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# Psychomotor abilities in diagnostic upper gastrointestinal endoscopy derived from procedural task analysis techniques and expert review

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## Abstract:

**BACKGROUND:** Any prediction of a person's ability to succeed in a motor skill depends on the detection and accurate measurement of the basic abilities for the performance of that skill. Task analysis is needed to determine the psychomotor skills and abilities required to perform an action. This study aimed to determine the components of psychomotor abilities for diagnostic upper gastrointestinal (GI) endoscopy through procedural task analysis (PTA) and expert review.

**MATERIAL AND METHODS:** A multisource, multimethod task analysis was conducted in six metropolitan teaching hospitals affiliated with the adult gastroenterology and hepatology training centers in the Islamic Republic of Iran in 2019. Observation, video-recording, and think-aloud protocols were used while diagnostic upper GI endoscopy was performed. To confirm the accuracy of the PTA, the incorporated the views of the adult gastroenterology and hepatology subspecialty experts through the checklist of PTA assessment criteria. Finally, to determine the psychomotor abilities for each stage of the procedure, the study incorporated a panel of experts from occupational therapy, physical education, physical medicine, and adult gastroenterology and hepatology subspecialty.

**RESULTS:** Of the 15 psychomotor abilities examined, 11 were determined for upper GI endoscopy procedure, of which six cases (including visuospatial and perceptual abilities, hand-eye coordination, multilimb coordination, finger dexterity, arm-hand steadiness, and manual dexterity) were the most frequent.

**CONCLUSIONS:** PTA techniques and subsequent expert review were used to identify the components of psychomotor abilities for diagnostic upper GI endoscopy. It is suggested that PTA is performed for other procedures, and after psychomotor abilities are specified, proportional tests are developed.

## Keywords:

Analysis task, endoscopy, gastrointestinal, performance, psychomotor performance

## Introduction

The development of psychomotor skills is the primary outcome of learning for more procedurally focused careers.<sup>[1]</sup> Psychomotor skills involve the use of psychomotor abilities to perform different activities. Psychomotor ability can be split

into many components, each of which can be separately evaluated.<sup>[2]</sup>

As individuals may have varying degrees of psychomotor ability, training courses must provide different degrees of psychomotor training for learners. Each person should have the chance for fair practice based on his/her psychomotor ability to achieve

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the desired level of competency. Evidently, at the end of the course, trainees will acquire different levels of competency in psychomotor skills, depending on their psychomotor ability and practice.<sup>[2]</sup>

Task analysis is required to determine the psychomotor skills needed to perform different actions.<sup>[2,3]</sup> Procedural task analysis (PTA) can be defined as the systematic breakup of a task (a job or activity) such that the stages can be delimited operationally and arranged in a hierarchy to facilitate training and learning.<sup>[4]</sup> The outcome of PTA is an educational blueprint or a flowchart that specifies the steps to be followed by learners.<sup>[4,5]</sup>

Moreover, the prediction of a person's potential to succeed in a motor skill depends on the identification and accurate measurement of the fundamental abilities required to perform that skill.<sup>[6]</sup> Learning procedural skills is one of the critical elements of education for health professions in future. There is little information available about the way to learn and practice skills related to procedures during training. Trainers need to be aware of the interventions that they can use to enhance the learning of these skills.<sup>[7]</sup>

On the other hand, the increasing number of minimally invasive procedures in surgery and gastroenterology has raised issues such as the learning curve, training, and quality assurance to have minimal harm to patients.<sup>[8]</sup> It is not easy to acquire skills in flexible endoscopy, and the extent to which trainees learn these skills varies from one trainee to another. The difference is also evident in the number of recommendations that international endoscopic communities have specified for competency in flexible endoscopy (between 50 and 300 cases).<sup>[9]</sup> Acquiring technical competence plays a vital role in implementing endoscopic procedures. Flexible endoscopy requires different skills in open or laparoscopic surgery, where even senior residents spend substantial time observing endoscopic procedures rather than doing them to acquire basic knowledge.<sup>[10]</sup> Nevertheless, while the American Board of Surgery requires all residents to learn flexible endoscopy, there is no clear guideline for it. Similarly, the Accreditation Council for Graduate Medical Education encourages flexible endoscopy and monitors these operations, although it fails to define the minimum requirements for successful completion of the course.<sup>[9]</sup> In parallel with this, a study focused on the American Society for Gastrointestinal Endoscopy principles of endoscopic training, aiming to formulate recommendations on the critical principles of training endoscopy trainers. Following similar lines and referring to principles such as breaking complex procedures into separate component steps and adjusting training to each learner,<sup>[11]</sup> the current study points to the two principles mentioned.

Many issues in acquiring endoscopic skills can be due to differences in the essential abilities of trainees. Basic ability tests can help detect trainees who need further training to achieve the desired performance goals.<sup>[9]</sup>

On the other hand, a literature review indicates that task analysis has failed to receive sufficient attention in the medical field for detecting learners' psychomotor abilities. Rather, studies have focused on identifying skills and competencies instead of underlying abilities. Psychomotor abilities are the foundation for the rapid acquisition of skills.

Given that a wide range of health professionals use psychomotor skills as part of their professional performance, and the need to identify psychomotor abilities and to design appropriate tests for their evaluation as highlighted by several studies, this study aimed to determine the components of psychomotor abilities for upper gastrointestinal (GI) endoscopy procedure using PTA. This study is describing a novel methodology for understanding the abilities that are need to complete a skill and ultimately a task. Furthermore, this study helping build better assessment tools and selecting individuals into a program.

## Materials and Methods

This study was conducted in six metropolitan teaching hospitals (Tehran, Isfahan, Tabriz, Mashhad, Rasht, and Sari) affiliated with the adult gastroenterology and hepatology training centers in the Islamic Republic of Iran in 2019.

Eleven faculty members of the adult gastroenterology and hepatology subspecialty (approved by members of the respective board) were incorporated in the PTA stage. Four faculty members (two of whom participating earlier in the initial phase) contributed to the subsequent expert review process.

The participants came from each of the centers that trained subspecialty assistants across Iran. To determine the psychomotor abilities for each stage of the procedure, we incorporated three experts from fields associated with psychomotor assessment including occupational therapy, physical education, and physical medicine, and three faculty members of the adult gastroenterology and hepatology subspecialty through purposive sampling method.

The ethics committee of Isfahan University of Medical Sciences, Isfahan, Iran, approved the study with the code of IR.MUI.MED.REC. 1398.050.

Before the data collection process initiated, the "think-aloud" protocol was explained in brief to each of

the participating faculty members. They were instructed and required to express during each procedure: their goals and expectations; cues used for navigation and the identification of abnormalities; strategies, endoscope handling techniques, and endoscope shape awareness; and any other processes that would pass through their mind while performing the task.

Moreover, the following three questions were taken into account in each stage of the procedure and at any anatomical point:

1. What movement is exactly being performed in the organs and the whole body at the moment?
2. What goes on in the expert's mind when doing any physical movement and to which the expert is subconsciously attending for this stage of endoscopy to complete desirably?
3. What assures at each stage that the expert has taken the necessary measure?

The endoscopy was performed on real cases (patients). During videotaping, we tried to keep ethical considerations whereby the expert provided oral informed consent. Moreover, the movements of the organs and the whole body of the expert and the monitor screen were filmed (attempts were made not to film the patients' faces). Altogether, nine endoscopy videos were selected from the 11 video clips. The quality of the videos was assessed by two independent observers using a checklist with the three items of sound quality, high-resolution image, and the adequacy of the expert's referral to the details of the procedure. In the case of disagreement between the two raters, a third observer was used. The contents of the videos were noted down and controlled by two gastroenterologists. Subsequently, the contents were summarized by four gastroenterology experts. Furthermore, specialized texts, such as Cotton and Williams' Practical gastrointestinal endoscopy – the fundamentals, were used to complement the contents. One gastroenterology expert provided the final summary.

Importantly, there were two distinct time points where the experts were requested to describe the procedure: during endoscopy and during the follow-up "free recall" session. At both times, each expert was asked to go on as completely as possible and to describe each step and decision point made during an endoscopy. Notably, during the endoscopies, the experts did not verbalize all essential steps of the procedure nor did they share all the critical decisions that were required during an endoscopy.

Given the complexity of the endoscopy procedure based on the review of the texts and experts' opinions, the procedure was broken into five steps including

the correct grip of the endoscope and its insertion, endoscope's movement through the esophagus, stomach, and duodenum, and its removal from the body.

To confirm the accuracy of the PTA, we incorporated the views of the adult gastroenterology and hepatology subspecialty board members and other trainers of this program through the checklist of PTA assessment criteria, which was e-mailed to them. The criteria used to evaluate PTA were as follows.

1. Completeness: All the stages exist; complicated procedures are broken into steps.
2. All the steps are described with performance terms (using verbs).
3. Procedural analysis is appropriate to represent the task.
4. Validity and accuracy: Procedural analysis represents an actual task.<sup>[5]</sup>

Finally, to determine the psychomotor abilities for each stage of the procedure, a panel of experts was formed that comprised experts from occupational therapy, physical education, physical medicine, and adult gastroenterology and hepatology. At this stage, background information, including the definition of psychomotor ability, the checklist of Perceptual-motor abilities [Table 1], and the final contents of the endoscopy task analysis, was provided to the participants.

The components of psychomotor abilities were extracted from the Fleishman's taxonomy, attached as Table 2, and related texts in the field of medical sciences.<sup>[6,12,13]</sup>

There was a facilitator to run the meetings. After the project was briefly introduced, the video of the first stage of the endoscopy procedure (the endoscope's insertion and its passage into the esophagus) was displayed. Afterward, the participants had 5 min to contemplate in silence and mark the psychomotor ability/abilities required for the first stage of endoscopy on the psychomotor ability checklist. Afterward, each person was asked to express the psychomotor ability/abilities needed for the first phase of the endoscopy procedure. Subsequently, a discussion was held on the abilities, which continued until all the participants were convinced of the relevance of the abilities. Similar lines were followed for other stages of the endoscopy procedure.

## Results

Based on the review of the texts and opinions of the experts, the endoscopy stages were broken into the five stages of endoscope insertion, its passage through the esophagus, stomach, and duodenum, and its removal

**Table 1: The checklist of Perceptual-motor abilities**

Perceptual-motor abilities	Stages of the upper gastrointestinal tract diagnostic endoscopy				
	Insertion	Esophagus	Stomach	Duodenum	Exit
Control precision					
Multi-limb coordination					
Response orientation					
Reaction time					
Speed of limb movement					
Rate control					
Manual dexterity					
Finger dexterity					
Arm-hand steadiness					
Wrist-finger speed					
Aiming					
Hand-eye coordination					
Visuospatial					
Balance-visual cues					
Static strength					

**Table 2: Perceptual-motor abilities (Fleishman, 1967)**

Perceptual-motor abilities	Description
Control precision	Ability to make highly controlled movement adjustments, especially when large muscle groups are involved
Multilimb coordination	Ability to coordinate the movement of some to several limbs concurrently
Rate control	Ability to create continuous anticipatory movement adjustments in reaction to changes in the speed of a constantly moving object or target
Arm-hand steadiness	Ability to make exact arm and hand positioning movements when speed and strength are not needed
Finger dexterity	Ability to manipulate small objects
Manual dexterity	Ability to manipulate fairly large objects with hands and arms
Reaction time	The pace at which an individual can react to a stimulus by means of a prescribed movement
Response orientation	Ability to make fast choices from among several alternative actions, often measured as the choice reaction time
Wrist-finger speed	Ability to rapidly move the wrist and fingers with little or no accuracy demands.
Aiming	A highly restricted type of ability that needs the making of accurate hand movements to targets under speeded conditions.

Adapted from Edwards WH. Motor learning and control: From theory to practice. Cengage Learning; 2010

from the body. The outcome of PTA is presented in a flowchart that specifies the steps to be followed by learners [Figure 1]. Characteristics of participants in the PTA stage are shown in Table 3.

Of the 15 psychomotor abilities examined, 11 were decided as specifically relevant to the upper GI endoscopy procedure, of which six cases (with over 50% of the frequency of expert responses) were the most frequent [Table 4]. Characteristics of participants in the expert panel are shown in Table 5.

In this study, 100% of the experts had consensus regarding the following terms: visuospatial and perceptual abilities were needed for moving the endoscope through the stomach and duodenum; coordination between the eyes and the hands was required for endoscope insertion and movement through the esophagus, stomach, and duodenum; multilimb coordination was necessary for endoscope insertion and its movement in the stomach and duodenum; finger dexterity was a must to insert and

remove the endoscope; and arm-hand steadiness was required for the endoscope insertion [Table 4].

According to the literature review and experts' opinions, the psychomotor abilities indicated for the endoscopy procedure can be grouped into three categories [Table 6].

## Discussion

The results of the current study showed that the essential abilities for diagnostic upper GI endoscopy comprise visuospatial and perceptual abilities, hand-eye coordination, multilimb coordination, finger dexterity, arm-hand steadiness, and manual dexterity abilities. In motor skills, hands function as a powerful system for moving and grasping skills, while the trunk and limbs are the main factors for skills, in which the whole body is involved. Another important system is the eye motor system that is involved in spatial behavior, in particular, tracking and localization. The integration of an object's properties, the type of movement required,

and the systems involved in determining the type of control needed are vital to performing therapeutic and diagnostic tasks.<sup>[13]</sup> Motor ability provides the information required to move and control one's body and surrounding objects and facilitates the interaction between them. Precise integration of visuospatial, perceptual, and psychomotor information is vital in almost all spheres of life. Similar to minimal-access surgical techniques, endoscopic procedures entail major psychomotor issues related to hand-eye coordination and finger and manual dexterity.<sup>[13]</sup>

In their study, Cuschieri and Francis stated that three categories of psychomotor abilities are of significance in minimal-access surgeries: manipulation abilities (stability, aiming, two-hand coordination, and manual dexterity), visuospatial and perceptual abilities (focus on depth perception, mental processing, and accurate interpretation of images), and hand-eye coordination in the operation area.<sup>[14]</sup> It can be stated that these abilities are, to a degree, similar to those of the upper GI diagnostic endoscopy. In open surgery, the most crucial characteristic for the surgeon is eye-hand coordination and finger dexterity.<sup>[15]</sup> Laparoscopic surgery similarly requires both surgical and psychomotor skills. The European Academy of Gynecological Surgery

has developed the Laparoscopic Skills Testing and Training model to train laparoscopic psychomotor skills such as laparoscopic camera orientation, hand-eye coordination, and two-hand coordination.<sup>[15]</sup> In the Royal College of Surgeons in Ireland, the technical skills and basic abilities (e.g., psychomotor, visuospatial, and depth perception) of all the outstanding candidates are officially tested to assure eligibility for the advanced course. Reports on the performance of each candidate are provided to the interviewing committee. In addition, a database is used to examine the association between the test results and the future performance of the admitted candidates in surgery.<sup>[16]</sup>

Perceptual problems in the endoscopy procedure arise from the difficulty with constructing a three-dimensional (3D) structure out of two-dimensional monitor views. This process is not an easy one because it requires solving problems associated with size, depth, direction, movement, shadow, texture, color, experience, and learning. The ability to control the mental re-creation of a 3D image out of a two-dimensional image is theoretically comparable to the mental ability to route in the large intestine, duodenum, or bladder at the time of flexible endoscopy. This ability is essential in all monitor-based procedures.<sup>[9]</sup> Accordingly, 100% of the experts in this study believed that visuospatial and perceptual abilities were needed for moving the endoscope through the stomach and duodenum. Even, 60% believed that this ability is required for the insertion of the endoscope, its movement in the esophagus, and its withdrawal.

Different visuospatial problems during endoscopy procedures, similar to minimally invasive procedures in surgery, can be derived from cognitive and hand-eye coordination problems. The anatomy may appear tremendously different depending on the angle of the camera and magnification of the object by the camera. Moreover, the views are inverted. Visuospatial differences can be due to the misunderstanding of angular

**Table 3: Characteristics of participants in the procedural task analysis stage**

Characteristic	n (%)
Gender	
Male	7 (63.7)
Female	4 (36.3)
Academic rank	
Assistant professor	7 (63.7)
Associate professor	1 (9.0)
Professor	3 (27.3)
Years in practice (years)	
5-10	4 (36.3)
10-20	5 (45.5)
>20	2 (18.2)

**Table 4: Perceptual-motor abilities in the upper gastrointestinal tract diagnostic endoscopy**

Perceptual-motor abilities	Stages of the upper gastrointestinal tract diagnostic endoscopy				
	Insertion, n (%)	Esophagus, n (%)	Stomach, n (%)	Duodenum, n (%)	Exit, n (%)
Visuospatial and perceptual	3 (60.0)	3 (60.0)	5 (100.0)	5 (100.0)	3 (60.0)
Hand-eye coordination	5 (100.0)	5 (100.0)	5 (100.0)	5 (100.0)	4 (80.0)
Multilimb coordination	5 (100.0)	3 (60.0)	5 (100.0)	5 (100.0)	3 (60.0)
Finger dexterity	5 (100.0)	3 (60.0)	4 (80.0)	3 (60.0)	5 (100.0)
Arm-hand steadiness	5 (100.0)	3 (60.0)	3 (60.0)	3 (60.0)	3 (60.0)
Manual dexterity	4 (80.0)	4 (80.0)	3 (60.0)	2 (40.0)	4 (80.0)
Rate control	1 (20.0)	1 (20.0)	1 (20.0)	1 (20.0)	1 (20.0)
Control precision	2 (40.0)	1 (20.0)	3 (60.0)	3 (60.0)	1 (20.0)
Balance-visual cues	1 (20.0)	1 (20.0)	1 (20.0)	2 (40.0)	2 (40.0)
Speed of limb movement	0 (0.0)	0 (0.0)	2 (40.0)	2 (40.0)	1 (20.0)
Wrist-finger speed	1 (20.0)	2 (40.0)	1 (20.0)	2 (40.0)	2 (40.0)

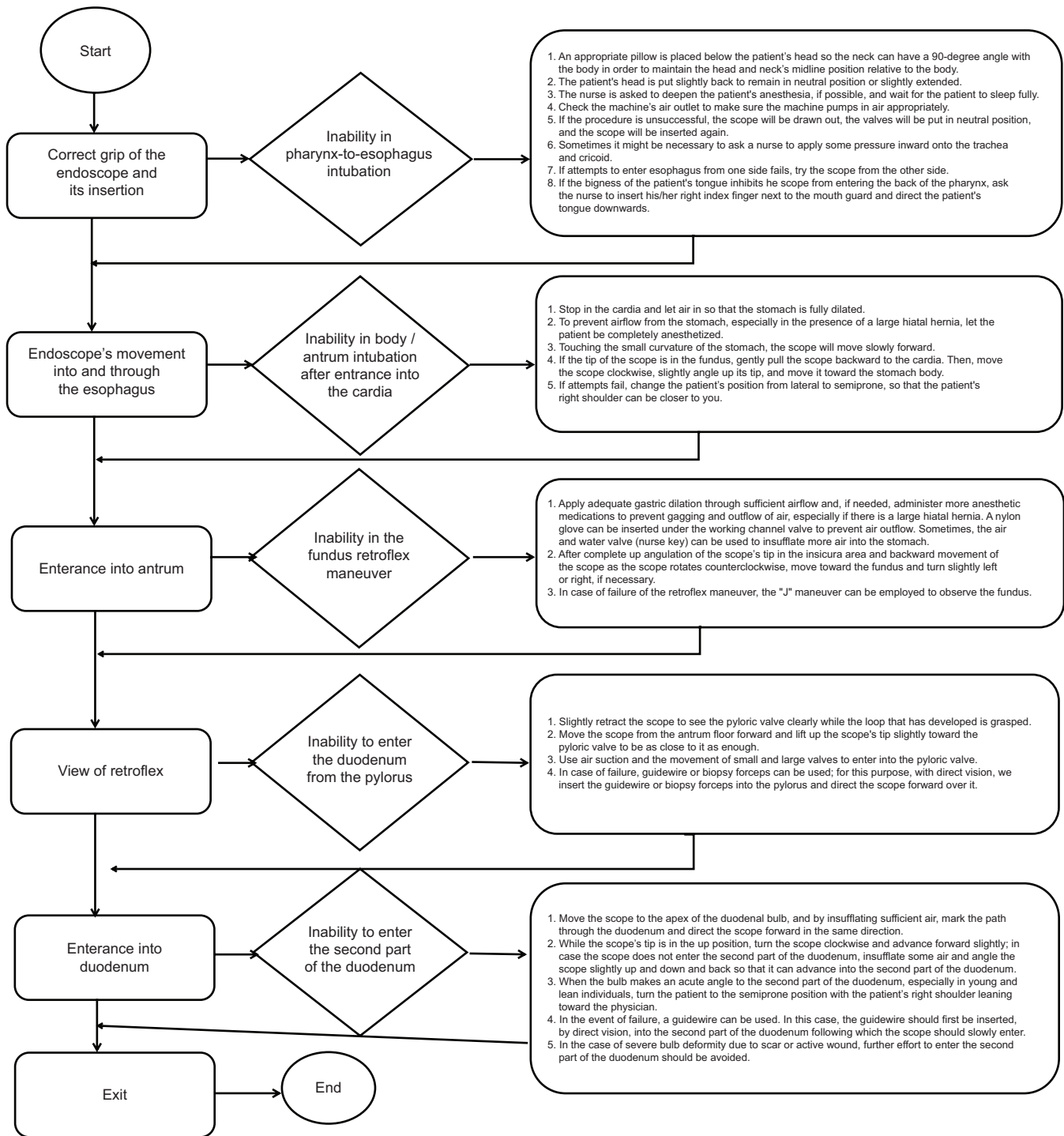


Figure 1: The outcome of procedural task analysis is presented in a flowchart that specifies the steps to be followed by learners

relationships since the points where the tools are inserted are not consistent with the optical axis of the camera.<sup>[13]</sup>

Hand-eye coordination is the ability to perform skills that require vision and correct use of the hands. In the endoscopy procedure, the endoscope movements are consistent with what is observed on the monitor and are quite evident during the procedure. Hence, 100% of the experts believed that coordination between the eyes

and the hands was necessary for endoscope insertion and movement through the esophagus, stomach, and duodenum. Moreover, 80% believed that this ability is necessary for endoscope withdrawal.

Multilimb coordination involves tasks, in which parts of organs must work in coordination when moving, similar to the two hands during an endoscopy procedure. Therefore, 100% of the experts believed that multilimb

**Table 5: Characteristics of participants in the expert panel**

Characteristic	n (%)
Gender	
Male	2 (33.3)
Female	4 (66.7)
Academic rank	
Assistant professor	3 (50.2)
Associate professor	1 (16.6)
Professor	1 (16.6)
Other	1 (16.6)
Specialty	
Occupational therapy	1 (16.6)
Physical education	1 (16.6)
Physical medicine	1 (16.6)
Adult gastroenterology and hepatology	3 (50.2)

**Table 6: Perceptual-motor abilities classification in the upper gastrointestinal tract diagnostic endoscopy**

Classification	Perceptual-motor abilities
Stability	Arm-hand steadiness, balance-visual cues
Manipulating	Multi-limb coordination, manual dexterity, finger dexterity, hand-eye coordination
Perceptual	Control precision, visuospatial

coordination was necessary for endoscope insertion and its movement in the stomach and duodenum. Furthermore, 60% believed that this ability was necessary for the endoscope passage through the esophagus and its removal from the body.

Finger dexterity entails tasks where small objects are manipulated mainly with fingers in a skillful, controlled manner. To do an endoscopy, the endoscopist holds the control head in the left palm so that the thumb rests on the angulation control (up/down), the index finger (second finger) on the suction valve, the middle finger (third finger) on the air/water valve, and the other two fingers on the endoscope underneath the air/water valve. The thumb is free and can be used to rotate right and left using the small knob. Accordingly, 100% of the experts believed that finger dexterity was a must to insert and remove the endoscope, and 80% believed that this ability was necessary for the movement of the scope in the stomach, while 60% considered finger dexterity essential for the movement of the scope in the esophagus and duodenum.

Arm-hand steadiness is an ability involved in tasks, in which the hand must be completely stable, while the strength and speed play a minimal role. During endoscopy, the elbow of the left hand that holds the endoscope should be stuck to the body as closely as possible. Thus, 100% of the experts believed that arm-hand steadiness was required for an endoscope insertion. However, 60% believed that this ability was a

need for moving the scope in the esophagus, stomach, duodenum, or its removal from the body.

The manual dexterity ability is involved in tasks where relatively large objects are manipulated with hands and arms in a skilled and well-directed manner. For endoscopy, the endoscope end is posited between the right-hand fingers and is skillfully manipulated to view the digestive system. Therefore, 80% of the experts considered manual dexterity critical for endoscope insertion, its movement in the esophagus, and its removal from the body. Moreover, 60% believed that this ability was required to pass the scope through the stomach.

Regarding the available reports and facts, it can be said that psychomotor, perceptual, and visuospatial abilities are conducive to performance and learning skills, especially during image-based procedures.<sup>[9,16]</sup> On the other hand, the training of minimally invasive procedures, such as the GI endoscopy, is noticeably more stressful for trainers because there is limited control over inclusive practices. Therefore, given the reduced time available today for training and the uncertainty and differences in qualification standards, it is vital to determine which learners require further education and which need less training to achieve competency. We hypothesize that one way to distinguish between these two categories of learners is to evaluate basic abilities.

That the experts could not verbalize all the steps and decisions associated with the task conforms to the expertise literature showing that, when the knowledge of a procedure is automated, experts tend to leave out important components at the time of describing it.<sup>[17-19]</sup> Essentially, as experts develop expertise, their knowledge of the task transforms from declarative to procedural knowledge. Automated procedural knowledge operates outside of conscious awareness. A skill that is automated will be tuned to run automatically and executes significantly faster than a conscious process. Automation will guide experts to skip steps and decision points at the time of teaching a procedure since they have virtually lost access to the cognitive decisions and behaviors that are adopted during skill execution.<sup>[17]</sup>

Building on the PTA techniques, we were able to access the automated competencies of our experts and identify the basic steps and decision points that are not often stated during traditional teaching.

One limitation of this study was that video-recording the performance of novice trainees was not possible since they did not have consent or willingness to collaborate. Videos recorded of a task performed by novices can be

examined by researchers, instructors, domain-specific experts, and experts from a different specialty or domain, providing an opportunity for probing the strategies used by the novice trainees, their pitfalls, and their learning difficulties.<sup>[3]</sup> Nevertheless, building on the validation process, we found that the task flow developed in this study was complete and robust. Another limitation with PTA was the fact that it was time consuming and required intensive work. However, its time-consuming nature relies on the number of experts involved, the complexity and length of the procedure, and the experience of the PTA analyst.

## Conclusions

PTA techniques (i.e., video recording, observation, think-aloud protocols, and cued recall) and subsequent expert review were used to identify the components of psychomotor abilities for diagnostic upper GI endoscopy. Based on the PTA, the underlying abilities for diagnostic upper GI endoscopy comprise visuospatial and perceptual abilities, hand-eye coordination, multilimb coordination, finger dexterity, hand-arm steadiness, and manual dexterity abilities. It is suggested that PTA is performed for other procedures, and after psychomotor abilities are specified, proportional tests are developed.

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## Conflicts of interest

There are no conflicts of interest.

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