Master Thesis

Through a surgeon's eyes

The influence of visual-spatial ability and different camera positions on laparoscopic simulator task performance, among novices

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Abstract

Objective: From previous research, it is known that visual-spatial ability (VSA) is a predictor of laparoscopic task performance. It helps surgeons to adapt to the indirect and sometimes shifted view on their performance. In this study, we tried to reproduce and validate earlier findings on the influence of camera angle and VSA on laparoscopic task performance. It was the overall aim to investigate under which camera angles the influence of VSA would be of significant impact.

Method: For this study, a sample consisting of 37 inexperienced students was used. During the experimental session, the participants completed a mental rotation test and a computerized 'paper folding test' in order to quantify their VSA. Afterwards, the participants were given a custom-made artificial laparoscopic simulator task on a self-made simulator box. The task consisted of eight sessions, which were all conducted under a different camera angle (0°, 45°, 90°, 135°, 180°, -135°, -90°, -45°).

Results: The analysis of the collected data rendered significant evidence for a performance degradation under shifted camera angles and a significant interaction between VSA and the different camera angles.

Conclusion: In this study, we replicated earlier findings of performance degradation under shifted camera angles. Moreover, we were able to prove that participants high on VSA performed more accurate and faster than participants low on VSA under the conditions of non-zero-degree camera angles, except for a camera angle of 180 degrees. It can be stated that for some conditions VSA influences performance, but among novices, other navigational strategies seem to play a major role, too.

Keywords: visual-spatial ability, non-zero-degree camera angles, laparoscopic simulator task

Table of Contents

1. Introduction

The complex concept of spatial ability and its influences on our daily life, on learning different subjects and on being successful at certain jobs, is for quite some time recognized and under investigation (Lohman, 1996). There is good evidence that visual-spatial abilities are closely related to specialized achievements in, for instance, the fields of mathematics, engineering, and medicine (Kell, Lubinski, Benbow, & Steiger, 2013). Of course, there are significant differences between individuals regarding how distinctively this ability is present.

Research has shown that spatial ability plays a major role in surgery (Kramp et al., 2016) since surgeons have to be capable of performing high-risk procedures on hard to access internal organs, with tiny instruments, in a very precise way. Most of the time, these procedures are performed under the circumstance of direct view on the area of interest. However, this subject becomes more interesting when the aspect of vision on the performed task, changes from direct to indirect vision - as is the case in laparoscopic surgery. Indirect vision here means that the surgeons' task performance is recorded and provided to the surgeons on a computer screen. To make matters worse, the angle of incidence of the camera sometimes is shifted from the natural view of the surgeons and is not in line with their hands. As a consequence, they see their task performance, on the screen, from a different perspective. Under these conditions, even the simplest tasks can become extremely difficult.

This project aims to investigate whether, and to which extent, there is a degradation in performance within laparoscopic surgery among people with different spatial abilities, under the conditions of indirect sight and a shifted viewing angle on the performed task.

1.1 Advantages and disadvantages of laparoscopic surgery

During the last years 'laparoscopic surgery', which is a specific type of minimal invasive surgery (MIS), became the golden standard for many surgical procedures (Al-Abed & Cooper, 2009), for example, in the abdominal cavity or the spine surgery. The reasons for its popularity are mainly related to its much less invasive character when compared to classic 'open surgery', leading to lower blood loss and lower infection rates. In addition, this technique generates improved clinical outcomes, facilitates a faster recovery of the patient after the surgery and leads to better cosmetic results (McAfee, Garfin, Rodgers, Allen, Phillips & Kim, 2011). Instead of opening the area in which the procedure needs to be undertaken, only small incisions need to be made. Through these incisions plastic objects called trocars are placed,

which serve as a seal and a channel for the surgical instruments, including the laparoscope. A laparoscope consists of a small high-resolution camera mounted on the distal end of a rigid tube. In order to create a workspace for the surgeon, the area of interest is briefly inflated with carbon dioxide (CO2). During the procedure, the camera captures the image from inside the area and provides it to surgeons on a television screen. Due to the fact that surgeons have no direct view the camera replaces their eyes and the specially developed tools function as their hands (Hiemstra, Dobbelsteen, Dankelman, & Jansen, 2012).

Although this procedure has become common practice in the last years, it carries many challenges for surgeons. Due to the fact that the surgeons use tools which are fitted at the end of a 35 cm long and 5 mm wide tube, and the camera only provides a two-dimensional video image, tactile feedback and visual information are reduced. For instance, the surgeons have no binocular depth cues and the resolution and the quality of the image on the monitor are less compared to direct viewing (Berguer, 2006). Additionally, a loss of the peripheral view takes place. This means that the visual field of the surgeons, which is provided by the camera, is only focused on one specific point. There is no possibility for the surgeons to spot the surrounding area, which makes the navigation of the tools more difficult (Berguer, 2006). Navigation is also impeded by the so-called fulcrum effect. This effect leads to counterintuitive movements of the laparoscopic instrument (LI) because motions in the patient's body are reversed compared to those performed on the instrument (Conrad et al., 2006). On top of this comes that surgeons have to perform the procedure while the angle between the direction of their natural view and the one of the insert position of the instruments is often shifted from the direction in which the optic device is pointed. This means that the picture provided on the computer screen is incongruous with the natural view of the surgeons (Ames, Frisella, Yan, Shulam & Landman, 2006) increasing the complexity of the procedures. Consequently, there is evidence that during laparoscopic surgery a surgeon's mental and physical reserve is significantly reduced compared to open surgery (Berguer, Smith, & Chung, 2001).

In order to enhance patient safety, the risk factors related to the ergonomics of the procedure and the cognitive abilities of the surgeon candidates have to be minimized through particular training and adjustments. The common practice is to use simulators, which are either highly technical and expensive machines, or more basic and cheap custom-made simulators (Al-Abed & Cooper, 2009). The custom-made video box simulator used in this study was developed to investigate the effect of camera angle when performing a laparoscopic procedure.

1.2 Viewing angle in laparoscopic surgery

There are many ergonomic factors that play a role in laparoscopic surgery. Based on the fact that surgeons have no direct view of the procedure, the camera becomes the substitute for the surgeon's eyes, which means that its angle is highly important (Hiemstra et al., 2006). Classical open surgery requires that surgeons are looking directly to where they are performing, i.e. between their hands (Ames et al., 2006). In accordance with this, research has shown that in laparoscopic surgical simulation tasks the performance of the surgeons was best when the camera was located without any deviation from their natural view, thus in a zero-degree angle (Haveran et al., 2007; Hiemstra et al., 2006). Moreover, performance improves when the monitor is in line with the camera, the surgeon's view, and his hands. A 45-degrees shift of the monitor position still leads to an acceptable performance (Verwey, Stroomer, Lammens, Schulz, & Ehrenstein, 2005). Unfortunately, in practice, this setup, which would be most natural for surgeons, is not always possible because of constraints of human anatomy and the surgical procedure itself. As a consequence, mental and physical workload increases and surgical performance is likely to suffer (Haveran et al., 2007). Rhee and her colleagues found evidence for the influence of a shifted camera angle above 45 degrees on the time for task completion and errors on task, among novices (Rhee, Fernandez, Bush & Seymour, 2014).

The increased difficulty of laparoscopic procedures with a visual-spatial discordance is grounded in the fact that surgeons need to make a mental transformation to adjust the non-naturalistic visual information. While taking action with their hands, surgeons need to mentally transform the image provided by a non-zero-degree camera angle real-time video stream back to a naturalistic zero-degree camera angle image. However, there is interference when performing mental object rotation and, simultaneously, mentally planning for performing a motor action with the hands (Wohlschläger, 2001). According to Wohlschläger (2001), this interference occurs because mental object rotation and mental planning, which lead to motor action, make use of the same system formed by parietal and premotor areas. Therefore, when performed simultaneously, these processes claim too many mental resources, leading to a drop of performance. Nevertheless, experienced surgeons are able to perform these kinds of procedures, up to a 135-degree of angle deviation of the camera without a significant decline of performance (Rhee et al., 2014). However, for every task performance above a camera angle deviation of 135-degree, a significant decline was observed. In comparison, non-experts already showed a significant decline in performance at a deviation of 90-degree. Therefore, it is

concluded that laparoscopic surgeons acquire these essential skills over time through clinical practice.

Although these skills might be acquired over time, it would be desirable if surgeons were capable of these skills at the onset of their laparoscopic career. The common practice of learning surgical skills is the teaching method of "see one, do one, teach one". This means that when a trainee observes a procedure, he should be able to perform it and teach it to another trainee afterwards (Kotsis & Chung, 2013). However, from the literature, it is clear that this kind of strategy is rather outdated and inadequate (Zahiri, Park, Pugh, Vassiliou, & Voeller, 2015). Especially in laparoscopic surgical training, there is an upcoming need of facilitation and standardization of learning, in order to enhance patient safety. Therefore, adequate simulator tasks are of major importance.

Moreover, it is indicated that visual-spatial ability, which is formed by a set of separate but related factors including mental rotation, is a stable determinant for predicting results of laparoscopic surgery performed by novices. Novices with a high visual-spatial intelligence showed a better performance on laparoscopic simulation task (Jungmann, 2011). Additionally, Luursema et al. (2010) concluded that the visual-spatial factor of visualization is important due to the fact that it indicates "fewer training sessions for high scorers on this ability to attain the same level of skill when compared to low scorers" (p. 691). However, the latter point still needs to be discussed.

1.3 Visual-spatial ability (VSA)

Spatial ability is a comprehensive construct, which is investigated already for a long time. However, there are still many contradictions in the domain of spatial ability literature, referring to the terminology and the factor structure of the concept (Yilmaz, 2009). The most valid attempt of defining the factor structure of spatial ability is embedded into the Three-Stratum Model of Caroll (1993). Based on a factorial re-analysis of more than 400 datasets, he explained individual differences in cognitive abilities. As the name states, this model divides cognitive ability into three layers reaching from narrow to broad to general cognitive ability (g) (Caroll, 1993). The first tier of general intelligence is defined as the shared factor loadings of several second-tier factors of which visual-spatial ability is counted among together with, for instance, verbal intelligence. Again, the second tier is defined as the shared factor loadings of the third-tier factors. John Caroll classified the second-tier factor of spatial ability, which is of interest for this study, into five main factors clusters namely: visualization, spatial relations, the speed of closure, the flexibility of closure, and perceptual speed. These third-tier factors can be

measured by specific psychometric tests, as for instance visualization is measured by the Mental Rotation Test (Vandenberg & Kuse, 1978). This method was already used in the study of Luursema et al. (2010) and was also used in the present study.

Previous research shows that the score on the third-tier factors of visualization and, to a lesser degree, spatial relations are positively correlated with time on task and quality of performance in laparoscopic training tasks (e.g., Luursema et al., 2010). Visualization includes the ability to manipulate complex representations of a visuospatial nature (Lohman, 1979). The factor of spatial relations involves "imagination of an object in two or three-dimensional space in relation to another object" and is very close related to the concept of mental rotation, which includes "rotating a two- or three-dimensional object or figure" (Yilmaz, 2009, p.89).

Knowing that there is a correlation between visualization, spatial relations, and surgical skills among novices, a debate arose whether this kind of intelligence should be a selection criterion for prospective surgeons. According to Keehner et al. (2006), this depends on whether the correlation between spatial ability and performance occurs only in early learning stages or whether the relationship is enduring even after the experience has been gained. Only if correlation persists with practice a selection based on this criterion could be important. The results from their later study show that this rather is the case. Unexpectedly, visual-spatial ability seemed to influence task performance even when the surgical experience was gained. In agreement with that, Luursema and his colleagues (2010) argue that spatial ability remains important since every new case of surgery includes a large degree of unpredictability, which cannot be covered by automated skills. Although Groenier et al. (2014) also confirmed that cognitive aptitudes like VSA remain important after experience was gained, there is discordance in the literature about the question whether VSA has an influence on the learning duration of laparoscopic skills. Whereas Luursema et al. (2010) stated that higher VSA would lead to faster learning of laparoscopic skills, in the study of Groenier et al. (2014) all novices needed the same number of practice runs to reach proficiency on the task.

Moreover, it has been shown, that laparoscopic task performance significantly deteriorates as the angle between laparoscope and working instrument moves away from zero degrees (Haveran et al., 2007; Hiemstra et al., 2006) - a phenomenon likely to reflect an increase in task complexity arising from an increase in imposed cognitive demand (Wood, 1986). This led to the conclusion that visual-spatial ability is positively related to laparoscopic task performance and that this relationship is more pronounced as task complexity increases.

Keeping these aspects in mind, it seems to be relevant to investigate how these complexity issues of laparoscopic tasks are tackled by novices in a simulation environment. Is

visual-spatial ability the only contribute that helps people to adequately work and adapt to the impeded circumstance? Or are there other strategies that, for instance, could help people with lower VSA skills to perform equally? For instance, although the studies of Rhee et al. (2014) and Ames et al. (2006) showed that performance was worst under the condition of an 180 degree camera angle, the study by Dunnican et al. (2010) has shown that training novices on mirrored image simulators also leads to skill learning for forward-facing simulator task manipulation (zero-degree camera angle). The reverse effect, however, was not seen in their study. This emphasizes the need to train novices under the circumstances of mirrored images because it can provide skill learning to everyone regardless of people's intrinsic visual-spatial ability.

In the context of laparoscopic surgery, it is obviously very important to be aware of the severity of the issue of proper training for surgeon candidates since lives depend on it. From a practical point of view, the results of this study could help to determine whether only people with high visual-spatial abilities are suitable candidates for becoming a laparoscopic surgeon or if, in principle, everyone regardless their visual-spatial ability would suit. From earlier studies, it is known that spatial performance can be improved (Okagaki & Frensch, 1994), which is why the present research also aims to get more insight into possible mechanisms used by novices in laparoscopic training tasks. Through advanced and adjusted training methods, it might be possible to help candidates with rather low visual-spatial ability to make use of these strategies to successfully perform laparoscopic tasks.

1.4 Research question

The present research is focused on investigating whether among novices there is a statistical interaction between the effects of camera angle and visual-spatial ability in the context of laparoscopic simulator tasks. There is evidence that people with high visual-spatial ability show better performance on laparoscopic simulator tasks. Furthermore, it is known that performance degradation depends on the increase of angle deviation between viewing and working angle (Gallagher, Al-Akash, Seymour, & Satava, 2009), i.e. the camera angle. It is the aim of this research project to investigate these two aspects among novices in more detail by re-examining the earlier findings and use these results to verify whether there is a statistical interaction between visual-spatial ability (VSA) and the changing 'line of sight and line of work' (i.e. camera angle) on simulated laparoscopic task performance.

It was expected that

- with an increasing deviation of the camera angle the performance of both high and low scorers in visual spatial ability would decrease.

- that people with a high visual-spatial ability would show a significantly better performance under each non-zero-degree camera angle due to their mental rotation skills on the simulator task than people with a low visual spatial ability.
- that the performance for people with low visuospatial ability would decrease significantly more, above a camera angle of +/- 45 degrees, except for a camera angle of 180 degrees since under this condition other reasoning strategies were expected to influence performance.

2. Method and Materials

2.1 Participants

In total 37 participants joined the experimental session. However, due to software problems, only data from 33 participants were analysed. From the used cases, 20 participants were male (60.6%) and 13 participants were female (39.4%). Age ranged from 19 to 33 years. The mean age was 22.9 years with a standard deviation of 3.2 years. Most of the participants were German (60.6%), the rest was Dutch (33.3%) or had another nationality (6.1%). One participant was left-handed. None of them reported previous experience with surgical procedures or restricted visual faculty. All the participants were recruited from the University of Twente and were given study credits for their participation.

2.2 Apparatus

In order to conduct the experiment, several materials were needed. Most important was the custom-made simulator setup consisting of the simulator box with the rotatable camera cap, the respective power supplies, and a standard monitor (figure 1). Moreover, the OpenSesame 3.0.7 experiment platform was used on a Samsung Galaxy Note 10.1 GT-N8000 touchscreen tablet with Android version 4.1.2. In order to conduct the experimental task, a laparoscopic instrument was utilized with a stylus fitted at its end. For the assessment of visual-spatial ability and the experimental task, the appropriate computerized versions were used, also written in OpenSesame 3.0.7 and running on a computer, respectively a tablet.

2.3 Procedure

Before the start of every experimental session, the participants were informed about the procedure and what kind of tasks they were about to do. It was mentioned that the data would be treated confidentially, that participation would be voluntarily and, therefore, the participants

were free to stop at any time. Additionally, the participants were told that there would be no risks and that the whole session would take approximately one hour. Afterwards, the participant was asked to fill in the informed consent and a short questionnaire for assessing demographic data.

The experimental sessions took place in a separated research cubicle at the University of Twente. The experiment was divided into two parts. The first part of the experiment aimed to assess the visual-spatial ability of the participant through the Mental Rotations Test (MRT) (Vandenberg & Kuse, 1978) and the Surface Development Test (Ekstrom, French, Harman, & Dermen, 1976). These tests were conducted on a laptop because the participant had to give input via a keyboard.

For the second part, the participant completed an experimental task. This part of the experiment was conducted on a tablet, which was placed in the simulator box. A camera, mounted underneath a rotatable cap, transmitted the performance of the participant to an external screen. Figure 1 shows the overall setup of the experiment, during which the participant had no direct view on the screen of the tablet. In total, eight runs with eight different camera positions were conducted. After every run the participant was notified by an arrow, appearing on the tablet, to adjust the camera position in a particular order, following a random sequence. Through rotating the cap of the simulator box, the arrow was adjusted in a way that it pointed at the middle of the upper edge of the monitor. This was done until all positions were covered. When eight runs were completed, and all angles had been covered, the experimental session ended.

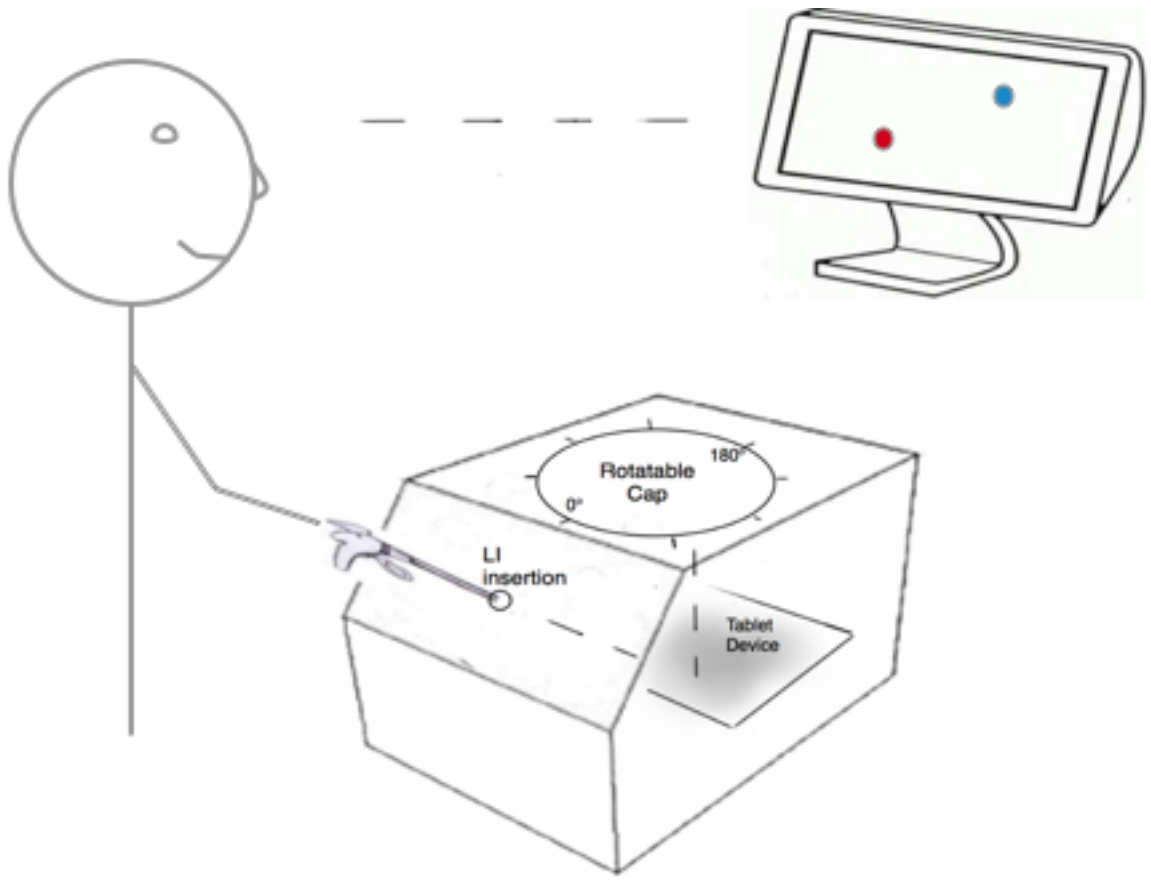

Figure 1. Schematic representation of the experimental task setup. The participants stood in one line with the simulator box and the monitor. In their hands, they held a laparoscopic instrument, which they used to tap on the tablet device. The tablet device was placed inside the simulator box. The task, which was shown on the tablet, was captured by a camera, fixated under the rotatable cap. The captured performance was provided to the participant on the monitor.

At the beginning of both parts of the experiment, instructions and a training run were provided to the participant, in order to ensure that the task was properly understood. The instructions of the training for the assessment of visual-spatial ability were designed to enable the participants to conduct the experiment all by themselves. For the experimental task, it was intended that the participants only tried to make one good input by a single tap. To ensure that this was the case the participants got a demonstration of the correct behavior from the researcher. The researcher interfered in between the two parts of the experiment in order to set up the second part correctly. After the second part of the experiment, the participant was thanked for his participation and if there were still questions the experimenter answered them.

2.4 Visuospatial ability tests

2.4.1 Mental Rotation Test (MRT)

The original version of the mental rotation test, designed by Vandenberg and Kuse (1978), consists of 20 items originally developed by Shepard and Metzler (1971). Each item includes one criterion figure and four alternatives, of which two are identical to the criterion

figure but provided in a rotated manner. For this study, the test was computerized. Moreover, the original version was adapted in that participants were provided with one example item and only one item of comparison, instead of four (figure 2). The task was to estimate whether the 3D objects were the same or not. However, one of the objects was rotated. Depending on his judgment, the participant was asked to give the response via the keyboard of the computer, which had a German letter arrangement ('y' = same; 'v' = different). This part consisted of 48 trials and the participants had maximum ten seconds of time to give an answer. If no answer was given within this timeframe the program would automatically continue with the following trial. During this session, the average response time and the rate of correct answers of the participant were collected.

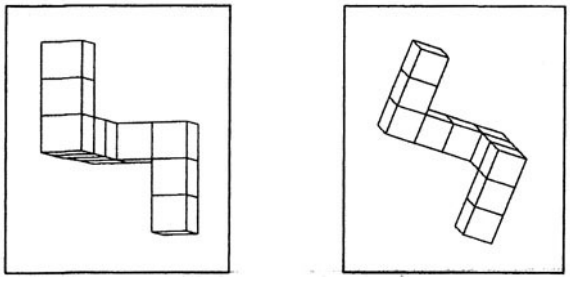

Figure 2. Example of a MRT task. Two objects, either the same or different ones were shown. If they were the same objects, one of them was rotated. The participants indicated whether the objects were the same or different ones.

2.4.2 Surface Development Test (SDT)

The second visuospatial ability test was about visualizing spatial folding of a piece of paper. It was developed by Ekstrom, French, and Harman, (1976). For each trial, the participant was provided with an unfolded object with folding lines at the left side of the computer screen and at the right side of the screen the properly folded object (figure 3). At both of them, a fixation point was marked in order to show the outside of the object. One of the borders of the unfolded left side object was marked yellow whereas in the folded object the borders are marked with numbers. The task was to identify which of the numbered borders corresponded to the yellow marked border. The participants had to be aware that multiple borders of the construction plan could concur with one border of the folded object. In order to give the answer, the numeric buttons on the keyboard of the computer were used. In total 25 trials were given without any time limit. When using this test for assessing visuospatial ability among 46 college students, Ekstrom et al. (1976) reported reliability values of .90.

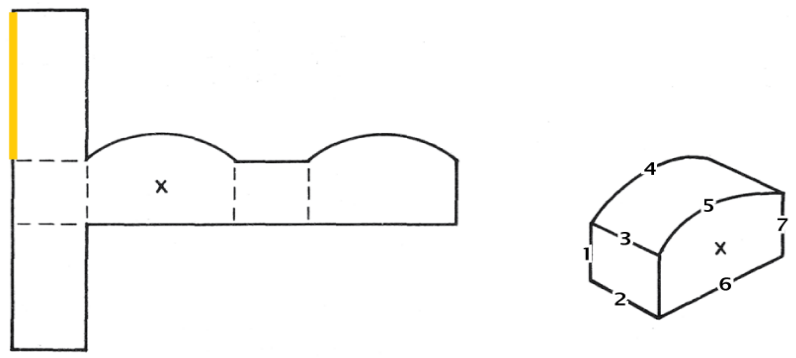

Figure 3. Sample item of the SDT. In this case, the correct answer was 4.

2.4 Experimental Task

For the experimental task, the setup was mounted as shown in figure 4: the tablet was placed in the simulator box, the performance was recorded by a camera fixed on a rotatable cap and shown on an external screen. The designed experiment consisted of eight runs in total and each run consisted of eight task versions (see Appendix 7.1 for the task versions). For each run, the camera position was different which means the participants got a different viewing perspective via the computer screen (differing from the normal zero-degree view). Every participant performed the runs with a 0°, 45°, 90°, 135°, 180°, -135°, -90°, -45° camera angle. The order of the eight different camera angles and, likewise, the order of the eight different task versions, was randomized in order to compensate for any learning effect. For instance, the camera could be turned 180 degrees (figure 1), with as consequence that the participants saw their reversed laparoscopic instrument performance, on the screen. The computer screen and the laparoscopic tool alignment remained fixed during the whole experimental session. Additionally, the participant was asked to either perform the task with his right or his left hand. This factor was also implemented in this study with the purpose of reducing learning effects. For this kind of simple motor skill, which was required for task solving, no significant decrement of performance from one hand to the other was expected (MacKay, 1982). The order of which hand had to be used at which run was determined randomly for each participant before the session started. The participant was given a list that told him when to use which hand.

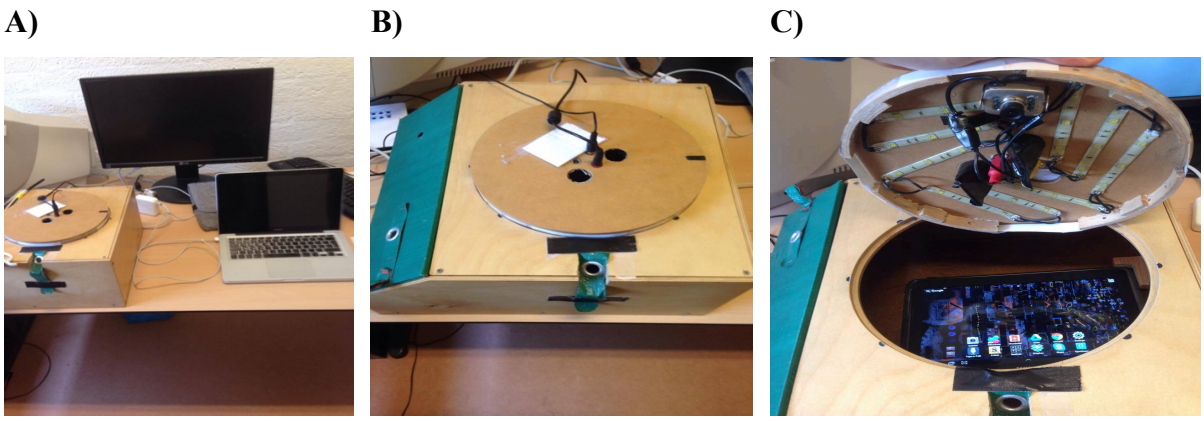

Figure 4. A) Experimental setup with the laptop used for assessing VSA and the monitor used for the experimental task. B) Rotatable cap with camera connection. C) Cap in open position showing the camera installed under the rotatable cap and tablet placed inside the simulator box.

The actual task was intentionally kept very simple and involved hitting targets, which were a red and a blue dot. At first, the participant had to tap a red fixation target (figure 5A), followed by hitting the two target areas positioned diagonally from each other (figure 5B). The target areas appeared simultaneously and, through color-coding, the order was stated in which the targets had to be tapped. The color-coding was explained during the instructions: first the red target and afterward the blue target needed to be tapped. After every hit on a target, an audio signal appeared in order to report to the participants that the input had been given and that the attempt was either successful or unsuccessful. Regardless of the accuracy of the first attempt, after an input had been made, participants continued with the second target. The program would continue with the following task trial even if the screen was hit two times randomly. The purpose of the sounds was to motivate the participant to correctly tap on the target areas and not become neglectful. Due to the fact that the sound of the feedback for a missed attempt was rather unpleasant, it was expected to motivate the participant to make a correct input in order to avoid that the sound appears again. It applies the concept of positive punishment by Skinner (1974), which involves presenting an unfavorable outcome or event following an undesirable behavior. Yet, the program recognized a target as tapped, even when the tablet was tapped within the area slightly next to the target, due to the fact that the targets were placed into, for the participant invisible, single square areas upon a grid. The square had the size of 64 x 64 pixel on an 800 x 1280 tablet screen with a resolution of 149 ppi, which is a square of 2,89 cm^2. For this reason, not only the tap on the dot but the tap on the square led to a correct input.

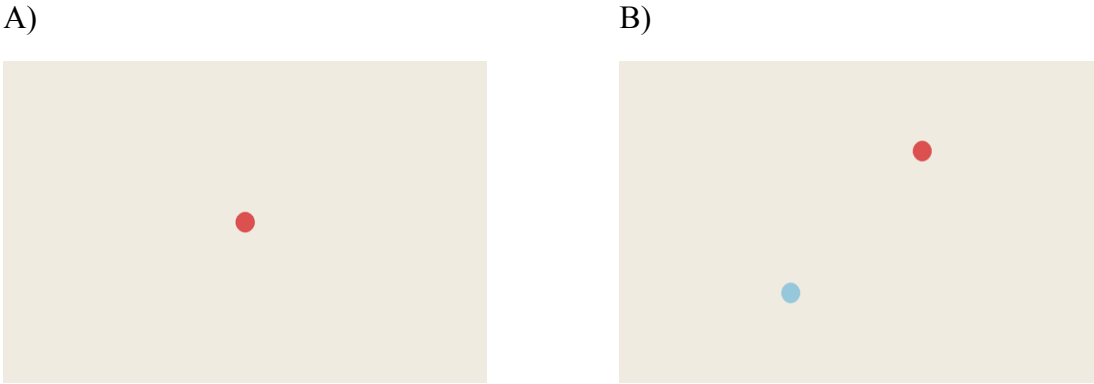

Figure 5. A) Participant started the task by hitting the starting dot, which was located in the center of the tablet screen. B) Afterwards, the two target dots appeared. The task was always to first hit the red dot and then the blue dot.

The touch-screen interactions were performed by the participant using the laparoscopic instrument, on the end of which a stylus was fitted (figure 7). The tip of the stylus making contact with the touch-screen resulted in a registered input. For insertion of the laparoscopic instrument, the angle of incidence was important. It had to be steep enough so that the tip of the stylus could make a correct input on the touch-screen tablet. In order to increase the chance of making a registered input, the connection piece between the laparoscopic tool and the stylus was bent a little bit to ensure a steeper incidence angle. Furthermore, for the right insertion angle, the height of the table was also taken into account and was adapted in a way that the angle between the upper arm and the forearm of the participant was between 90 and 120 degrees (Berguer, 2006)

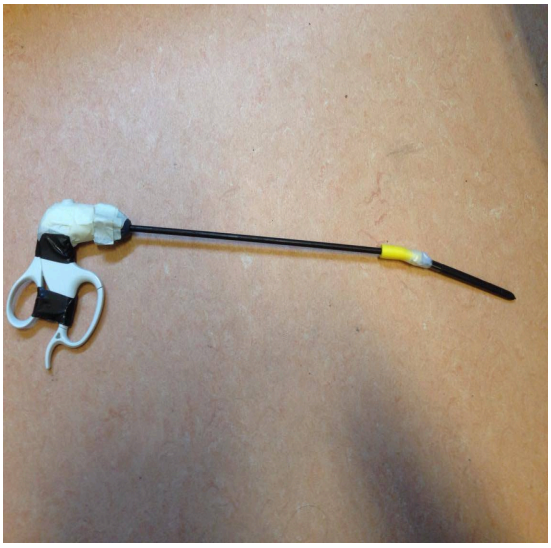

Figure 7. Laparoscopic tool with fitted stylus

2.5 Data

2.5.1 MRT and SDT data

In the case of the MRT and SDT tasks, the relevant information was only the given answers on the different tasks trials (either right or wrong). For each participant, a total score was calculated for each test, through the addition of the correct responses, as it is intended by the designers of the MRT (Vandenberg & Kuse,1978). Afterwards, these scores were normalized in order to calculate, through averaging of both visual-spatial ability measures, the MRT (Vandenberg & Kuse, 1978) and the Surface Development test (Ekstrom et al., 1976), one composite z score for the visual-spatial ability for each participant.

2.5.2 Experimental task data

The dependent variables were the accuracy of tapping attempts on the targets, and the time between tapping the first target and the second target. In the course of this thesis, these variables are referred to as accuracy and duration. These two variables were chosen as indicators of laparoscopic task performance because previous research has shown that they are an effective index of technical skills on laparoscopic procedures (Rhee et al., 2014 & Wanzel et al., 2003). Tapping on both targets was the main task and the task was only fulfilled if both attempts were successful. However, in order to prevent biased results of task duration, because of expected higher error rates in the low visual spatial ability group; all attempts including errors were used to derive temporal performance variables. For every condition of the eight different camera angles the duration and accuracy per subject were derived. The duration score for each camera angle was averaged across all eight different task trials and the accuracy score for each camera angle was the number of all correctly solved task trials. Thus, the maximum accuracy score for one condition could be 8. Based on these scores an overall score of duration and accuracy across all eight conditions for every participant was calculated.

The red fixation target, which occurred before every single task, was not taken into account. Its function was to guarantee that every participant would conduct the task under the same conditions, aiming to make the data comparable. The measurement of performance time just started at target onset.

2.5.3 Statistical analysis

The Shapiro-Wilk test was used to determine deviations from a normal distribution. A significant deviation from normality was found for the dependent variable of duration, whereas

accuracy and VSA were not significantly deviating from normal. Based on this, it was decided to use parametric tests for analyzing the accuracy and a non-parametric test for analyzing the duration scores.

In order to indicate that this study was able to reproduce the known effect of shifted camera angles on performance, a repeated measurement analysis was conducted for both dependent variables. For the trial duration, Wilcoxon's signed rank test was used and for the accuracy variable a repeated measure ANOVA was conducted. This kind of analysis was conducted across the whole sample ($N = 33$).

For the next step, the between-subjects factor of VSA was added to the analysis. In order to explore the influence of visual-spatial ability on laparoscopic simulator task performance, the groups of participants who scored either high or low on visual-spatial ability were identified. Only those two groups ($N = 11 + 11$) were of interest, in order to control for an existing effect of VSA on task duration and were included in the analysis. Scores that fell in the intermediate range of visual spatial ability were neglected. The intermediate range included al scores within a threshold of .5 standard deviation, above, respectively, beneath the mean of the normalized visuospatial ability score. A Shapiro-Wilk test was conducted in order to verify if accuracy and duration were normally distributed within the groups. The result of this analysis showed that one participant in the low VSA group had a total z-standardized duration score that lays more than three standard deviations above the z-standardized group norm. This participant was excluded from the analysis and, consequently, both dependent variables were not significantly different from normality within the two VSA groups. In order to investigate the difference between the groups and the presence of a statistical interaction between VSA and the camera angle a mixed repeated measure ANOVA with camera angle as repeated measure and VSA as a between-subject factor was conducted for all measures of the dependent variables.

2.6 Design

The dependent variables of interest were accuracy and duration during the experimental task. For the first part of the analysis, the independent variable were the camera angles (within-subject: 5 different positions) and for the second part of the analysis, VSA (between-subject: high vs. low) was added as a second independent variable. This study follows a mixed design.

3. Results

3.1 Verification of performance degradation

To replicate earlier findings, the duration needed for the task and accuracy were taken as indicators of performance among the different camera angles. In this context, a longer duration between the first and the second tap on the targets, respectively a lower accuracy score, is representative for performance degradation. For this analysis, the data of all participants (N = 33) was used.

3.1.1 Time on task

The data shows that with each increased shift of the camera angle the performance degraded (figure 8). The zero-degree position, which represents the natural perspective on the task, is clearly the one with the shortest mean duration, which is 3.4 seconds with a standard deviation of 1.8 seconds. Friedman's test of differences among repeated measures of trial time was conducted among all eight camera positions and showed that there was a significant difference between the mean ranks for each camera angle, χ^2 (7, N = 33) = 96.2, $p < .001$. Wilcoxon tests were used for testing the hypotheses that performance under shifted camera angles differed from a zero-degree view and that performance was less influenced by a camera angle of 180°. Due to the fact that there was no reason to expect a significant performance difference between the negative and the positive camera angles, performance was averaged across the positive camera angle and its negative counterpart. Therefore, the comparison was conducted between the 0° camera angle and the shifted camera angles of +/- 45°, +/- 90, +/- 135 and 180°. Additionally, a comparison was conducted between all non-zero-degree camera angles. It appeared that the performance under every other camera position significantly differed from the performance of a zero-degree camera ($Z_{\pm 45}$= -3.910, p = .001; $Z_{\pm 90;\ \pm 135;\ 180}$ = -4.015, p_s = .001) angle and likewise from a 180° camera angle ($Z_{\pm 45}$= -3.215, p = .001; $Z_{\pm 90}$ = -2.868, p = .004; $Z_{\pm 135}$ = -3.146, p = .002). As it can be seen from figures 8 and 9, a camera alignment of 180 degrees was the only exception from a stepwise degrading overall performance curve. It appeared that performance with a 180-degree camera angle (M = 6094.69 ms, SD = 2543.96) was significantly faster than with a camera angle of +/- 90 (M = 8694.14 ms, SD = 4119.20) and +/- 135 degrees (M = 8364.33ms, SD = 3628.91). Furthermore, it appeared that for the camera angle of +/- 45° the performance degradation was less than under the angle of +/- 90° and +/- 135° since there were significant differences between the mean ranks ($Z_{\pm 90}$ = -4.015, p = .001; $Z_{\pm 135}$ = -3.910, p = .001) and they show much longer average

duration. The performance under the angles of +/-90° and +/- 135° was the same because no significant difference in mean ranks was found (Z = -.49, p = .62). Therefore, in line with the literature and the formulated hypothesis, a significant performance degradation occurred with every increase of the 'line of sight and line of work' angle until 180 degrees.

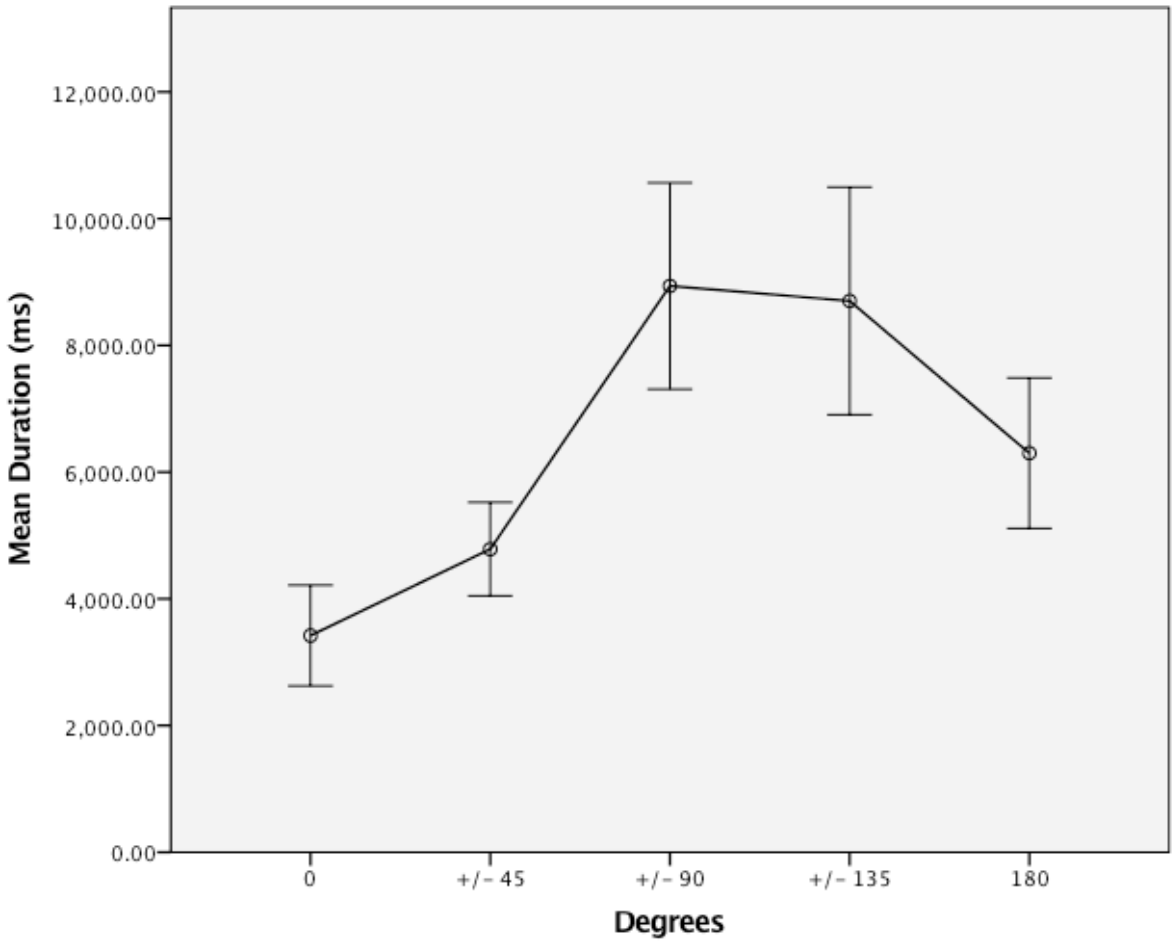

Figure 8. Mean task duration under different camera angles. The mean duration was averaged across the positive and the negative correspondent camera angle. The figure includes error bars of a confidence interval of 95%.

3.1.2 Task accuracy

Further evidence for performance degradation under the non-zero degree camera angles was found when inspecting the accuracy scores. A repeated measures ANOVA was conducted. Since Mauchly's assumption of sphericity had been violated χ^2 (9) = 18.56, p = .029, Greenhouse-Geisser's corrected test is reported (ε = .79). The results indicated that the accuracy of task solving was significantly affected by the camera angle (F(3.147, 100.70) = 28.46, p = .00, partial η^2 = .471). The significance levels for differences between the different camera positions showed that the effect of the camera angle on accuracy occurred when the camera angle was over +/- 45 degrees because no significant difference was found only between the

zero-degree angle and the +/- 45° angle ($p = .59$). All other non-zero camera angles significantly differed from the zero degrees and +/- 45° angles ($p_s = .001$). No significant difference in accuracy was found between the angles of +/- 90° and 180° ($p = .46$). Yet the +/- 135° angle significantly differed from the +/- 90° and 180° angles ($p_s < .02$).

In short, the data show that the accuracy of the performance was influenced under shifted camera angles over +/- 45°. Moreover, it was indicated that performance accuracy was most influenced by a camera angle of +/- 135°. Figure 9 demonstrates these findings.

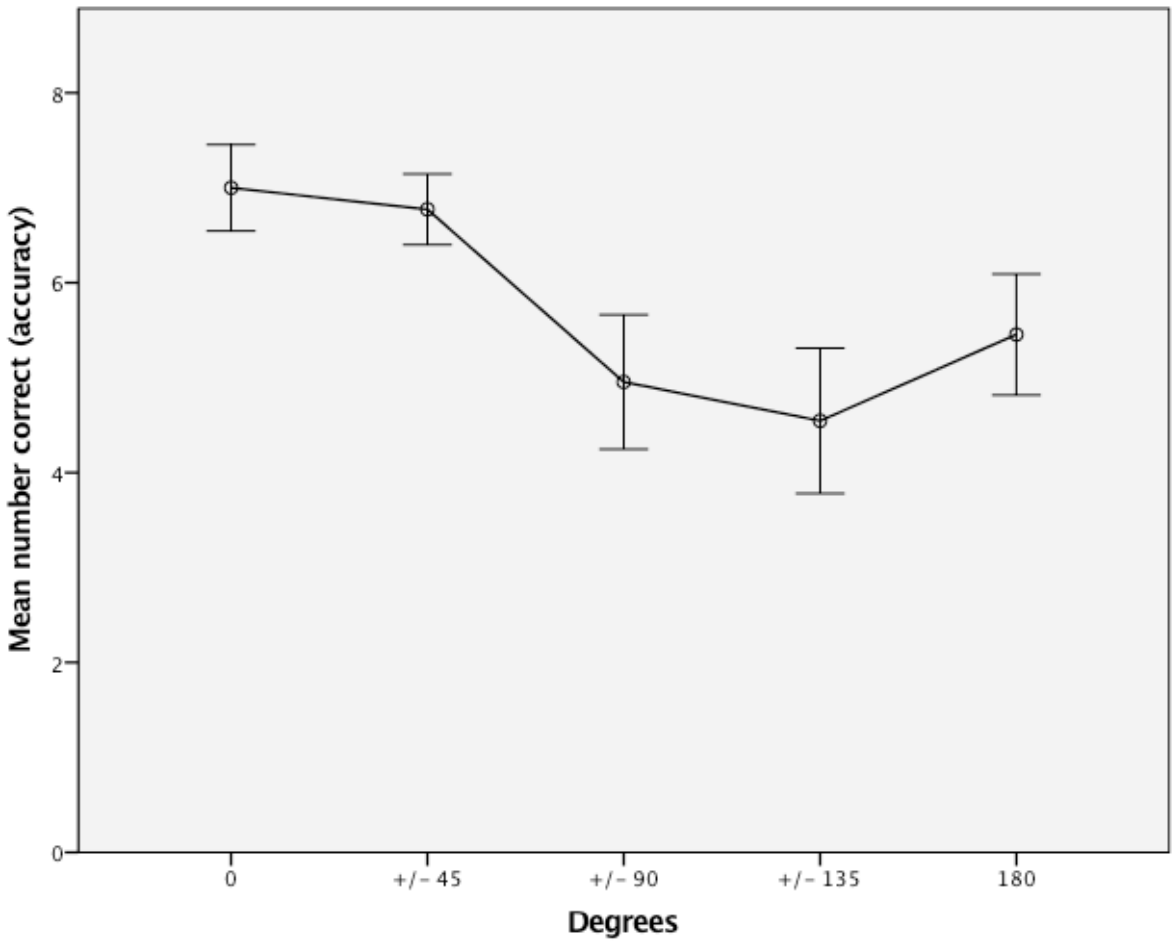

Figure 9. Mean task accuracy scores under different camera angles. The mean number of correct attempts was again averaged across the positive and the negative correspondent camera angle. The figure includes error bars of a confidence interval of 95%.

3.2 Differences between low and high VSA

To demonstrate the effect of VSA on laparoscopic task performance the data was divided into two groups based on the standardized visual-spatial ability (ZVSA) scores. The first group contained participants with low visual-spatial ability ($N = 10$) and the second group participants with high visual-spatial ability ($N = 11$). Again, the averaged values of the positive

camera angle and its negative counterpart were used. This study used a 2 (VSA groups: high and low) by 5 (camera angles) factorial design.

3.2.1 Time on task

Referring to the repeated measure analysis of the dependent variable of duration, Mauchly's test indicated that the assumption of sphericity was violated, χ^2 (9) = 35.70, p = .001. Therefore, Greenhouse-Geisser corrected tests are reported (ε = .53). The results revealed a main within-subject effect of camera angle, F(2.11, 40.10) = 32.90, p = .001 partial η^2 = .634. The main effect of camera angle indicates the same effect of performance change across the different camera positions, which we already reported in the previous section. Under most camera angles the performances were significantly different from each other (p_s < .004). The only exception where through pairwise comparisons no difference in performance was found, were the camera angles of +/- 90° and +/- 135° (p = .234). Yet, there was no indication for a main effect of VSA (F(1,19) = 1.33, p = .263, partial η^2 = .066). Because our a priori prediction about a possible interaction between VSA and camera angle was directional, a one-tailed test was used with a significance level of p < .05, for testing the hypothesis which rendered a significant interaction F(2.11, 40.10) = 2.82, p = .035, partial η^2 = .129. This means that participants from the high VSA group significantly needed less time for task solving under the circumstances of the non-zero degree camera angles than the participants from the low VSA group. On average, participants from the high VSA group needed 5160 ms with a standard deviation of 1400 ms whereas participants from the low VSA group needed on average 6985 ms with a standard deviation of 1851. These results are shown in figure 10.

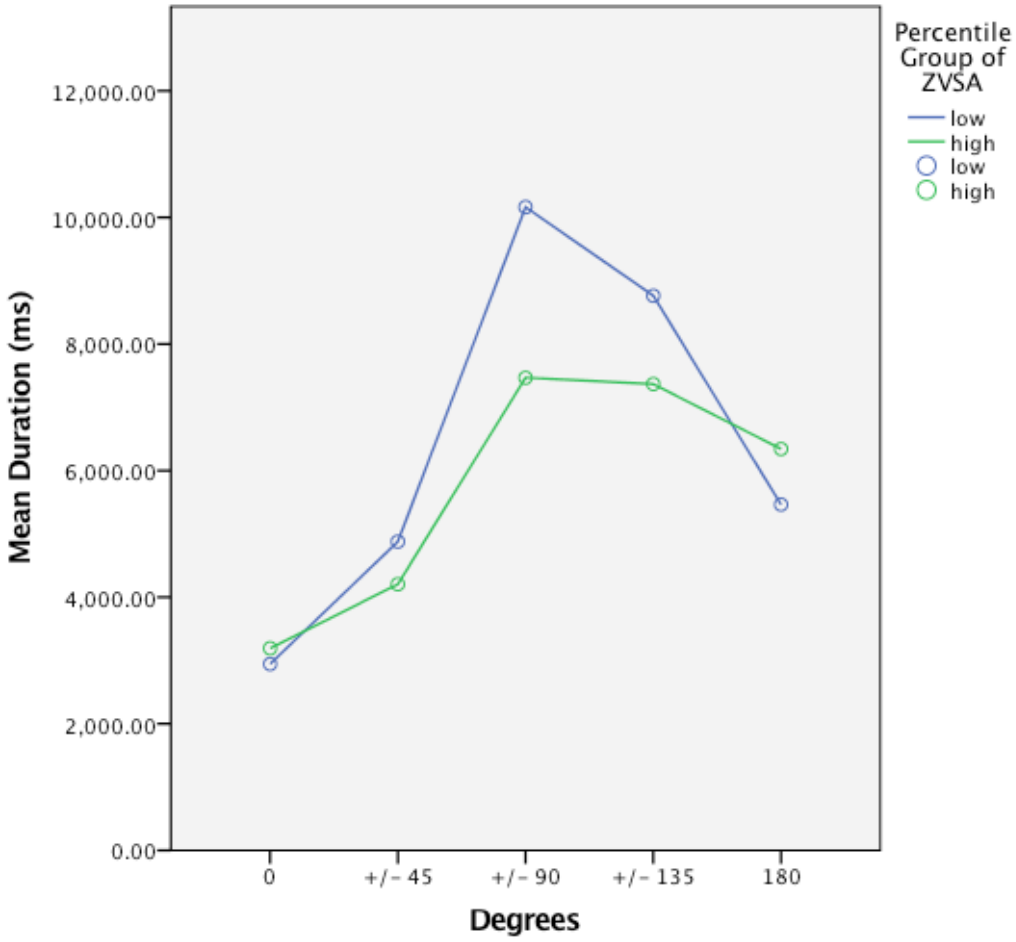

Figure 10. Mean duration scores for the different camera angle of the high and low VSA group

3.2.2 Task accuracy

With respect to the repeated measure analysis of accuracy scores, a main effect of camera angle ($F(4, 76) = 27.27$, $p = .001$, partial $\eta^2 = .589$) was found. The pattern was almost the same as found for task accuracy in the previous section 3.1.2. Again, no significant performance difference was found between the 0° and +/- 45° camera angles ($p = .28$) but performance under these two conditions significantly differed from performance under all the other camera angles ($p_s = .001$). Additionally, no significant differences were found between the camera angle of +/- 90° and the other two greater camera angles ($p_s > .05$). Yet performance under a +/-135° camera angle significantly differed from performance under an 180° camera angle ($p = .004$). Additionally a main effect of VSA ($F(1, 19) = 4.38$, $p = .05$, partial $\eta^2 = .187$) was found.

Most interesting however was, that the results revealed a significant interaction between the camera angle and VSA ($F(4, 76) = 4.26$, $p = .004$, partial $\eta^2 = .183$), which means that the participants in the high VSA group performed significantly better under the circumstances of shifted camera angles. Within the group of low VSA, on average 64% of the

tasks were solved correctly (M = 41, *SD* = 9,04), whereas in the high VSA group on average 77% of the tasks were solved correctly (M = 49, *SD* = 6,04). From figure 11 and the mean ranks, it can be seen that the high VSA group had an advantage under the circumstances of non-zero degree camera angles except for an 180° camera angle. Here, the participants' performance was not influenced by their visual-spatial ability.

In summary, these results indicate that there is a significant interaction between visual-spatial abilities and camera angles, in the context of task accuracy. Moreover, it can be stated that participants high on VSA tend to not only show a faster performance, as it was reported in the previous secttion, but also a more accurate performance under non-zero-degree camera angles.

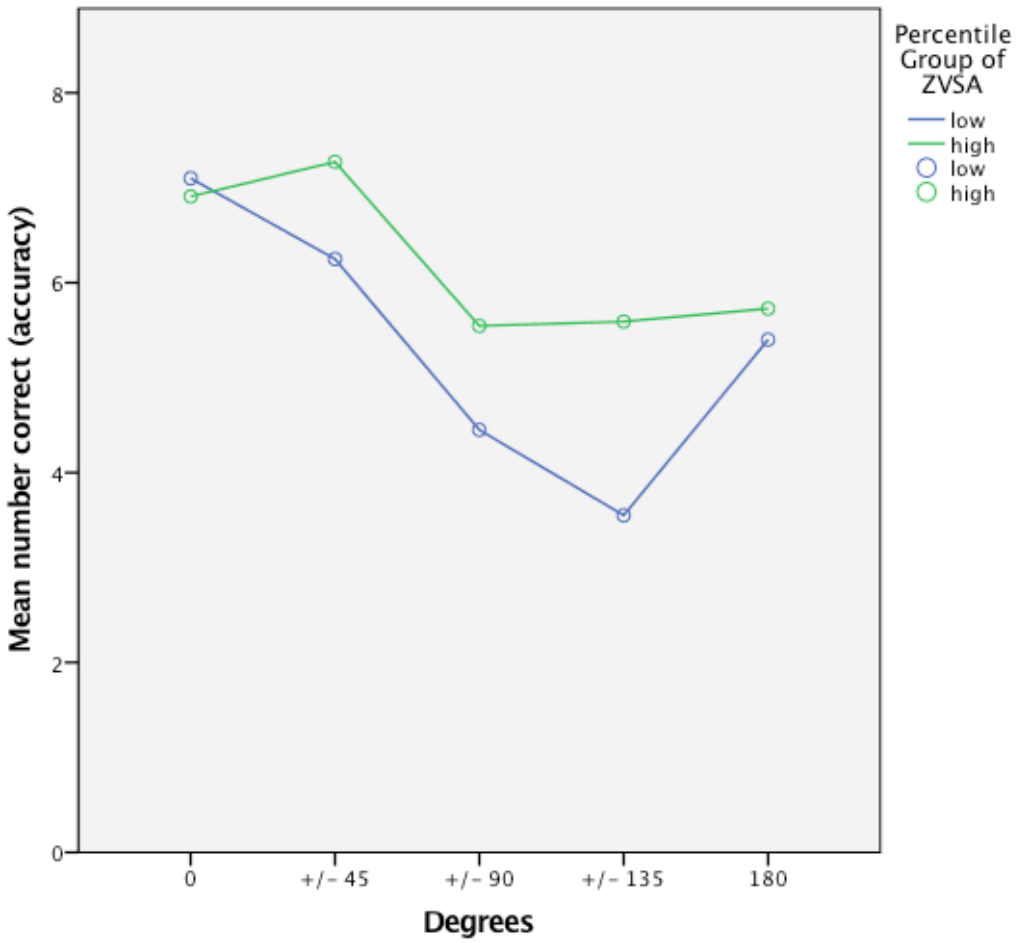

Figure 11. Mean accuracy for the different camera angle oh the high and low VSA group

4. Discussion

From the literature it is known, that non-zero degree camera angles lead to performance degradation on laparoscopic simulator task and that visual-spatial ability is an important factor for enhancing performance in the context of laparoscopic surgery. Therefore, it was the aim of this study to examine to what extent visual-spatial ability would influence task performance with different camera angles. As expected, our results confirm that performance degrades under the circumstances of shifted camera angles and that, under non-zero-degree camera angles, people high on VSA perform the laparoscopic simulator task faster and more accurately than people low on VSA, with an exception for an 180-degree camera angle.

4.1 Effect of camera angles

The experiment was designed with the most favourable camera alignment. On the one hand, since the task was conducted on a tablet, the camera was positioned such that a top view of the tablet screen was provided. On the other hand, the camera was fixed, meaning that the participants could not be distracted from the task by camera movements. Thus, the participants could focus their attention completely on the task. Yet, using a camera to provide environmental information to a user is always expected to lead to performance degradation compared to a direct view. According to Delucia and Griswold (2011), the reason for this is that the camera can never be aligned in the same position as the eyes of the user. In the present study, we were able to confirm this assumption by showing that, compared to the zero-degree camera angle, under every non-zero-degree camera angle the average duration for task performance measured was significantly higher and the task accuracy score significantly lower (figures 8 and 9). Additionally, our results showed the same phenomenon of performance decrease among novices at a camera angle of 90 degrees as Rhee et al. (2014) found. Yet, differently from the study of Rhee et al. (2014), our results showed that a camera angle of 180 degrees was an exception from a stepwise performance decrease from every non-zero-degree camera angle. Zhang and Cao (2010) stated that the larger the image rotation, the more mental transformation needs to be conducted, and the longer the performance would be and more errors would occur. Seemingly, in our study, this camera alignment, just as the +/- 45 degrees alignment, required less transformation and, on that account, less cognitive costs. One explanation for that could be that under a camera alignment of 180 degrees the fulcrum effect, for instance, gets lost (Dunnican et al., 2010). It has already been reported by earlier research that an inverted image condition facilitates the learning among novices due to the fact that a natural and expected representation of movement is given (Crothers, Gallagher, McClure, James, & McGuigan,

1999). In other words, when the handle is, for instance, moved to the right, the tip of the laparoscopic instrument is also moving to the right on the monitor.

The research of Delucia and Griswold (2011) has shown that, in the context of laparoscopic surgery, performance under different camera alignments depends on the required tool movement. In our study, the tasks were deliberately designed with inconsistency or varied mapping between the required tool movements and the camera position. This means that participants had to perform every kind of tool movement in every condition. Due to this inconsistency, the cognitive costs and benefits that the participants were facing, were equally spread in each task. Furthermore, it added a more realistic aspect to the experimental setup because, under most circumstances, surgical interventions cannot be undertaken by, for instance, simplified forwards/ backward movements. The increased task difficulty introduced by the embedded variability leads to a higher validity of the outcomes. On grounds of that, the experimental setting enables us to make more general estimations about which camera alignments are preferable for the chosen sample.

For the first part of this study, a close look was taken on the influence of camera angle on laparoscopic simulator task performance. In the following section, a closer look is taken at the subjects' ability of mental transformation and possible differences between the participants regarding this skill that led to better performance, under the different camera angles.

4.2 Effect of VSA on duration and accuracy of task performance

From previous research, it is known that visual-spatial ability influences laparoscopic task performance especially in early learning stages (Keehner et al., 2004; Wanzel et al., 2003). Within our sample of novices, it was shown that high VSA led to better, respectively faster and more accurate, simulator performance under the circumstance of non-zero-degree camera angles. In the context of laparoscopic surgery, time on task is a valid indicator of technical skills (e.g., Luursema et al. 2010; Keehner et al., 2006). Yet, speed should not be overestimated among the performance of novices since it is a quality that is developed later in the learning process. More important indicators of performance quality in early learning stages are attention to detail and accuracy (Eldred-Evans et al., 2013). The present findings of higher accuracy in the high VSA group are in accordance with the findings of Wanzel et al. (2003): they observed a high correlation between visual-spatial ability and efficient movement of the laparoscopic tools, which as consequence led to higher final product quality.

The results of our study show that already at a camera angle of +/-45 degrees VSA did have a significant influence on task accuracy. A better performance under these camera angles,

by people with higher visual-spatial abilities or more experience in the field, is based on a faster mental adaptation to the alteration in camera angle (Ames et al., 2006). Yet, this does not hold for the camera angle of 180 degrees, where performance was not to be influenced by visual-spatial ability and, therefore, no mental rotation was used (figure 10 and 11). Our results show that in this experiment there is no difference in performance between the two VSA groups under this condition. It is hypothesized that, in the conditions where VSA was no influence, other navigational strategies were applied by both groups which led to efficient laparoscopic instrument movement. Efficient tool movement presumes that the surgeon is able to cope for the discordance between the expected and the actual response of the laparoscopic instrument when navigating under non-zero-degree camera angles. In order to do so, an appropriate orientation and estimation of self-position are needed for creating an internal representation of the environment (Wolbers & Hegarty, 2010). From our study, it appears that under the condition of 180 degrees low VSA participants were just as able as high VSA participants to create a suitable internal representation of the experimental environment. The reason for that might be the fact that almost every person has previous experiences with mirrored images as, for instance, through hair styling or parking a car backwards. It is assumed that during the experiment previous experience with mirrored images led to a faster awareness of the visuomotor discrepancy in this condition, which as a consequence, led to faster appropriate motor adaptation (Saijo & Gomi, 2010). Additionally, from the literature, it is acknowledged that people with lower VSA ability tend to rely on route strategies when it comes to self-orientation. Route strategies presume that these people rely on local cues and think more in terms of linear connections between points and less about the overall configuration of the environment (Malinowski, 2001). Instead of computing information in their mind, they try to do it in the outside world. This goes along with the literature that states that another strategy applied by novices in the field of laparoscopic surgeries, is information gathering through more laparoscopic instrument motion (Tendick, Jennings, Tharp, & Stark, 1993; Xin, Zelek, & Carnahan, 2006). This strategy helps participants to search for the appropriate motor planning adaptation for reaching the targets. Another possible cue that low VSA participants could have used under the condition of 180 degrees was their own body representation to remember the location of left and right. This strategy includes embodying self-mental rotation and was found to occur more widespread among people than simple mental rotation when it comes to perspective taking (Surtees, Apperly, & Samson, 2013). Yet, within the group of high VSA, it is expected that people are more flexible, meaning that they can easily but probably

unconsciously switch between using their abilities or other strategies (Wolbers & Hegarty, 2010).

Considering our findings in general, we were able to confirm that participants high on VSA performed significantly better under the conditions of shifted camera angles than participants with low VSA. So, what are the practical implications of these findings and how do they translate to the assessment and training of surgeon candidates? Considering our results, surgeon candidates don't necessarily have to be selected by their VSA since there are conditions where VSA has no influence on the performance. Although our findings also indicated that there are camera positions where high VSA participants had significant advantages, it is important to mention once again that our sample was constituted by only novices and no training aspects were included in this research. The question that needs to be answered is whether these advantages, especially under the condition of a 90-degree and 135-degree camera angle, would remain after more training would have been provided to the candidates. Since it was mentioned by Keehner et al. (2006), that, after training and skill learning, the relation between VSA and laparoscopic task performance will remain, yet the relation between strategic components and performance diminishes, high VSA participants would outperform low VSA participants. Even under the condition of 180 degrees. Furthermore, our findings support the estimations of Dunnican et al. (2010) which state that training novices on mirrored images is important for skill learning since it does not enhance VSA but other navigational strategies. For freshman surgeons in practice, it is advisable to avoid camera angles of 90 and 135 degrees since these are the ones, which require the most skills.

4.3 Research limitations

Some limitations faced during this research should be kept in mind when interpreting the findings. First to mention is that by virtue of using a repeated measures model, which included multiple repetitions of a monotonic task, the aspect of boredom might have influenced task performance (Berg & Vrana, 1998), especially of participants low on VSA. Furthermore, using repeated measures assumes sphericity. Yet, when violated, the corrected values of, for instance, Greenhouse-Geisser, inflate the chance of type I error and, consequently, the significance found becomes overestimated (see Gueorguieva & Krystal, 2004 for a widespread discussion).

Lately, the American Statistical Association refocused their attention on the discussion whether a single index, in this case the p-value, should be a substitute for scientific reasoning. It is mentioned that there are other methods which more directly address the size of an effect

and its associated uncertainty. Therefore they disrecommended the use of p-values (Wasserstein & Lazar, 2016). Since this discussion has not yet come to an end and will probably be continued for some more time, we further relied on what is still common practice in the field of social research.

Moreover, when choosing for the right tests to analyze the data, assumptions of normality were controlled. Yet, it appears that the power of the common assumption tests is low for small sample sizes (Öztuna, Elhan, & Tüccar, 2006; Razali & Wah, 2011) which means that small samples mostly pass normality tests. A small sample in this context referred to less than 30 participants (Razali & Wah, 2011).

Additionally, the collected data probably contained some noise, which was caused by two aspects. Firstly, although bimanual dexterity is an important skill in laparoscopic surgery (Middleton et al., 2013), letting the participants perform the task with both hands, the dominant and non-dominant, should rather be excluded from the experiment since it takes a lot of time and training to develop this skill. Secondly, the technical problems need to be solved, which constantly appeared during the experimental session.

4.4 Future Research

For future research, it seems to be interesting to investigate navigational strategies, which help people to orientate and create an estimation of self-positioning, since it is was indicated that people low, as well as high on VSA, under some conditions tend to unconsciously make use of it. Especially the performance under the condition of an 180-degree camera angle should be further investigated since the findings of this study are conflicting with the literature.

Additionally, for future research, it would be possible to break down the experiment to only five different camera positions in order to investigate learning effects on the task performance. Every camera position could be provided to the participants twice, with each time 16 tasks (using the eight tasks from the first experiment twice). Applying this design to the experiment would ease the task due to the repetition. Hence, the participants become more used to the task and start to learn some of the required technical skills. It would be interesting to see whether the participants high on VSA would still perform significantly better than participants from the low VSA group.

The visual-spatial ability assessment procedure has proven to be valid, as it already did in the study of Luursema et al., (2010), and can be recommended for future research.

5. Conclusions

All in all, we were able to verify earlier findings that stated that non-zero degree camera angles lead to performance degradation. However, conflicting with the findings of Rhee et al. (2014) and Ames et al. (2006), in our study the greatest shift between the line of sight and line of work (180 degrees) did not likewise lead to worst task performance. Furthermore, we tried to investigate the influence of visual-spatial ability effects on laparoscopic simulator task performance. In order to do so, we tried to compensate for all learning possibilities within the experimental tasks. In the end, it could be seen that, indeed, higher VSA led to higher accuracy as well as shorter time on task. Yet under some conditions, no differences between the different VSA groups were found and it was concluded that navigational strategies, as relying on previous experience or embodied self-mental rotation, play a major role for novices, too. Of special interest was the condition of an 180-degree camera angle, where navigational strategies facilitated enormous performance improvement, especially for participants low on VSA.

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7. Appendix

7.1 Eight experimental task versions

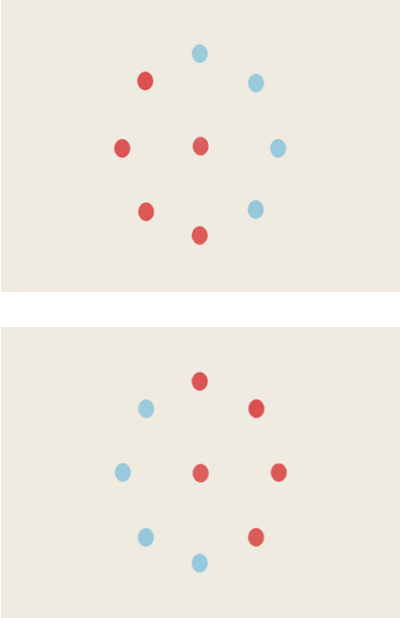

Figure 12. These graphics were only made for the purpose of showing all eight different task versions. They were never shown to the participants.

7.2 Syntax

7.2.1 Demographics

```
DATASET NAME DataSet1 WINDOW=FRONT.
FREQUENCIES VARIABLES=gender citizenship age
  /STATISTICS=MEAN
  /ORDER=ANALYSIS.
```

7.2.2 Shapiro-Wilks tests for normality

```
EXAMINE VARIABLES=ZExperiment_score ZVSA Experiment_average_time
  /PLOT NPPLOT
  /STATISTICS DESCRIPTIVES EXTREME
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.
```

```
EXAMINE VARIABLES=Position1_score Position1_time Position2_score Position2_time
Position3_score
   Position3_time Position4_score Position4_time Position5_score Position5_time
Position6_score
   Position6_time Position7_score Position7_time Position8_score Position8_time
  /PLOT NPPLOT
  /STATISTICS DESCRIPTIVES
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.

EXAMINE VARIABLES=RES_time RES_score RES_VSA BY NZVSA
  /PLOT BOXPLOT STEMLEAF NPPLOT
  /COMPARE GROUPS
  /STATISTICS DESCRIPTIVES
  /CINTERVAL 95
  /MISSING LISTWISE
  /NOTOTAL.
```

7.2.3 Friedman's tests

```
NPAR TESTS
  /FRIEDMAN=P1_time P2_time P3_time P4_time P5_time P6_time P7_time P8_time
  /STATISTICS DESCRIPTIVES QUARTILES
  /MISSING LISTWISE.

NPAR TESTS
  /FRIEDMAN=P1_time m45time m90time m135time P5_time
  /STATISTICS DESCRIPTIVES
  /MISSING LISTWISE.
```

7.2.4 Wilcoxon

```
NPAR TESTS
  /WILCOXON=P1_time P1_time P1_time P1_time P5_time P5_time P5_time WITH
m45time m90time m135time
   P5_time m45time m90time m135time (PAIRED)
  /SIGN=P1_time P1_time P1_time P1_time P5_time P5_time P5_time WITH m45time
m90time m135time
   P5_time m45time m90time m135time (PAIRED)
  /STATISTICS DESCRIPTIVES
  /MISSING ANALYSIS.

NPAR TESTS
  /WILCOXON=m45time m45time WITH m90time m135time (PAIRED)
  /MISSING ANALYSIS.

NPAR TESTS
  /WILCOXON=m90time WITH m135time (PAIRED)
  /MISSING ANALYSIS.
```

7.2.5 Repeated measuer analysis for accuracy

```
GLM P1_score m45accuracy m90accuracy m135accuracy P5_score
  /WSFACTOR=CameraAngle 5 Polynomial
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(CameraAngle)
  /PRINT=ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=CameraAngle.
```

7.2.6 Repeated measure analysis for duration with VSA as between subject factor

```
GLM P1_time m45time m90time m135time P5_time BY NZVSA
  /WSFACTOR=CameraAngle 5 Polynomial
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(CameraAngle*NZVSA)
  /EMMEANS=TABLES(CameraAngle) COMPARE ADJ(LSD)
  /PRINT=DESCRIPTIVE ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=CameraAngle
  /DESIGN=NZVSA.
```

7.2.7 Repeated measure analysis for accuracy with VSA as between subject factor

```
GLM P1_score m45accuracy m90accuracy m135accuracy P5_score BY NZVSA
  /WSFACTOR=CameraAngle 5 Polynomial
  /METHOD=SSTYPE(3)
  /PLOT=PROFILE(CameraAngle*NZVSA)
  /EMMEANS=TABLES(CameraAngle) COMPARE ADJ(LSD)
  /PRINT=DESCRIPTIVE ETASQ HOMOGENEITY
  /CRITERIA=ALPHA(.05)
  /WSDESIGN=CameraAngle
  /DESIGN=NZVSA.
```