Effects of Experience, Withdrawal Speed and Monitor Size on Colonoscopists’ visual detection of polyps


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This paper examined the effects of experience, withdrawal speed and monitor size on colonoscopists’ visual detection of polyps during colonoscopy. Five novice and five expert colonoscopists participated in a simulation experiment, where they viewed colonoscopy videos and indicated the presence or absence of polyps. Hit rate and false alarm rate of polyp detection were calculated and analyzed. The results showed that expert colonoscopists had superior visual detection skills in terms of hit rate. An increase of withdrawal speed significantly reduced the hit rate for both novice and expert colonoscopists.

INTRODUCTION

Colorectal cancer is the second leading cause of cancer death in the United States (American Cancer Society, 2013) and the most common cancer in Singapore (National Cancer Center Singapore, 2011). To prevent the incidence of colorectal cancer, colonoscopy is used to detect and remove adenomatous polyps before their potential progress to adenocarcinomas (Chen & Rex, 2007). Approximately, colonoscopy and polypectomy contributed to 80% reduction of colorectal cancers (Winawer et al., 1993).

In spite of the obvious importance of adequate detection of polyps in colonoscopy screening, studies showed that colonoscopies were not performed perfectly. The miss rate for polyps ranged from 6% to 27%, with a significant increase in smaller sized polyps (Simmons et al., 2006). In order to improve polyp detection in colonoscopy screening, the adoption of optimal examination techniques have been emphasized by expert clinicians (Barclay, Vicari, Doughty, Johanson, & Greenlaw, 2006; Chen & Rex, 2007; Kaminski et al., 2010).

It has been proposed that colonoscopy examination techniques include two aspects: the ability of controlling the colonoscope tip to reach various sections of the colon, and the ability of visualizing and recognizing polyps (Haseman, Lemmel, Rahmani, & Rex, 1997). The former aspect has received extensive attention in the past decade, leading to the recommendation of cecal intubation rate (i.e. whether the colonoscope tip reaches the cecum) as one quality indicator for colonoscopy (Kaminski et al., 2010). The latter aspect, however, has not yet been examined carefully in the literature.

This paper, therefore, aimed to examine the factors influencing colonoscopists’ visual detection performance. In particular, we aimed to study the effects of experience, colonoscope withdrawal speed and colonoscopy monitor size on visual detection performance.

BACKGROUND

What is colonoscopy?

Colonoscopy is a medical procedure involving a well-trained specialist inserting a long flexible tube with a camera and a beaming light source to look inside the large intestine (American Society for Gastrointestinal Endoscopy, 2015). Colonoscopy is normally performed by a gastroenterologist or a surgeon. During the examination, the colonoscopist inserts the scope through the large intestine including anus, rectum, colon and cecum, and examines each part during the withdrawal of the colonoscope. Colonoscopy is one of the most challenging procedures in endoscopy due to the presence of flexures and haustral folds, and the orientation of the large intestine. The large intestine is not straight but arranged in an inverted U shape in the abdominal cavity with acute angle changes when it approaches the spleen and the liver (Niwa, Sakai, & Williams, 2003). In order to examine the large intestine thoroughly, the colonoscopists need to carefully control the direction of the scope by manipulating the driving dial on top of the colonoscope with one hand and handling the tube in another. The video from the colonoscope is shown real-time on a TV monitor (Figure 1).

To improve the polyp detection rate during colonoscopy, research efforts have been made to develop advanced imaging techniques. In the past few years, high definition colonoscopes and visual image enhancement technologies such as narrow band imaging (NBI) have been introduced. These technologies aim to enhance the colonoscopy video quality and hence improve the detection performance. However, limited increase in diagnostic yield has been reported (Adler et al., 2008; Dik, Moons, & Siersma, 2014; Kaltenbach, Friedland, & Soetikno, 2008; Paggi et al., 2009; Rex & Helbig, 2007; Sabbagh, Reveiz, Aponte, & de Aguiar, 2011).
and CR rates are equally important as a FA will likely harm
the hit and miss rates. We argue that the examination of FA
Previous studies on polyp detection have primarily focused on
false alarm (FA), and correct rejection (CR)
the
true state. The combination of the state of the
world, the human operator may or may not be able to identify
present or signal absent. As there are noises in the state of the
1954)

ability of detecting signals among noises
model the relationship between signals and noises, and the

such study protocols commonly used in
these studies. In a typical field or simulation study, participants performed real or simulated colonoscopies by
manipulating the colonoscope to examine different sections of
the colon and detecting possible polyps/adenomas.
Polyp/adenoma detection rates were measured afterwards.
Such study protocols prevent the researchers from analyzing
the effects of motor control and visual detection separately.
In the present study, therefore, we adopted a new
simulation approach by using a recorded video colonoscopy
instead of a conventional colonoscopy simulator or a tandem
colonoscopy (van Rijn et al., 2006). By doing this, we were
able to accurately examine colonoscopists’ visual detection
skills.

Signal detection theory

The signal detection theory (SDT) was proposed to
model the relationship between signals and noises, and the
ability of detecting signals among noises (Tanner & Swets,
1954). SDT models the state of the world to be either signal
present or signal absent. As there are noises in the state of the
world, the human operator may or may not be able to identify
the true state. The combination of the state of the world and
the operator’s decision results in four possible states: hit, miss,
false alarm (FA), and correct rejection (CR) (Table 1).
Previous studies on polyp detection have primarily focused on
the hit and miss rates. We argue that the examination of FA
and CR rates are equally important as a FA will likely harm
patients physiologically, emotionally and financially.

Table 1 Four possible states according to SDT

<table>
<thead>
<tr>
<th>Human decision</th>
<th>State of the world</th>
<th>Signal</th>
<th>No Signal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Signal</td>
<td>Hit</td>
<td>False alarm (FA)</td>
<td></td>
</tr>
<tr>
<td>No Signal</td>
<td>Miss</td>
<td>Correct rejection (CR)</td>
<td></td>
</tr>
</tbody>
</table>

METHODOLOGY

Participants

Five expert and five novice colonoscopists from the
Department of Molecular Gastroenterology and Hepatology,
Kyoto Prefectural University of Medicine participated in the
study. The expert colonoscopists were attending
gastroenterologists aged 45 years (SD = 4.0) and had
performed 15200 (SD = 5020) colonoscopies on average. The
novice colonoscopist were residents/clinical fellows aged 32
years (SD = 1.3) and had performed 900 (SD = 224)
colonoscopies on average. An independent sample t-test
showed a significant difference (t(1, 8) = 6.363, p < .001) in
the number of colonoscopies performed by the two groups.
The study was approved by the institutional review
board and the ethics committees of Kyoto Prefectural
University of Medicine and all participants provided written
informed consent. In addition, this study was performed in
accordance with the World Medical Association Helsinki
Declaration and was registered in the University Hospital
Medical Information Network Clinical Trials Registry
(UMIN-CTR) as number UMIN000014013.

Experimental materials and design

An expert colonoscopist developed 15 colonoscopy
videos for the experiment. The length of the videos ranged
from 106 seconds to 115 seconds for normal speed videos, and
from 62 seconds to 64 seconds for fast speed video. Each
video was made up of 16 separate movie clips of real-life
colonoscopy withdrawal process. Among the 16 movie clips
in one video, polyps were present in 8 movie clips and absent
in the other 8. The order of the 16 movie clips were fully
randomized in a video. The polyps could appear in the
beginning, middle or end of a movie clip. To imitate natural
colonoscopy withdrawal process, all the movie clips were also
arranged according to withdrawal route from caecum,
ascending colon, descending colon, sigmoid colon to rectum.
Table 2 shows the 15 videos and the corresponding
treatment conditions. The videos varied in 5 dimensions: light
depicts the type of imaging technique for colonoscopic
videos. Narrow band imaging (NBI) utilizes light of specific
blue and green wavelengths to enhance the details of the colon
surface, whereas white light utilizes a combination of lights of
different wavelengths. Speed indicates how fast the
colonoscope is withdrawn from the patient. In the slow
colonoscopy withdrawal process, all the movie clips were also
arranged according to withdrawal route from caecum,
ascending colon, descending colon, sigmoid colon to rectum.
Figure 1 shows the 15 videos and the corresponding
treatment conditions. The videos varied in 5 dimensions: light
depicts the type of imaging technique for colonoscopic
videos. Narrow band imaging (NBI) utilizes light of specific
blue and green wavelengths to enhance the details of the colon
surface, whereas white light utilizes a combination of lights of
different wavelengths. Speed indicates how fast the
colonoscope is withdrawn from the patient. In the slow
condition, a video was played at the normal speed of scope.
withdrawal (simulating the normal withdrawal speed) and in the fast condition a video was played at the 2x speed of scope withdrawal (simulating the fast withdrawal speed). Distance is the physical distance from the colonoscopist and the monitor, which was 0.5 meter at near and 1 meter at far. The size of the monitor also varied in two levels: 24 inches versus 42 inches. Review refers to whether a participant was allowed to rewind the video and view it again.

**Table 2 The 15 videos and corresponding treatment conditions**

<table>
<thead>
<tr>
<th>Video</th>
<th>Light</th>
<th>Speed</th>
<th>Distance</th>
<th>Size</th>
<th>Review</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>white</td>
<td>slow</td>
<td>near</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>J</td>
<td>white</td>
<td>fast</td>
<td>near</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>K</td>
<td>white</td>
<td>fast</td>
<td>far</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>L</td>
<td>white</td>
<td>slow</td>
<td>near</td>
<td>Small</td>
<td>Yes</td>
</tr>
<tr>
<td>M</td>
<td>white</td>
<td>slow</td>
<td>far</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>N</td>
<td>white</td>
<td>slow</td>
<td>near</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>O</td>
<td>NBI</td>
<td>slow</td>
<td>near</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>P</td>
<td>NBI</td>
<td>fast</td>
<td>near</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>Q</td>
<td>NBI</td>
<td>fast</td>
<td>far</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>R</td>
<td>NBI</td>
<td>slow</td>
<td>near</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>S</td>
<td>NBI</td>
<td>slow</td>
<td>Near</td>
<td>Small</td>
<td>No</td>
</tr>
<tr>
<td>T</td>
<td>white</td>
<td>slow</td>
<td>near</td>
<td>Big</td>
<td>No</td>
</tr>
<tr>
<td>U</td>
<td>white</td>
<td>fast</td>
<td>near</td>
<td>Big</td>
<td>No</td>
</tr>
<tr>
<td>V</td>
<td>NBI</td>
<td>slow</td>
<td>Near</td>
<td>Big</td>
<td>No</td>
</tr>
<tr>
<td>W</td>
<td>NBI</td>
<td>fast</td>
<td>near</td>
<td>Big</td>
<td>No</td>
</tr>
</tbody>
</table>

Each participant watched the 15 videos in a fully randomized order and indicated the presence of a polyp by both verbally narrating 'polyp' and pointing to the position of the polyp to the experimenter.

**Data analysis**

As the original design of treatment conditions for the 15 videos was a full factorial design, we extracted data of videos I, J, N, O, P, R, T, U, V, W in order to form a 2 (Light) × 2 (Speed) × 2 (Size) factorial design. As videos I and N corresponded to the same treatment condition, a mean value was calculated and used in the analysis. The same method was applied to videos O and R. Mixed design ANOVAs were conducted to analyze the data, with experience as the between-subject factor and Light, Speed, Size and the within-subject factors.

**RESULTS**

Table 3 shows the mean and SD values of hit and FA rates at each level of treatment conditions.

Two mixed design ANOVAs were conducted to analyze the effects of the four independent variables on Hit rate and FA rate separately. Results pertinent to the effects of Light have been reported in a separate paper therefore we do not report those results in the present study.

**Table 3 Mean and SD values of hit and FA at each level of treatment conditions (/8 means out of 8)**

<table>
<thead>
<tr>
<th>Treatment conditions</th>
<th>Novice</th>
<th>Expert</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Colonoscopists</td>
<td>Colonoscopists</td>
</tr>
<tr>
<td></td>
<td>Hit (SD)</td>
<td>FA (SD)</td>
</tr>
<tr>
<td>Video</td>
<td>Light</td>
<td>Speed</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>I/N</td>
<td>white</td>
<td>slow</td>
</tr>
<tr>
<td>J</td>
<td>white</td>
<td>fast</td>
</tr>
<tr>
<td>O/R</td>
<td>NBI</td>
<td>slow</td>
</tr>
<tr>
<td>P</td>
<td>NBI</td>
<td>fast</td>
</tr>
<tr>
<td>Q</td>
<td>NBI</td>
<td>fast</td>
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<tr>
<td>R</td>
<td>NBI</td>
<td>slow</td>
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<tr>
<td>S</td>
<td>NBI</td>
<td>slow</td>
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<tr>
<td>T</td>
<td>white</td>
<td>slow</td>
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<tr>
<td>U</td>
<td>white</td>
<td>fast</td>
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<tr>
<td>V</td>
<td>NBI</td>
<td>slow</td>
</tr>
<tr>
<td>W</td>
<td>NBI</td>
<td>fast</td>
</tr>
</tbody>
</table>

The analysis on hit rate showed a significant main effect of experience (F(1,8) = 1454.472, p < .001) (Figure 2). Expert colonoscopists demonstrated superior detection skills when polyps were present. The detection rate, however, even in the hand of experts, was nowhere near perfect. Out of the 40 data points of polyp detection made by the 5 experts (each expert colonoscopist viewed 8 videos, each of which contained 8 polyps), perfect detection (8 out of 8) were only observed 4 times.

**Figure 2. Hit rate and SE by experience**
The withdrawal speed of colonoscope affected hit rate significantly (F(1,8) = 20.395, p < .01) (Figure 3). Doubling the withdrawal speed reduced the accuracy of detection when polyps were present.

![Figure 3. Hit rate and SE by speed](image)

The effect of monitor size on hit was not significant (F(1,8) = 1.163, p = .312). None of the interaction effects between experience, speed and size were significant either.

The analysis on FA rate showed non-significant main effects of experience (F(1,8) = .189, p = .675), speed (F(1,8) = .011, p = .919) and size (F(1,8) = 2.283, p = .169). None of the interaction effects between experience, speed and size were significant either. The extremely low FA rate by both expert and novice colonoscopists indicates that both groups were able to correctly reject the presence of polyps when they were absent in truth (Figure 4).

![Figure 4. FA rate and SE by experience](image)

**DISCUSSION**

The present study revealed a significant positive effect of experience on hit rate, which is consistent with our expectation. The positive impact of experience on hit rate could be explained by the increasing level of sensitivity, as experience usually enhances the “keenness of the senses” of the human operators (Wickens, Lee, Liu, & Becker, 2003).

In addition, we found that slower withdrawal speed improved the hit rate. Previous studies have demonstrated the negative relationship between withdrawal speed and polyp detection rate (Butterly et al., 2014). However, due to their simulation settings, the effect of withdrawal speed could have been due to a superior motor control skill and then higher area coverage of the large intestine, or due to a superior visual detection performance, or a combination of the two. Our finding provides an elucidation that a slower withdrawal speed did improve visual detection performance. The slowing down of the rate of signal presentation improved the signal-to-noise ratio as well as the sensitivity of the detection.

Contrary to our speculation, there was no significant effect of size on hit rate. The lack of significance could have been due to a combination of two forces: on one, enlargement of the video were expected to increase the signal-to-noise ratio and the sensitivity, leading to higher detection rate. On the other hand, the increase of size required higher amount of effort for eye movement and head movement. According to the SEEV (Salience, Expectancy, Effort and Value) model on visual attention (Wickens, Goh, Helleberg, Horrey, & Talleur, 2003), such an increase of effort hinders visual scan of the peripheral region, which may have affected visual detection performance negatively.

In addition, our results showed that both the novice and expert colonoscopists were able to correctly reject the presence of polyps when they were absent in truth.

**CONCLUSION**

By adopting a new simulation approach, we presented a pioneering study to examine colonoscopists’ visual detection of polyps.

We extended the traditional measurement metric of detection rates (Hit rate only) in colonoscopy literature and examined both hit and FA rates. To our best knowledge, it is among the few studies, if not only, which have adopted a well-established detection theory.

The negative impact of increasing withdrawal speed has raised a design challenge. A faster withdrawal speed might be expected due to resource limitations or monetary incentives. However, it has a detrimental impact on the visual detection performance. Computer aided recognition techniques may be a viable way to solve the dilemma.

There are some limitations which need to be taken into consideration when interpreting the findings. The original design of treatment conditions for the 15 videos was not optimal, leading to the drop of analysis of the effects of distance and review.

**REFERENCE**


