learn how to make a movement only by observing others' performance, especially when it is committed to do it.

In another study, Kelly et al. (2003) suggest that it is possible to learn through observation even for high-level information movements. However, the learner needs explicit knowledge of the movements' sequence. They conclude that sequence learning by observation is mediated by explicit knowledge subcomponents.

Similarly, thinking about more complex movements, Petrosini et al. (2003) demonstrated the link between observational learning and the cerebellum. According to the authors, the cerebellum also contributes to the understanding and learning of others' action through imitation, especially for acquiring complex procedures. Spatial learning through observation is one the main processes where cerebellar processes play a large role.

On the other hand, Wulf and Shea (2002) questioned the lack of studies using complex tasks to explain motor skills learning, suggesting it might be because it is difficult to define complex movement. Increases in reaction time, movement time, errors, and variability have all been used in an attempt to classify what exactly constitutes a complex movement. No single definition has been shown to apply to all cases; however each definition has its use when applied to investigate specific interests. Nevertheless, research in observational learning has often utilized complex tasks. In fact, according to Wulf et al., observational learning seems to be more effective for complex performance than simple tasks. Interestingly, someone observing an action can in some ways receive more useful information about that specific motor skill than the person performing the action, as the observer is not as cognitively engaged as the performer. Therefore, the observer can better evaluate effective or ineffective performance strategies. In other words, the observer reduces the task complexity and selects the essential information. The observer can then break the whole task into subcomponents and construct an appropriate strategy to reconstruct them for themselves. Thus, because complex tasks usually require more attention, observational practice seems to be more effective for complex skills than simple ones.

In conclusion, the mechanisms of observational learning have been carefully studied and the existence of the mirror neuron system shown. The use of observational practice to learn general tasks is suggested by some authors, although it could be even more beneficial when applied to complex procedures. What remains to be answered is whether it is possible to take advantage of observational learning to improve medical motor skill education strategies.

Observational learning in medical education

Different approaches to motor skill education have been discussed in several studies due to the impact they have in improving performance of medical procedures (Elliott et al. 2011; Wulf et al. 2010; Kantak and Winstein 2012; Janelle et al. 2003; Moulton et al. 2006). Observational practice appears to be an effective learning method not only for lower level motor control but also for higher cognitive processes (Elliott et al. 2011). Although there is no evidence that observation is better than practice in medical education, it has been shown that it can improve motor skills specially when combined with practice (Wulf et al. 2010). The goal of this segment is to discuss the potential of observational learning to improve motor skills in medical education. First, whether it is appropriate to learn complex and high-stakes skills, like surgical procedures, through observation will be discussed, followed by a review of findings linking observational learning and medical training in general.

As discussed before, it is difficult to define a simple versus complex task due the variety of movement characteristics involved. Most medical procedures require movements in an environment with unpredictable changes. Additionally, they require a high level of knowledge and motor precision. Thus, we could assume that most of them are relatively complex tasks to perform.

A few studies demonstrated the efficacy of observational practice for simple task learning. Blandin et al. (1994) studied the link between observational learning and the simple movement of reaching a metal plate in front of the subject. In this experiment three different patterns were analyzed. The authors concluded that observation reduced the time to touch the metal, thus observational learning would be beneficial for simple tasks. Lee and White (1990) described the positive value of observational learning for a simple task, as well. The study showed a significant observational learning effect in a simple timing task.

On the other hand, some studies did not find correlation between simple task execution and observational practice. Wright et al. (1994) compared the task of executing a sequence of five key presses in response to a monitor presentation. The study revealed little benefit to prior observation of the task.

Nevertheless, most researchers considered observational learning effective for complex skills (McCullagh et al. 1989; Wulf and Shea 2002). For example, Shea et al. (1999) examined the effect of observational practice in the complex task of remaining in balance on a wooden platform. The results indicated that observation helped to improve performance. Because medical procedures are usually complex, we can expect that they will be improved through observation.

Thinking about observational learning for medical education, Bathalon et al. (2005) tested the use of kinesiology as a method to teach cricothyrotomy. The technique of cricothyrotomy was divided into eight steps, which were described and discussed. Participants were then asked to perform the cricothyrotomy on a mannequin and feedback was given at the end. The subjects were evaluated 2 weeks later to measure short-term retention. The authors concluded that observation of the movements improved short-term acquisition of the technique of cricothyrotomy.

Custers et al. (1999) demonstrated the effect of observational learning in a surgical procedure. Pre-clinical medical students were asked to excise a skin lesion and then close the wound after watching an instructional video. The subjects were divided into three groups: (1) no video demonstrating the task, (2) watched one video, and (3) watched four videotapes. Subjects who watched either one or four models demonstrated better performance than subjects who did not watch any video.

Observational practice seems to be an effective method to teach complex medical procedures. However, perhaps more important would be to investigate which approach to observational learning would be the most effective. Wulf and Shea (2002) suggested that a combination of physical and observational practice would be ideal. Shea et al. (2000) compared observational and physical practice on learning a video-game task. The authors tested retention and transfer performance 24-h after the experiment. The retention results indicated that observational practice is inferior to physical practice. The transfer results indicated no differences between observation and physical practice groups. According to the authors, this is a very important finding because although the groups used different processes, they end up getting similar performances. Thus, a combination of observational and physical practice could result in better transfer of knowledge than physical practice alone. Retention and transfer were also tested in physical and combined (alternating physical and observational) practice. The retention results showed no differences between the combined and physical practice groups, but the combined group performed significantly better than the physical practice group on the transfer test. In conclusion, combined observational and physical practice is better than physical practice alone.

While a combination of observational and physical practice seems to be ideal, observation alone is not considered as efficient as practice. According to Blandin et al. (1994) some of the performer cognitive activities are similar to observer activities. However, the observer does not have the sensory feedback to improve muscle control. Physical practice activates neurons associated with mental and muscle activity. Thus, observational practice and physical practice have some common points related to cognitive brain activity, but they are not similar in regards to muscle activity.

Expanding on the role of motor neurons, Badets and Blandin (2010) brought up another interesting question: Does feedback for observational practice work? The importance of an observer’s knowledge of results of a specific task for motor skill learning is already well known (Wulf et al. 2010). It is also well known that knowledge of results has an important effect not only during physical practice but also during observational learning (Badets and Blandin 2004). However it is still not well established how it could improve observational practice in education. Badets et al. tested different knowledge of results schedules in observational and physical practice. The two schedules were either a bandwidth feedback (feedback provided to the subject whenever performance was outside a pre-defined band, the amount of error tolerated) or yoked (feedback provided to the subject after the performance). The bandwidth knowledge of results provides a quantitative feedback. The results showed that a bandwidth feedback improves learning in both practice, observational, and physical.

Blandin et al. (1994) investigated observational practice comparing blocked versus random practice. In their study, subjects were separated into two groups: physical and observational practice. The groups were asked to perform three different movement patterns either on a blocked or random practice schedule. The results showed that both groups were affected similarly by the practice schedule. In other words, observer and performer were engaged in similar cognitive activities while learning the action. In this study the practice schedule did not show performance difference. According to the authors, the amount of physical practice was sufficient enough to minimize the expected disadvantage of blocked schedule.

In conclusion, there are more studies about observational learning related to general tasks than specifically to medical education. However, there is sufficient literature to demonstrate a place for observational practice within the medical learning curriculum.

Observational learning in the anesthesia setting

Observational learning could play a relevant role during anesthesia training since the learner is assigned to a particular staff anesthesiologist each day, forcing them to work in pairs most of the time (dyad practice). In addition, another important contribution of observational learning could be during the short period of an anesthesia clerkship rotation. This short interaction could explain the variation that occurs on hands-on practice opportunities and on students' performance (Smith et al. 2013). Thus, the acquisition of motor skills by watching what the anesthesiologist is doing could be an alternative to situations in which the staff does not think physical practice is appropriate. Physical practice combined with observational learning could adjust the student's performance variations.

Shea et al. (1999) tested the efficiency and effectiveness of dyad practice. The authors define effectiveness as a reduction in time and errors, better movement patterns, and better transfer to novel tasks. Efficiency was associated with the resources spent in a training session (money, time), and potential injuries. In their experiment, the subjects were divided into three groups: one group was told to perform the task individually while the other two groups were told to practice in dyads in which one person performed the task and the other watched. The two dyad groups were subdivided in dyad-alternate (participants alternated between physical practice, observational practice, and dialog on each trial), and dyad-control (participants used one kind of practice for each trial). The task involved cognitive and physical demands. The results showed that dyad practice was more effective than individual practice. An important finding is that subjects in the "dyad-alternate" group were able to transfer the knowledge acquired to performing the task alone. This is essential in anesthesia training, because the resident is trained in a dyad situation (resident-staff), and later expected to work individually. Another interesting result is that the dyad-control group performed worse in the retention test than the dyad-alternate, but equal to individual practice group. Training with another person in an interactive way (dyad-alternative) apparently enhanced motivation, involved the learners in the process by sharing strategies after each practice, and increased cognitive effort by exchanging ideas with the partner after each trial. Moreover, subjects that observed the task before physical practice performed better than subjects who observed after physical practice. However the retention analysis did not show difference between the subgroups, suggesting that observational learning has benefit both before and after physical practice. In conclusion, dyad practice combining observation, physical practice, and dialog increases efficacy and efficiency in training.

Another study favourable to dyad practice was developed by Shebilske et al. (1992). The authors investigated a particular form of dyad training called active interlocked modeling (AIM). They tested a group sharing the performance of a videogame task (one partner controlled the joystick and the other the keyboard). While one partner was performing the task, the other was observing. The authors compared this group with another group in which the subjects individually performed the task, and found no significant differences between the groups. In conclusion, there was an increase in efficiency by doubling the number of trainers, without decreasing learning effectiveness.

However, sharing the control of a task, as demonstrated by Shebilske et al., might not be ideal in the anesthesia field, as most procedures require only one person to perform them. Thus a more efficient and effective protocol for anesthesia training would be to alternate between physical and observational practice. As described by Shea et al. (2000), when 50 % of physical practice were replaced by observation, there was no decrease in retention test and the performance was superior.

Besides all of the motor skill learning advantages of observational practice in anesthesia, there are many other factors that could be improved with dyad training. Working in pairs could enhance motivation, set appropriate performance goals, and develop important social skills (Badets and Blandin 2005; Shea et al. 1999). Moreover observational learning requires less physical energy, reduces the risk of injuries, and it is not dependent on extra equipment and space (Wulf and Shea 2002). In addition, this type of learning creates opportunities for students without contextual stresses of the operating room. Finally, the enhancement in learning by the combination of observational and physical practice could minimize the variation that occurs on learning opportunities for students.

Conclusions

This review intended to investigate whether it is possible to take advantage of observational practice in the motor skills teaching strategies for medical education in general, and specifically for anesthesia. In order to do that, I first described and understood the mechanisms of observational learning. Then I analyzed several articles comparing physical and observational practice in medical tasks related.

As discussed, the literature surrounding this topic does support the use of observational learning to teach motor skills because humans are able to map representations for movement strategies and outcomes of observed actions. In additional, it is an effective learning method for lower level motor control, but also for higher cognitive processes like the ones encountered in medical training.

Some teaching approaches should be taken into consideration to enhance learning and skill acquisition through observational practice. First, the motor system has to be committed to learn, so an implicit engagement of the observer motor system is required. In additional, immediate feedback seems to have an important effect not only during physical practice but also during observational learning. Moreover, it seems that a combination of observational and physical practice could be better than physical practice alone. The "dyad-alternate" protocol (observation, physical practice, and dialogue) was found to increase efficacy and efficiency in training, so it could be an acceptable alternative for medical training.

The advantages of observational practice go beyond enhancing motor skills. Medical education faces several challenges such as medical legal issues, patient safety, cost, equal learning opportunities, and an increasing number of techniques along with limited clinical exposure due to work hour restrictions. In the anesthesia setting, the students (and staff) also have to deal with the stressful operating room context, emergency procedures, and the pressure to perform fast to keep the surgery schedule on time. In an environment where effectiveness and efficacy are essential, observational learning seems to fit well.

Nevertheless, further investigation targeted at medical procedures teaching approaches would be appreciated (e.g. practice schedule). By knowing which anesthesia procedures would benefit the most from observational learning we could develop specific protocols for curriculum implementation.

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