Unravelling early endovascular skill acquisition

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DOI: 10.33612/diss.236719428

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Document Version
Publisher's PDF, also known as Version of record

Publication date:
2022

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):

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Summary

Endovascular interventions (EI) are minimally invasive procedures to diagnose and treat vascular disease. As the procedure is performed via a small access to an artery or vein using dynamic x-ray images as guidance, performing EIs is associated with visuo-motor challenges. To overcome these visuo-motor challenges, adequate training is needed that focuses on the crucial sub-skills needed to perform EIs safely and effectively. However, to date little is known about which sub-skills are crucial to endovascular skill acquisition.

The goal of this thesis was to understand early endovascular skill acquisition and factors that influence learning and performance using behavioural metrics and magnetic resonance imaging (MRI). In the context of this thesis, we defined endovascular skills as the psychomotor skills needed to perform a simple EI, where the whole procedure has been predefined such that higher levels skills are not necessary. First, we reviewed the literature about complex skill acquisition and brain plasticity (Chapter 2). Next, we conducted a longitudinal training study to determine psychomotor predictors of skill acquisition (Chapter 3) and examined brain changes associated with endovascular skill acquisition (Chapter 4).

In Chapter 2, we described the differences between declarative and procedural knowledge. Teaching of endovascular interventions has mainly focused on declarative knowledge, while procedural knowledge has been assumed to develop with practice implicitly. Magnetic resonance imaging (MRI) can be used to study structural and functional brain reorganisations as a result of declarative and procedural knowledge acquisition. Neural correlates of skill acquisition uncovered by MRI may provide unique insight into crucial sub-skills that drive endovascular skill acquisition.

In Chapter 3, we tested whether novice operators can acquire basic endovascular skills during a brief, structured simulator training. Further, we tested whether pre-existing abilities predict learning of EIs using cognitive ability and manual dexterity tests. To answer these questions, medical students performed a three-day training on an endovascular simulator, before training they completed a battery of tests. Participants’ performance was quantitatively assessed as well as rated by a clinical expert. The quantitative evaluation showed that participants’ performance improved across training, however the expert evaluation revealed that the more complex part of the intervention was not learned adequately. Both performance assessments highlighted large individual differences in performance. Further, we found that mental rotation ability predicted the rate of skill acquisition using the quantitative assessment. Based on the results, we concluded that mental rotation ability plays a
role in acquiring basic EI skills and that multiple performance measures are needed to gain full insight into complex skill acquisition. Simulator training can be a useful tool to assess trainees’ early skill level, individual weaknesses can be targeted in dedicated simulator-based training sessions.

In Chapter 4, we tested whether endovascular skill acquisition is associated with brain plasticity and whether potential changes are behaviourally relevant. Further, we examined whether brain tissue structure before training can predict overall training success. To answer these questions, we acquired multimodal MR data at baseline, before and after simulator-based EI training. To be able to attribute brain plasticity to endovascular skill acquisition, a separate control group performed a simplified version of the endovascular training on the simulator. We found training-specific changes in grey matter volume (GMV) and intrinsic connectivity in the intraparietal sulcus (IPS), and fractional anisotropy in white matter surrounding the IPS. However, these changes were not directly related to behavioural improvements. Revealed plastic changes in the IPS are in line with the visuo–motor learning literature that has implicated this brain structure in visuo–motor coordination. Interestingly, independent fMRI evidence showed that the IPS is activated during mental rotation tasks as well. Our results provide strong, multimodal evidence of the role of the IPS in endovascular skill acquisition and point to sub–skills that drive endovascular skill acquisition, i.e., mental rotation ability and visuo–motor coordination. Grey matter volume before training in the right cerebellar Lobule VIIIb predicted overall training success. This brain structure is associated with finger movements and somatosensory representations of the hand; these representations might have facilitated manipulating the endovascular tools. Thus, our result shows that differences in macroscopic tissue structure before training influence overall training success. Hence, our imaging findings not only shed light on the plasticity process accompanying endovascular skill acquisition, but also identify predictors of performance and reveal new evidence for rapid changes in GMV due to visuo–motor training.

In essence, we showed that novice operators can acquire basic endovascular skills within a brief training regime and that skill acquisition induced structural and functional brain changes. Together, the results presented in this thesis provide behavioural and MRI–based evidence for the crucial role of visuo–motor coordination and mental rotation ability in early endovascular skill acquisition. Visuo–spatial skills, such as reading and interpreting fluoroscopy images can be trained explicitly on a simulator; such training can be adapted to the individual needs of the trainee. In the final chapter of this thesis, we discussed teaching strategies that could be applied during training. To gain full insight into complex skill acquisition, multiple performance measures are necessary to capture crucial facets of skill. Standardized and validated performance measures would alleviate studying EI skill acquisition
and allow comparison between different studies.