

**Title:** Factors Influencing Variation in Physician Adenoma Detection Rates: a Theory-Based Approach

**Short Title:** Physician Adenoma Detection Rate Variability

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**Acronyms:** ADR, adenoma detection rate; COM-B model, Capability, Opportunity, and Motivation behavior model.

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## **Abstract**

**Background & Aims:** Interventions to improve physician adenoma detection rates for colonoscopy have generally not been successful and there are little data on the factors contributing to variation that may be appropriate targets for intervention. We sought to identify factors that may influence variation in detection rates using theory-based tools for understanding behavior.

**Methods:** We separately studied gastroenterologists and endoscopy nurses at three Kaiser Permanente Northern California medical centers to identify potentially modifiable factors relevant to physician adenoma detection rate variability using structured group interviews (focus groups) and theory-based tools for understanding behavior and eliciting behavior change: the Capability, Opportunity, and Motivation behavior model; the Theoretical Domains Framework; and the Behavior Change Wheel.

**Results:** Nine factors potentially associated with detection rate variability were identified, including six related to capability (uncertainty about which types of polyps to remove; style of endoscopy team leadership; compromised ability to focus during an exam due to distractions; examination technique during withdrawal; difficulty detecting certain types of adenomas; and examiner fatigue and pain), two related to opportunity (perceived pressure due to the number of exams expected per shift and social pressure to finish exams before scheduled breaks or the end of a shift), and one related to motivation (valuing a meticulous exam as the top priority). Examples of potential intervention strategies are provided.

**Conclusions:** Using theory-based tools, this study identified several novel and potentially modifiable factors relating to capability, opportunity, and motivation that may contribute to adenoma detection rate variability and be appropriate targets for future intervention trials.

**Keywords:** Adenoma/diagnosis; colonoscopy/standards; implementation science; quality improvement

## Introduction

Colonoscopy is a commonly used primary or follow-up screening test to detect colorectal cancer,<sup>1-3</sup> the second leading cause of death from cancer in the United States.<sup>4,5</sup> Colonoscopy can reduce the risk of death from colorectal cancer through detection of tumors at an earlier, more treatable stage and through the removal of precancerous adenomas.<sup>3,6</sup> Physician adenoma detection rate (ADR), the proportion of a physician's screening colonoscopies that detect one or more adenomas, is a recommended quality metric by specialty societies<sup>7</sup> and has been recently introduced by the Centers for Medicare and Medicaid Services as a reportable quality measure. Target adenoma detection rates were recently increased to 20% or higher for female patients and 30% or higher for male patients as indicators of adequate colonoscopy quality.<sup>8</sup> However, ADRs have been found to vary widely in clinical practice,<sup>9</sup> and this variation is associated with patients' subsequent risk of colorectal cancer and mortality.<sup>10,11</sup>

While interventions to increase ADRs have been attempted, few have been successful, potentially because they used "best guess" methods from experts rather than theory-based approaches.<sup>9</sup> A systematic review of 17 interventions reported that only use of an audible timer requiring a minimum inspection time in different colonic segments combined with training on enhanced inspection techniques was successful in increasing detection rates.<sup>9</sup> Videorecording colonoscopy withdrawals and use of periodic report cards on colonoscopy quality measures may offer promise.<sup>12,13</sup> Also, more recently, an educational intervention focused on techniques for performing meticulous exams and identifying adenomas was shown to improve detection rates,<sup>14,15</sup> although similar types of training were not successful in other studies, even when combined with interventions such as feedback, minimum withdrawal times, and financial incentives.<sup>16-18</sup> The poor performance of most interventions attempted may be related to the paucity of evidence on appropriate factors to target for modification. Use of behavior change theory allows for a more systematic identification of potentially modifiable factors that may contribute to variation in the target behavior and the subsequent design of interventions that address those factors.<sup>19-21</sup> Implementation research is an emerging field,<sup>22</sup> but theory-based behavior change interventions designed using a "from the ground-up" approach that incorporates the target audience of the intervention may be more effective than those derived primarily from empiric expert-only speculation,<sup>23-28</sup> particularly when such expert-only non-theory-based interventions have been largely unsuccessful. For example, understanding the barriers and facilitators to hand hygiene led to the

design of a new method that more than doubled the use of hand sanitizing, a notoriously challenging problem in hospitals, to greater than 90%.<sup>29</sup>

The goal of this study was to identify potentially-modifiable factors that may be associated with variation in physician ADRs using theory-based tools for understanding behavior: the Capability, Opportunity, and Motivation behavior (COM-B) model<sup>30</sup> and the Theoretical Domains Framework.<sup>31</sup> These factors can then be used to design and test relevant interventions in future clinical effectiveness trials.

## Methods

### *Behavior change theory-based approach*

This was a focus group study which sought to identify modifiable factors potentially influencing variation in physician ADRs using two theory-based tools for understanding behavior: the COM-B model<sup>30</sup> and the Theoretical Domains Framework (**Figure 1**).<sup>31</sup> The COM-B model (**Appendix 1**) is based on the premise that capability, opportunity, and motivation interact to generate behavior. It has been used to understand behavior and design interventions in a variety of health contexts including a dietary intervention<sup>32</sup> and an evaluation of factors influencing physician use of cardiovascular disease risk assessment strategies.<sup>33</sup> The Theoretical Domains Framework (**Appendix 2**) is a synthesis of 128 theoretical constructs into 14 domains: knowledge; skills; social/professional role and identity; beliefs about capabilities; optimism; beliefs about consequences; reinforcement; intentions; goals; memory, attention and decision processes; environmental context and resources; social influences; emotions; and behavioral regulation. It can be thought of as an elaboration of the COM-B model, with subdivisions of capability, opportunity, and motivation. A number of studies have used this framework to assess implementation problems and to then design and test interventions to improve implementation of evidence-based practice in a variety of health settings.<sup>34</sup> These include: smoking cessation by midwives<sup>35</sup> and dental providers;<sup>36</sup> acute low back pain in primary care;<sup>37</sup> transfusion prescribing;<sup>38</sup> hand hygiene;<sup>39</sup> mental health;<sup>40</sup> and physician prescribing for upper-respiratory tract infections.<sup>41</sup> The protocol was approved by the institutional review board of Kaiser Permanente Northern California.

### *Focus group topic guides*

Focus group topic guides featured a semi-structured list of questions following the COM-B model and Theoretical Domains Framework and were developed to identify factors potentially relevant to physician ADR variability. Because of time limitations for focus group participants, an adaptive one-hour interviewing approach was utilized in which participants were first asked questions covering the three components of the COM-B model (i.e., capability, opportunity, and motivation to improve ADR), and then were asked questions covering the relevant domains of the Theoretical Domains Framework within each applicable COM-B component (script available from authors upon request). The questions allowed for flexibility in exploring different potential causal factors. Two different topic guides were developed; one for gastroenterologists and one for endoscopy nurses. The focus group scripts were developed in conjunction with experienced interviewers, a psychologist with substantial focus group experience, and practicing gastroenterologists to allow pilot testing prior to use.

### *Focus group procedure*

The study used a convenience sample of gastroenterologists and endoscopy nurses working in three different Kaiser Permanente medical centers in Northern California; all relevant personnel at each center were invited to participate. Across the three medical centers this provided six focus group sessions: three for gastroenterologists and, separately, three for endoscopy nurses; a total of sixteen gastroenterologists and twelve endoscopy nurses participated. The six separate focus groups were conducted mid-day or at the end of the work day in medical center conference rooms; a meal was provided and participants were given a \$50 gift card for their time. Two trained researchers (LA and EH) facilitated three focus groups each. The sessions were audio recorded, transcribed, and anonymized.

### *Analysis of focus group findings*

Four trained reviewers independently coded focus group transcripts to identify the primary factors linked to variation in physician ADRs. These emergent factors were identified and coded using the COM-B model and Theoretical Domains Framework. Coding results were discussed among the reviewers and differences were resolved by consensus.

### *Identification of potentially relevant intervention functions and examples of intervention strategies*

The factors identified in focus groups as possibly influencing variation in physician ADRs were linked to intervention functions likely to bring about behavior change using the Behavior Change Wheel (**Figure**

2).<sup>30,42</sup> The Behavior Change Wheel is a synthesis of 19 frameworks of behavior change which suggests links between the COM-B model components (capability, opportunity and motivation) and nine potential intervention strategies to effect behavior change: education, persuasion, incentivization, coercion, training, restriction, environmental restructuring, modeling, and enablement. For illustration purposes, examples of potential intervention strategies are provided.

## Results

### *Emergent factors*

The gastroenterologists and endoscopy nurses identified nine factors that they believed may influence variation in physician ADRs, including: 1) uncertainty about which types of polyps to remove; 2) style of endoscopy team leadership; 3) compromised ability to focus during an exam due to distractions; 4) examination technique during withdrawal; 5) difficulty detecting certain types of adenomas; 6) examiner fatigue and pain; 7) perceived pressure due to the number of exams expected per shift; 8) social pressure to finish exams before scheduled breaks or the end of a shift; and 9) valuing a meticulous exam as the top priority (**Table 1**).

The following are brief descriptions of the nine factors. Relevant quotes from physicians and nurses that illustrate these factors are shown in **Table 1**.

Uncertainty about which types of polyps to remove: Opinions differed as to the clinical importance of removing small polyps. Some physicians felt all detected polyps should be removed, regardless of size, because they could potentially develop into adenomas; others felt diminutive polyps could be ignored.

Style of endoscopy team leadership: Nurses identified physician leadership style of the endoscopy team as a potential contributor to variation in detection rates. Some nurses expressed that physicians who take command of the exam room set the tone for a team approach to the procedure, where all members of the endoscopy team are engaged in the task, and distractions are minimized. Also, physicians noted occasions when nurses spotted polyps they might otherwise have missed.

Compromised ability to focus during an exam due to distractions: The extent to which physicians are able to focus during exams was identified as a possible source of variation; some perceived the ability to focus as an innate skill, though it can vary from day to day; others suggested that it may be a skill that

can be developed. Distractions in the exam room may contribute to variation in detection rates. Distractions include physicians and nurses engaging in conversation during exams; other hospital staff walking in during an exam to retrieve supplies, ask questions, or check when an exam will be done; responding to pagers and call; and background music. Some participants expressed the view that background music improved exam quality, while others felt the opposite.

Examination technique during withdrawal: Performing a meticulous examination of the colon was ranked by both physicians and nurses as the strongest factor predicting ADR. High-performing physicians were viewed as performing more meticulous exams than lower-performing physicians. Some participants perceived meticulousness to be part of a physician's identity; others viewed it as a skill that can be taught. Some physicians perceived that ADR variability can be explained in part by variation in the use of examination techniques such as washing residual stool or mucous.

Difficulty detecting certain types of adenomas: Physicians expressed concern about detecting flat and depressed adenomas in the right colon.

Examiner fatigue and pain: Examiner fatigue and pain were acknowledged as problems that may potentially impact exam duration and quality.

Perceived pressure due to the number of exams expected per shift: The pressure to perform a large number of exams per day, and inflexibility of the schedule when more time-consuming exams are encountered, were suggested to contribute to adenoma detection. Differences in how physicians perceive and respond to that pressure may contribute to ADR variation.

Social pressure to finish exams before scheduled breaks or the end of a shift

Physicians reported feeling pressure to complete exams to avoid delaying endoscopy staff from taking scheduled breaks or incurring staff overtime. Physician responses to time pressure varied: some physicians asserted that they take whatever time they feel is needed to complete a meticulous exam; others respond by decreasing the duration of the exam.

Valuing a meticulous exam as the top priority: Physicians and nurses identified the intention to perform a meticulous exam as an important factor in ADR variability.

The links between the nine identified factors and the components of the COM-B model and Theoretical Domains Framework are shown in **Table 2**. Six factors are associated with psychological or physical capability, two with physical or social opportunity, and one with reflective motivation. The six domains represented include: knowledge; memory, attention, and decision processes; skills; environmental context/resources; social influences; and intentions.

#### *Potentially relevant intervention functions and examples of intervention strategies*

Using the Behavior Change Wheel, we linked the nine identified factors which are potential targets for change to intervention functions intended to bring about desirable behavior changes. As shown in **Table 2**, these links suggest that increasing capability and some aspects of opportunity for detecting adenomas could potentially be addressed through interventions that target education, training, and enablement. For example, an education intervention to increase psychological capability for knowing which polyps to remove might be to develop and implement best practice guidelines emphasizing the removal of all potential adenomas, large and small. An environmental restructuring intervention to address the physical and social opportunity issues of having to finish exams according to pre-set time schedules might be creating greater flexibility in the number or distribution of scheduled exams expected per shift, dependent upon expected or actual difficulty of the exam. And in the situation where clinicians are not valuing a meticulous exam as the top priority, an intervention might increase reflective motivation through persuasion in the form of team activities and evidence-based education reinforcing why it is important to perform a meticulous exam, and/or through innovative incentives for demonstrated increases in ADRs. Although it was beyond the scope of this analysis to test interventions, such potential interventions could be implemented individually or in combinations to address one or more of these identified factors, and strategies could have varying evidence-based methods of delivery to maximize the possibility of change (e.g., interactive, group-based, in-person), be tailored to the needs of individual providers, and be ongoing when warranted.

#### **Discussion**

Using a theory-based approach for understanding behavior, we identified several factors not previously addressed in intervention efforts that may contribute to variation in physician ADRs. Six factors relate to capability: uncertainty about which types of polyps to remove; style of endoscopy team leadership; compromised ability to focus during an exam due to distractions; examination technique during



withdrawal; difficulty detecting certain types of adenomas; and examiner fatigue and pain. Two factors relate to opportunity: perceived pressure due to the number of exams expected per shift and social pressure to finish exams before scheduled breaks or the end of a shift. One factor relates to motivation: valuing a meticulous exam as the top priority.

Prior studies have examined factors associated with ADR variability, including patient-related (e.g., sex, age, race/ethnicity),<sup>43</sup> physician-related (e.g., medical specialty, experience),<sup>44</sup> and exam-related factors (e.g., withdrawal time, morning vs. afternoon exams, numbers of procedures performed per unit time).<sup>45</sup> This study is unique in its use of a structured setting without prior assumptions to ascertain community physician- and endoscopy nurse-identified modifiable factors potentially associated with variability in physician ADR. While some aspects of examination technique have been addressed in prior intervention studies (e.g., particularly withdrawal/examination time),<sup>9</sup> prior interventions have not typically targeted the other factors identified in this study that may be related to the actual target behavior (adenoma detection), such as uncertainty whether or not to remove small polyps, physician differences in detecting depressed and flat adenomas, distractions in the exam room, examiner fatigue and pain, endoscopy team leadership style, productivity related to the total time available for each exam (rather than the amount of time the endoscopist chooses to spend on each exam), and expectations of endoscopy team members in terms of finishing exams before scheduled breaks or the end of a shift. These are novel areas for which future interventions could be considered.

We offer examples of possible intervention strategies that target some of the factors identified (**Table 2**). In practice, with implementation research, the next steps in the intervention design process are to engage stakeholders (e.g., gastroenterology department chiefs, endoscopists, and endoscopy nurses) to: 1) gauge which of the identified factors are most appropriate and feasible to test in an intervention trial; and 2) identify which behavior change techniques and specific methods of delivery are most likely to be successful in an intervention.<sup>42</sup> The final product of this iterative, multi-step, theory-based process is an intervention that targets relevant behaviors, uses appropriate techniques for eliciting behavior change, has the buy-in of those the intervention is intended for, and can then be tested in large trials.

A novel aspect of this study is its use of behavior change theory in a field that has largely taken empiric or “best guess” approaches to designing interventions. Furthermore, it adds to current implementation research methodology by using an adaptive structured interview approach during focus groups of the

target population of clinical gastroenterologists and endoscopy nurses, which allowed for many theoretical domains to be considered in a time-restricted setting. Limitations include the possibility that less time-restricted focus group sessions might have identified other potentially important factors. Also, the study was conducted in an integrated health care delivery system with salaried physicians; additional factors may be identified in fee-for-service endoscopy practices, although the factors identified herein would appear generalizable to most practice settings. Finally, the nine identified factors represent potential targets for intervention studies based on the collective yet subjective input of gastroenterologists and endoscopy nurses, and as such have not yet been shown to be causal factors related to ADR variability between physicians. Only direct testing can establish whether modification of these factors results in direct changes to ADR.

In summary, nine modifiable factors were identified by gastroenterologists and endoscopy nurses as potentially important to explaining ADR variation among physicians, a number of which have not been targeted for interventions in prior studies. These findings offer a theoretical basis for further developing and testing interventions to reduce variation in physician ADRs by targeting capability, opportunity, and motivation.

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**Table 1. Factors influencing physician ADR variability**

	Factor	Quotes
1	Uncertainty about which types of polyps to remove	<p><i>"... small polyps become big polyps, so you should remove all polyps regardless of the size." (physician)</i></p> <p><i>"...but there is disagreement there, should diminutive polyps be removed? You're going to find those polyps in 5 years." (physician)</i></p> <p><i>"Regardless of what the truth is, one of the things that might be driving differences in behavior is beliefs about small polyps." (physician)</i></p> <p><i>"There is disagreement in this room about whether every single polyp should be removed." (physician)</i></p> <p><i>"The small polyps are driving the ADR. I don't think it is 5-10 mm and up, I think it is 5 mm and below. That is the division between whether you are a high detector or low detector, the really small stuff." (physician)</i></p>
2	Style of endoscopy team leadership	<p><i>"Communication and team building - if doctors have those skills, they are going to be better at detecting adenomas because they are setting themselves up for success." (nurse)</i></p> <p><i>"The physician sets a nice pace in the room where no one is rushing, they command the center of the room, and you want to be a part of it, you don't feel like you are an outsider." (nurse)</i></p> <p><i>"The physician sets the stage. 'Here we are, this is the patient's history, this is what I want from you, this is all the equipment, and this is what I expect we will see.' And then everyone is watching the screen." (nurse)</i></p> <p><i>"Where staff is really important too, is focusing on the patient and not multi-tasking in the room with other issues, because it is another set of eyes." (physician)</i></p> <p><i>"The more people who look at the screen, the better your detection rate is." (nurse)</i></p> <p><i>"It can also be helpful to have 4 eyes in the rooms looking at the screen. Sometimes we miss things and the nurses will see it." (physician)</i></p>

3	Compromised ability to focus during an exam due to distractions	<p><i>“A physician’s innate level to concentrate is important, like some people have a concentration span for a certain period of time, some people are longer and some people are shorter. And some days you are just more attentive than others.”</i> (physician)</p> <p><i>“It could be that higher-performing physicians have developed a sense of focus, that distractions don’t interrupt them.”</i> (nurse)</p> <p><i>“Distractions influence the quality of exams - beepers going off, people coming in all the time, nurses asking questions and getting supplies.”</i> (physician)</p> <p><i>“Other conversations in the room can break things up a little bit, but can also be distracting and divert your attention away from the exam itself. Sometimes they are very social conversations.”</i> (physician)</p> <p><i>“A clinic staff person might come over and ask the doctor about a patient, about ordering a prep, or about a problem he or she could possibly address in between procedures. These kinds of distractions and interruptions are an opportunity where something can be missed.”</i> (nurse)</p> <p><i>“Music improves exam quality, not only does it make the doctor more relaxed, it makes the patient more relaxed, and the staff is more harmonious.”</i> (physician)</p> <p><i>“Some doctors tend to lose track. They get into the music and they wander off with their thoughts or their conversations.”</i> (nurse)</p>
4	Examination technique during withdrawal	<p><i>“I think attention to detail is a factor in terms of ADR and quality.”</i> (physician)</p> <p><i>“The higher-performing physicians get to the cecum and they actually look behind the ileocecal valve when they intubate the terminal ileum - I think that is meticulous.”</i> (nurse)</p> <p><i>“If Dr. X sees the slightest abnormality he will stop, he will go by, and then he looks upwards and downwards, left and right for a long time, he’ll change the light and he’ll really examine it.”</i> (nurse)</p> <p><i>“It’s a personality thing too. Some physicians are quick and dirty, while others are slow and meticulous.”</i> (physician)</p>

		<p><i>"Meticulousness is a personality characteristic that makes a good gastroenterologist."</i> (nurse)</p> <p><i>"As skilled as somebody might be, some people just have an eye for being meticulous."</i> (physician)</p> <p><i>"You can have a ton of experience, but if you weren't trained to be meticulous, it is a little different."</i> (physician)</p> <p><i>"I think it is both part of experience and part of your training to be meticulous."</i> (physician)</p> <p><i>"If there is a low ADR, maybe there is something about the technique that person uses, and maybe they just are not as good as the other person."</i> (physician)</p> <p><i>"I've learned a lot from Dr. X taking the time to clean out the bowel. I mean, the little mucous caps hide things. We were never trained to do that stuff."</i> (physician)</p>
5	<p>Difficulty detecting certain types of adenomas</p>	<p><i>"Sometimes you are certain that what you are looking at is a hyperplastic polyp, but now that the 'serrated adenoma' has come into our lexicon, I don't have a sense of whether I should remove everything that is a bump, or whether things that I used to confidently ignore in the past is still acceptable."</i> (physician)</p> <p><i>"In the right colon you have flat lateral-spreading tumors and if you are not trained to look for these things you are going to easily miss them, and they have higher rates of advanced histology."</i> (physician)</p>
6	<p>Examiner fatigue and pain</p>	<p><i>"It is exhausting for physicians all day doing that, procedure after procedure."</i> (nurse)</p> <p><i>"Sometimes if the physician has physical discomfort or pain, they will want to go a little bit faster to get it done."</i> (physician)</p> <p><i>"Physical and mental fatigue in terms of focusing on the screen are factors that influence exam quality."</i> (physician)</p> <p><i>"At this point in my career it is my hands. When I have a difficult exam these days, I'm thinking, I don't know if I can keep this up much longer."</i> (physician)</p>



<p>7</p>	<p>Perceived pressure due to the number of exams expected per shift</p>	<p><i>"...they are required to do this number of patients and they can't even take a stretch break."</i> (nurse)</p> <p><i>"...I go into the terminal ileum almost every time, and I think that makes me look at the cecum better, but that's because I have time. If I felt like I had no time to get it done, when I feel stressed for time, I don't do that."</i> (physician)</p> <p><i>"Sometimes we are judged by the numbers, the number of procedures and even the time it takes to do a procedure, and that jeopardizes quality because some people take more time. Female doctors get more female patients, and we know they are harder to do. But if there is not more time, you have to cut corners."</i> (physician)</p> <p><i>"The goal is for us to be doing 12 procedures per day and I would say that affects the quality of our procedures."</i> (physician)</p>
<p>8</p>	<p>Social pressure to finish exams before scheduled breaks or the end of a shift</p>	<p><i>"There are some personalities who don't care if they run late, and they don't care if they keep the nurses late. But sooner or later that person is going to hear about it. So there is some negative pushback to that."</i> (physician)</p> <p><i>"I would like to not be keeping the nurses over time and I'd like to get the job done on time, but if I need to in order to do my work, I'm doing my work no matter what."</i> (physician)</p> <p><i>"In reality, how it works is, towards the end of the morning or end of the afternoon, you have your charge nurse come in and ask, 'what number is this, which procedure is this, when are you going to be finished?' So that drives you a little bit, even if you try to resist that, you are constantly looking at the clock. It's also a reputation thing; you don't want to be known among the nurses as always slow, you want to run on time."</i> (physician)</p> <p><i>"One factor that I think a lot of people are influenced by to cut corners is the absolute deadline – we have to finish by 5 pm. You contrast that to the surgeons and it is different. You look at how the OR is scheduled – let's say there are six cases - if the second case takes longer, then it just takes longer and you do whatever is right, you get that belly open, and everybody else just shifts down to compensate, and the OR staff is going to be there until they</i></p>

		<p><i>finish. It is different for GI, because you have an absolute deadline of 4:30 or 5:30 because people are looking to go home. We do whatever, 12 cases per day, and one of them can turn out to be difficult, or several of them. But we have an absolute deadline.” (physician)</i></p>
<p>9</p>	<p>Valuing a meticulous exam as the top priority</p>	<p><i>“The gastroenterologist really needs to care, to want to do a good exam.” (physician)</i></p> <p><i>“Gastroenterologists as a whole have been through a lot to get to where they are, but I think there is still variation in the degree of caring and quality of the gastroenterologist.” (physician)</i></p> <p><i>“When exiting the parking garage onto a one-way street, some people only look to the left and then drive; some people look to the right for pedestrians and look to the left, and then drive out. What is it that makes some people look in both directions so that they don’t run anyone over, while some people just look to the left? I think it is a matter of being aware and thinking about it. I think some gastroenterologists just don’t think about sucking up a puddle to make sure they aren’t missing a polyp. They don’t think they need to do a little extra to get a better exam.” (physician)</i></p> <p><i>“It’s almost as if some doctors are just getting through their day and are not invested in the process.” (nurse)</i></p>

**Table 2. Links between the COM-B model and Theoretical Domains Framework identified factors and relevant intervention functions**

COM-B Component	TDF Domain	Factor	Relevant intervention functions										Examples of potential Intervention strategies that could be tested		
			Education	Training	Enablement	Restriction	Environmental restructuring	Modeling	Persuasion	Coercion	Incentivization				
Psychological capability	Knowledge	Uncertainty about which types of polyps to remove											<b>Education</b>	<ul style="list-style-type: none"> <li>Interactive or group-learning educational programs</li> </ul>	
		Style of endoscopy team leadership												<b>Training</b>	<ul style="list-style-type: none"> <li>Physician leadership training</li> <li>Team-based approaches in the endoscopy unit</li> <li>Structured team goals</li> </ul>
	Memory, attention and decision processes	Compromised ability to focus during an exam due to distractions												<b>Enablement</b>	<ul style="list-style-type: none"> <li>Minimization of distractions in the endoscopy unit</li> <li>Focused environment (e.g., sign on door indicating exam in progress)</li> </ul>
		Examination technique during withdrawal												<b>Training</b>	<ul style="list-style-type: none"> <li>Interactive practice of examination techniques</li> </ul>
Physical capability	Skills	Difficulty detecting certain types of adenomas												<b>Training</b>	<ul style="list-style-type: none"> <li>Detecting flat and depressed polyps</li> </ul>
		Examiner fatigue and pain												<b>Training:</b>	<ul style="list-style-type: none"> <li>Physical therapy for mitigating fatigue and pain</li> </ul>
Physical opportunity	Environmental context / resources	Perceived pressure due to the number of exams expected per shift											<b>Environmental restructuring:</b>	<ul style="list-style-type: none"> <li>Schedule modification and back-up to support physicians who encounter long cases</li> </ul>	
Social opportunity	Social influences	Social pressure to finish exams before scheduled breaks or the end of a shift													
Reflective motivation	Intentions	Valuing a meticulous exam as the top priority											<b>Persuasion and incentivization</b>	<ul style="list-style-type: none"> <li>Culture of valuing exam quality</li> <li>Individual and group incentives for higher adenoma detection</li> </ul>	

## Figure 1: Relationship between elements of the COM-B model and Theoretical Domains Framework

Category titles are from the COM-B model.

Bullet points below each title represent the corresponding Theoretical Domains Framework domains for each category.

**Figure 2: Behavior Change Wheel intervention functions and definitions**

## Appendix 1: COM-B model components and examples

COM-B model component Definition	<i>Example</i>
<b>Physical capability</b> Physical skill, strength or stamina	<i>Having the skill to steer and manipulate an endoscope</i>
<b>Psychological capability</b> Knowledge or psychological skills, strength or stamina to engage in the necessary thought processes	<i>Understanding the abnormalities requiring biopsy or removal during colonoscopy</i>
<b>Physical opportunity</b> Opportunity afforded by the environment involving time, resources, locations, physical barriers	<i>Availability of appropriate endoscopic equipment</i>
<b>Social opportunity</b> Opportunity afforded by interpersonal influences, social cues and cultural norms that influence the way that we think about things, e.g. the words and concepts that make up our language	<i>Presence of a common understanding among team members to minimize distractions during colonoscopy procedures</i>
<b>Reflective motivation</b> Reflective processes involving plans and evaluations	<i>Having goals and a plan for an endoscopic exam</i>
<b>Automatic motivation</b> Automatic processes involving emotional reactions, impulses and reflex responses that arise from associative learning and/or innate dispositions	<i>Feeling anticipated satisfaction at the prospect of detecting and removing adenomas that might otherwise progress to cancer</i>

**Appendix 2: Theoretical Domains Framework: domain definitions and theoretical constructs**

<b>Domain</b> Definition	<b>Theoretical constructs represented within each domain</b>
<b>Knowledge</b> An awareness of the existence of something	Knowledge (including knowledge of condition / scientific rationale); procedural knowledge; knowledge of task environment
<b>Skills</b> An ability or proficiency acquired through practice	Skills; skills development; competence; ability; interpersonal skills; practice; skill assessment
<b>Memory, attention and decision Processes</b> The ability to retain information, focus selectively on aspects of the environment and choose between two or more alternatives	Memory; attention; attention control; decision making; cognitive overload/tiredness
<b>Behavioral regulation</b> Anything aimed at managing or changing objectively observed or measured actions	Self-monitoring; breaking habit; action planning
<b>Social/professional role and identity</b> A coherent set of behaviors and displayed personal qualities of an individual in a social or work setting	Professional identity; professional role; social identity; identity; professional boundaries; professional confidence; group identity; leadership; organizational commitment
<b>Beliefs about capabilities</b> Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use	Self-confidence; perceived competence; self-efficacy; perceived behavioral control; beliefs; self-esteem; empowerment; professional confidence
<b>Optimism</b> The confidence that things will happen for the best or that desired goals will be attained	Optimism; pessimism; unrealistic optimism; identity
<b>Beliefs about consequences</b> Acceptance of the truth, reality, or validity about outcomes of a behavior in a given situation)	Beliefs; outcome expectancies; characteristics of outcome expectancies; anticipated regret; consequents
<b>Intentions</b>	Stability of intentions; stages of change model; transtheoretical model and stages of change

<b>Domain</b> Definition	<b>Theoretical constructs represented within each domain</b>
A conscious decision to perform a behaviour or a resolve to act in a certain way	
<b>Goals</b> Mental representations of outcomes or end states that an individual wants to achieve	Goals (distal / proximal) ; goal priority; goal / target setting; goals (autonomous / controlled); action planning; implementation intention
<b>Reinforcement</b> Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus	Rewards (proximal / distal, valued / not valued, probable / improbable); incentives; punishment; consequents; reinforcement; contingencies; sanctions
<b>Emotion</b> A complex reaction pattern, involving experiential, behavioral, and physiological elements, by which the individual attempts to deal with a personally significant matter or event	Fear; anxiety; affect; stress; depression; positive / negative affect; burn-out
<b>Environmental context and resources</b> Any circumstance of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behavior	Environmental stressors ; resources / material resources ; organizational culture /climate ; salient events / critical incidents; person x environment interaction; barriers and facilitators
<b>Social influences</b> Those interpersonal processes that can cause individuals to change their thoughts, feelings, or behaviors	Social pressure; social norms; group conformity; social comparisons; group norms; social support; power; intergroup conflict; alienation; group identity; modelling



Fig 1.

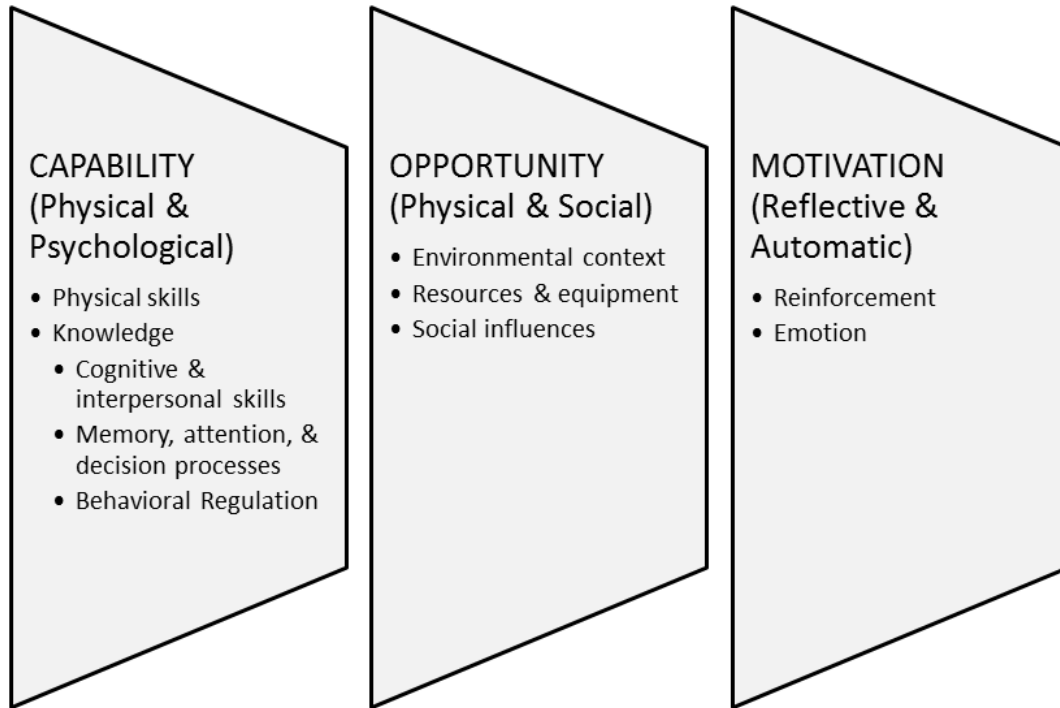


Fig 2.

