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Research review

Eye tracking for skills assessment and training: a systematic review

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ABSTRACT

Background: The development of quantitative objective tools is critical to the assessment of surgeon skill. Eye tracking is a novel tool, which has been proposed may provide suitable metrics for this task. The aim of this study was to review current evidence for the use of eye tracking in training and assessment.

Methods: A systematic literature review was conducted in line with PRISMA guidelines. A search of EMBASE, OVID MEDLINE, Maternity and Infant Care, PsycINFO, and Transport databases was conducted, till March 2013. Studies describing the use of eye tracking in the execution, training or assessment of a task, or for skill acquisition were included in the review.

Results: Initial search results returned 12,051 results. Twenty-four studies were included in the final qualitative synthesis. Sixteen studies were based on eye tracking in assessment and eight studies were on eye tacking in training. These demonstrated feasibility and validity in the use of eye tracking metrics and gaze tracking to differentiate between subjects of varying skill levels. Several training methods using gaze training and pattern recognition were also described.

Conclusions: Current literature demonstrates the ability of eye tracking to provide reliable quantitative data as an objective assessment tool, with potential applications to surgical training to improve performance. Eye tracking remains a promising area of research with the possibility of future implementation into surgical skill assessment.

1. Introduction

The development of valid, reliable, and objective methods of skills assessment is central to modern surgical training. The increased awareness of iatrogenic injury and error has heightened the need for surgeons to demonstrate proficiency [1] and achieve competency despite the shortening of training time available to trainees with the advent of working time directives [2,3].

Where in the past, surgical assessment was reliant on an apprenticeship model of informal skills acquisition and progression; numerous tools are now available to the surgical

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trainer. Numerous rating scales have been developed and validated with the aim of quantifying surgical performance, such as Operative Performance Rating System, which return a summative performance score from combined Likert scale ratings across a number of behavioral or procedural domains [4]. Objective Structured Assessment of Technical Skill incorporates a global rating scale with a checklist to assess surgical performance [5]. However, the design of many of these scoring systems has potential drawbacks in their reliability, with effective assessment dependent on the availability and presence of a reviewer trained in the assessment methodology [6].

The development of objective and independent systems remains the ultimate goal for surgical assessment. Through the use of objective metrics such as path length or number of movements to define surgical skill, this has, in part, been achieved in laparoscopic surgery [7]. However this remains largely limited to the training setting, recording computer-based metrics from virtual reality simulators [8].

Eye tracking has been proposed as a potential assessment tool not limited by some of the restrictions of laparoscopic metric measurement. The use of camera technology to analyze eye motion is a well-established concept, dating back to 1950, during which the use of picture cameras to study the gaze behavior of pilots was first described [9]. Since then, new techniques have been developed, documenting eye movement using stationary cameras or cameras integrated into otherwise standard eyeglasses. These record the corneal reflection of infrared lighting to track pupil position, mapping the subject's focus of attention on video recordings of the subject's field of view (gaze) [10]. In addition to tracking gaze, this has enabled the measurement of various eye metrics including fixation frequency and dwell time (used as a surrogate measure of perceived stimulus importance [9,11], as well as pupil dilation, a marker of subject effort and concentration [12,13]. Differences in these metrics between subjects of varying skill levels, it has been proposed, may allow use of these measurements as markers of ability [11,14–23].

Beyond a method of assessment, eye tracking has been proposed for other training uses, such as a visually guided control interface, particularly within the operating room where sterility (and therefore contact-free interfaces) must be maintained [24]. It may also be used to address some of the unique challenges presented by the continuing advances in surgical technology. Visual orientation can present a major problem in laparoscopic surgery—the analysis and identification of efficient orientation strategies through eye tracking have been demonstrated as one potential way to address this [25].

Despite such broad potential application, research in this area has been limited and disparate to date. Therefore, the aim of this article was to review and consolidate the current literature describing the evidence basis for the use of eye tracking in training and assessment.

2. Methods

A systematic review was conducted in line with PRISMA guidelines [26]. A search of EMBASE, OVID MEDLINE, Maternity and Infant Care, PsycINFO, and Transport databases was conducted, till March 2013. The following search terms were used: (eye tracking OR gaze) AND (education OR training OR learning OR skill acquisition).

After deduplication, results were first searched for relevant titles and abstracts. Full text versions of candidate studies were then retrieved and considered for final inclusion according to agreed selection criteria. In addition, reference lists were hand searched for other relevant articles, which may have been missed. Both literature search and data extraction were undertaken by two independent reviewers (T.T. and P.P.). Any disagreement was resolved by consensus.

2.1. *Selection criteria*

Studies were included, which used an eye-tracking device in the execution, training or assessment of a task, or skill acquisition in task completion.

2.2. *Quality analysis*

The quality of included studies was assessed using the Jadad score [27] for randomized trials and Newcastle–Ottawa Scale (NOS) [28] for cohort studies. The Jadad scale assigns or deducts points over several categories based on the quality of randomization, blinding, and outcomes reporting, for a total score of 1–5. The NOS assigns a score of 0–9 based on the methodological quality of a study's cohort selection, comparability, appropriate exposure, and analysis of outcome. To allow comparison of study quality across different study types, a summary score of "poor" (Jadad 1–2 and NOS 0–5), "moderate" (Jadad 3 and NOS 6–7), or "good" (Jadad 4–5 and NOS 8–9) was assigned.

3. Results

Initial search results returned 12,051 results, which were reduced to 7360 results after elimination of duplicates. Thirty-six full-text publications were retrieved for analysis, with final inclusion of 25 studies in the final qualitative synthesis (Figure).

Of the 24 studies of this review, 17 fit the requirements for quality analysis. The articles were mostly moderate in quality, with 16 of 17 articles being classed as moderate and the remaining article was classed as poor (Table 1).

Studies were divided into two domains of evidence and considered separately: (1) those describing use of eye tracking for assessment, including validation of assessment metrics and (2) use of eye tracking for training (Table 2).

3.1. *Eye tracking as an assessment tool*

Sixteen studies reported the use of eye tracking as an assessment tool across multiple disciplines, including surgery (4), medical specialties (6), nursing (2), and nonmedical applications (4).