

HOW DO ENDOSCOPISTS MAINTAIN SITUATION AWARENESS IN COLONOSCOPY?

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Disorientation is common for endoscopists performing colonoscopy. The objectives of this study were to examine how endoscopists acquire and maintain spatial awareness or situation awareness (SA), and how SA varies as a function of available perceptual cues, and as a function of the different segments of the colon. Retrospective analysis of verbal protocols from 11 colonoscopy procedures was conducted for evidence of spatial disorientation, assessment of situation and problem-solving. Analysis of verbal data revealed that the perceptual cues used for SA maintenance in colonoscopy are unreliable (i.e., anatomical landmarks are variable and ambiguous), giving rise to uncertainty in situational assessment (i.e., segments of the colon may be tortuous and twisted; loops may form in the colon), and multiple trial-and-error attempts at implementing strategies to regain control of the situation. Experienced endoscopists were better able to maintain SA than less experienced ones, and thus, better able to implement strategies in navigating the colon. However, all were equally likely to get lost or disoriented in the colon, especially in the sigmoid and transverse segments. Although the inferred degree of SA was not correlated with the incidence of disorientation, this study showed that SA is involved in colonoscopy. Endoscopists maintain SA by constantly seeking out relevant cues to update the situational model of the work domain. When the situational model is accurate, consequent decision-making, action-selection and execution are appropriate. This work has implications for the design of navigational systems for colonoscopy, a dynamic and impoverished environment.

INTRODUCTION

Colorectal cancer is the third most common cancer and the second-leading cause of cancer deaths among Americans (American Cancer Society, 2003). Even though colon cancer is 90% successfully treated if detected at an early stage, the compliance rate for screening is only 30% in the United States. This resistance to regular colonoscopies is due, in large part, to the fact that the procedure is extremely uncomfortable. Colonoscopy utilizes a flexible endoscope to examine the inner wall of the colon for lesions and tumours (see Figure 1). It requires that the endoscopist acquire a high degree of hand-eye coordination, as well as a good sense of spatial

orientation or spatial awareness. Disorientation is common even amongst expert endoscopists, and often results in a longer procedure with more pain-inducing scope manipulations (Cao & Milgram, 2000). Normally, disorientation in navigation is assumed to be associated with a low degree of spatial awareness or situation awareness (SA), as in aviation. However, despite the high incidence of disorientation, most endoscopists are able to complete 85-90% of the procedures and diagnose the patients' condition, suggesting a high degree of SA (if indeed high SA is necessary for good performance in colonoscopy). The objectives of this study, therefore, were to examine how endoscopists acquire and maintain situation awareness, and how SA varies as a function of

available perceptual cues, and as a function of the different segments of the colon.

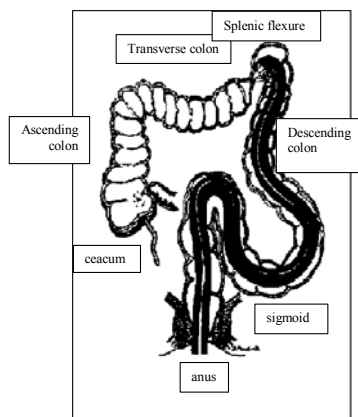


Figure 1. A schematic of the colon, showing the configuration of the colonoscope with the end of the scope at the splenic flexure.

METHODS

A retrospective analysis of the verbal protocols from a field study, conducted to examine disorientation in colonoscopy (Cao & Milgram, 2000), was performed. The verbal reports were from on-line talk-aloud protocols and verbal interactions during the examination of patients (recorded by hand-written notes, audiotapes, and videotapes).

Subjects

A total of fourteen endoscopists participated in the field study. These 14 subjects consisted of expert gastroenterologists, general surgeons who also performed colonoscopies, and gastroenterology fellows.

Procedure

Field study verbal protocols. Each subject went through an initial interview about the procedure of colonoscopy, the general types of difficulties encountered during the colonoscopy procedure, and strategies used for successful navigation through the colon, etc. The interviews were recorded on audiotape for subsequent transcription and analysis.

After the initial interviews, observation of clinical sessions was conducted within the natural setting of an actual colonoscopy procedure. During patient examination, the endoscopists were encouraged to speak aloud everything that he/she was thinking and doing, whenever possible, as though carrying on an internal conversation, presumably similar to a teaching session with a novice resident. An external microphone was placed in the room to record all verbalising for subsequent transcription and analysis.

Analysis. Audiotapes were transcribed and annotated. From the transcriptions, a retrospective analysis was performed to infer the various degrees of SA present according to the normative model of situation awareness in dynamic systems (Endsley, 1995). Evidence of 1) cue perception, 2) assessment of situation, and 3) successful problem-solving were coded and occurrence quantified. Each class of evidence from 1) to 3) can be considered analogous to increasing degrees of SA. The overall level of SA acquired or maintained was then correlated with the occurrence of local disorientation as a function of progress in the colonoscopy procedure.

RESULTS & DISCUSSION

Disorientation

In all eleven procedures, endoscopists were globally disoriented and locally disoriented at least once during the colonoscopy procedure. Disorientation in colonoscopy occurred on two different levels: globally and locally. Global disorientation was characterized by the sense of “not knowing where one is in the colon”. Even though there were landmarks to indicate the various segments of the colon, the landmarks were highly variable and ambiguous (see Table 1). Global disorientation can affect the planning and execution of navigation manoeuvres for upcoming turns in the colon, as well as the localization of tumours for subsequent surgery.

Local disorientation, on the other hand, was characterized by the sense of “not knowing which way to proceed”, and was observed when the endoscopist had lost sight of the lumen (the opening in the tunnel-like colon) in the endoscopic view.

This resulted in a visual search by manipulating the tip of the endoscope to sweep the surrounding area in the colon. Local disorientation was more frequent in the sigmoid colon, likely due to the redundant and floppy nature of the colon. Another area of frequent disorientation was in the transverse colon. This may be due to a combination of physical and perceptual constraints. In addition to the lack of landmarks, the long moment arm created at the point of insertion makes it more difficult to manipulate and control.

Table 1. Land List of landmarks in the colon, in order of appearance from rectum to caecum.

Location	Landmark
Rectum	Highly vascular, bluish vessels
Sigmoid colon	Ring-like valves
Descending colon	Narrow and tubular
Splenic flexure	Dark blue hue from spleen
Transverse colon	Triangular folds
Hepatic flexure	Dark blue hue from the liver
Ascending colon	Large lumen
Ileocecal valve	Fatty lip
Terminal ileum	Vascular, pink and smooth wall

Level 1 SA: Evidence of cue perception

Because the landmarks were ambiguous and variable, identification of the landmark did not guarantee that the location in the colon was correct. Therefore, the first stage of acquiring situation awareness was determined by the perception of visual cues, along with time elapsed and distance travelled. From the verbal protocol, it can be noted when the endoscopists perceived the anatomical landmarks or cues that would suggest the location within the colon. The frequency of cue perception represented the degree of level 1 SA acquired.

The landmarks corresponding to the caecum and sigmoid colon were the two most prominent in the verbal protocol at this perceptual level of SA acquisition. The caecum marked the end of the procedure, while the sigmoid was near the beginning of the procedure and the most difficult segment to navigate. The next most prominent landmarks perceived corresponded to the transverse colon and the hepatic flexure, suggesting that these are anchor points by which endoscopists update their situation models of the environment. A score

for the degree of SA was generated based on the frequency of noted verbalisation (see Figure 2).

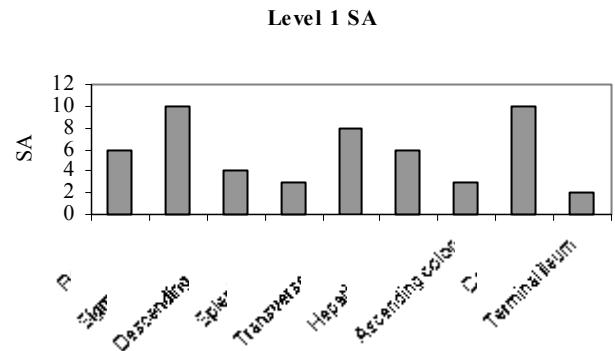


Figure 2. Degree of level 1 SA (arbitrary units) in various segments of the colon.

Level 2 SA: Evidence of active assessment

Once the landmarks were perceived, there followed an assessment of the current status of progress or location within the colon. The sigmoid colon was by far the most easily identified segment with a correct assessment rate of 91% (see Figure 3). Other segments of the colon were not as easily determined. In general, endoscopists had to make an initial assessment of the location within the colon which was then confirmed by the next landmark encountered. This retrospective confirmation seems to be a way for the endoscopist to maintain SA in the dynamic and impoverished environment of the colon. Therefore, endoscopists did not have as high a level 2 SA as level 1.

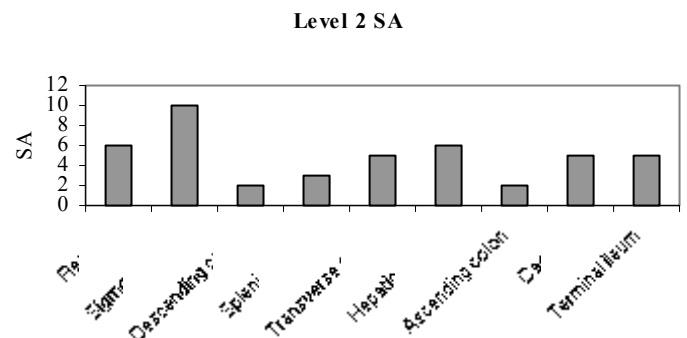


Figure 3. Degree of level 2 SA (arbitrary units) in various segments of the colon.

Level 3 SA: Problem solving

Given that a good prediction of upcoming events in the colon, such as a sharp corner or a loop formed in the colon, is possible only if the endoscopist was correct in assessing the status of the scope inside the colon, evidence of level 3 SA was rare. Many of the endoscopists' actions were reactive, such that many trial-and-error manipulations of the endoscope were necessary. However, the more expert endoscopists were able to run through these manipulations more quickly to find an appropriate manoeuvre.

SA and experience

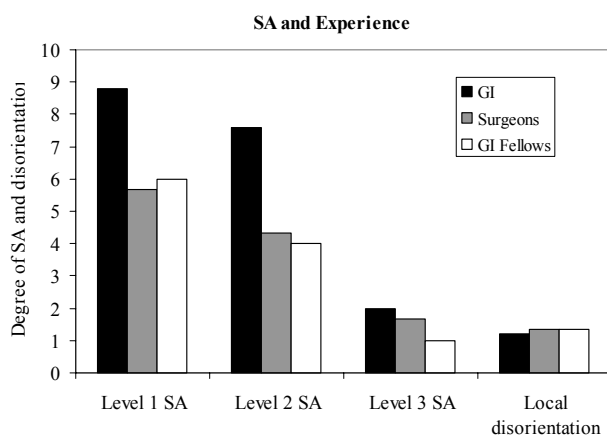


Figure 4. Degree of SA and disorientation (arbitrary units) and experience.

The subjects in this study were comprised of gastroenterologists (GI), general surgeons, and GI Fellows. The GIs had the most experience while the GI fellows and the general surgeons had about the same amount of experience in average number of colonoscopy cases performed. Figure 4 compares the three different groups of endoscopists at the various levels of SA and local disorientation. GIs seemed to have a relatively greater degree of SA at all 3 levels of SA, while the incidence of local disorientation was about the same as the other two groups of endoscopists. The results indicate that they were much more aware and able to make assessments and prediction from the perceived landmarks. The GIs know what to look for and what to expect in patients with certain medical histories (hysterectomy, chronic diarrhoea, etc.).

Since local disorientation is not correlated with SA, this would indicate that local disorientation is not associated with spatial awareness, and would therefore suggest that the difficulty experienced in performing manipulation of the endoscope is not related to situation awareness.

CONCLUSION

Experienced endoscopists were better able to maintain SA than less experienced ones, and better able to implement strategies in navigating the colon. However, all were equally likely to get lost or disoriented in the colon, especially in the sigmoid and transverse segments. Although the degree of SA was not correlated with the incidence of disorientation, this study showed that SA is involved in colonoscopy. Endoscopists maintain SA by constantly seeking out relevant cues to update the situational model of the work domain. When the situational model is accurate, subsequent decision-making, action-selection and execution are appropriate. This work has implications for the design of navigational systems for colonoscopy. By highlighting relevant cues on a navigational aid display, the endoscopist can better maintain SA and remain oriented in a dynamic and impoverished environment.

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