Automated Psychomotor Skill Assessment for Use in Ultrasound Competency Testing

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Abstract

Acquisition of robust psychomotor skills is a critical element of achieving ultrasound competency. A validated and scalable method for assessing psychomotor skills is a prerequisite for widespread implementation of ultrasound training and integration into clinical practice. In this study, a method for evaluating visuospatial and visuomotor (psychomotor) skills related to ultrasound proficiency was developed and used to collect data from 59 participants. Participants varied from novices with no prior ultrasound experience or training to sonographers with 20+ years of ultrasound experience. Successful completion of the tasks did not require prerequisite medical knowledge. Task performance on a series of exercises assessing visuospatial and visuomotor skills was analyzed in relation to participant age, experience, and specialty. There was a high level of correlation across the different tools used for psychomotor skill assessment, establishing the internal validity of this novel automated assessment method. Correlation analysis shows evidence of intrinsic visuospatial and visuomotor skills and inverse correlations to age but not to prior experience using general diagnostic ultrasound applications.

Introduction

The psychomotor skill requirements for performing ultrasound-guided procedures is remarkably similar to the requirements for laparoscopic surgery. Both procedures involve gross and fine motor movements with both right and left hands and navigation and interaction with a real 3D environment (i.e., internal human anatomy) using a 2D screen and acquired imagery for navigation of instruments held by the operator's hands. In the 1990's, a worrisome rapid increase in laparoscopic surgery complication rates followed the introduction of laparoscopic instruments into the general surgery. These negative results led to the development ¬¬of robust training and assessment standards and tools in order to objectively, accurately, and reliably evaluate and predict laparoscopic surgery performance of surgeons. Point-of-care ultrasound is following a similar pathway to the early years of laparoscopic surgery. A similar effort to develop robust ultrasound competency assessment methods will be required to avoid ultrasound-related negative outcomes related to insufficient training, assessment metrics and tools, and competency testing. The fundamentals of laparoscopic surgery education program (FLS) currently defines standards and provides training and assessment tools in the domain of surgery. Such a program does not yet exist in the domain of ultrasound, but it has been shown that simulation-based training improved performance (Tolsgaard et al., 2015) and that simulation-based assessment was valid and reliable (Madsen et al., 2014). As a step towards standards and tools for training and assessment of ultrasound knowledge and skills, a prototype assessment tool based on the SonoSim® Ultrasound Training Solution was developed. In this study, this tool was used to evaluate psychomotor skills agnostic of medical or ultrasound knowledge.

Study Goal

Assess psychomotor skill performance using the SonoSimulator® and validate measures against external performance measures.

Study

59 participants, 20 male and 39 female, 22 to 60 years old, ranging from medical students, to ultrasound technicians, to residents, were given a paper & pencil spatial orientation test before being tested on the SonoSim® simulator. Simulation tasks assessed a) visuospatial skills by having participants scan a hidden 3D geometric object and guess the shape from the 2D scan images, b) visuomotor skills where they had to follow a simple and a complex path, c) a combination of those skills where they had to align the probe to a given 3D probe image, and d) prioprioception skills where some of the previous tasks had to be done blindly. Results presented here focus mainly on c) and the consistency with the paper & pencil test results.

Paper & Pencil Spatial Orientation Performance

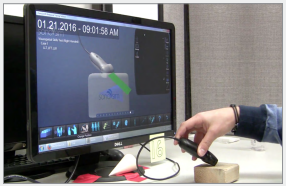
- Percent completed test items: **so%** (4)
- Error of orientation angle: **soErr** (3)
- Time required: **soTime** (5)

Background Data

- Age: **age** (1)
- Scanning experience: **expYrs** (2)

Simulator Performance

- Distance to optimal scan view: **VLD** (6)
- Path length of scan: **PLN** (7)
- Duration of scan: **DUR** (8)



Correlation Matrix		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
age	(1)	1							
expYrs	(2)	**.82**	1						
soErr	(3)	**.50**	**.35**	1					
so%	(4)	-.22	-.18	**-.38**	1				
soTime	(5)	**.31**	.16	**.47**	**-.43**	1			
VLD	(6)	**.40**	.12	**.50**	.05	**.32**	1		
PLN	(7)	-.05	-.03	-.02	-.05	.11	.04	1	
DUR	(8)	.21	.12	.25	-.14	.14	**.30**	**.67**	1

Correlation Analysis

- All **bolded values** in the table are **statistically significant at p < 0.05**
- Clearly years of scanning experience is correlated with age (r=0.85)
- Paper & pencil spatial orientation errors are correlated with simulator performance on distance to optimal scan view (r=0.5)

Results

- Intrinsic visuospatial and visuomotor skills were evident with our study group
- Number of scans and experience did not predict psychomotor ability
- Younger participants in our study group showed better psychomotor ability than older participants
- Spatial orientation performance decreased with increasing age which is consistent with previous findings (e.g. Krampe, 2002).
- Partial internal validity for simulator optimal view distance measures is indicated by their correlation with angle difference performance measures on the paper & pencil spatial orientation test (Hegarty & Waller, 2004).

Next Steps

- Perform hand motion analysis (HMA) on quaternion data and add more variables, such as measures related to scanning efficiency and steadiness.
- Confirm cognitive task analysis using latent variable models.

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