Development of a platform for evaluating sensomotor performance in microsurgery

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Abstract. Microsurgery is a fast developing field. Despite introduction of robot controlled surgical equipment, skills of surgeons have a decisive impact on the success of a surgical intervention in the vast majority of cases. Assessment of suitability of new surgical equipment include usability tests, which are carried out in the field. Alternatively, usability tests are carried out in the lab using a simulator, therefore not necessitating real patients and enabling for a better control of biasing factors. We present the development of a platform, enabling to evaluate objectively sensomotor performance in a task, similar to microsurgery. Applications of the platform range from development of instrumentation and equipment relevant to microsurgery up to realistic investigations of various physiological and psychological factors affecting the sensomotor performance of a surgeon. Results of an experimental evaluation of the platform as well as the experience gained by the authors, support the benefit of the platform for sensomotor tests in a microsurgical environment.

Keywords. Microsurgery, simulation, sensomotor performance, Fitts, pointing

1. Introduction

Performance in microsurgery varies with skills of the surgeon, with used instrumentation and with other surgical settings such as posture or surgical technique. A fast increasing body of literature reports about performance in microsurgery, in which effects of various factors on surgery outcome have been investigated. The nature of the literature is either a post hoc analysis of interventions or an experimental evaluation of specific factors related to surgery. Post hoc analysis of interventions lack from the possibility of actively varying investigated factors therefore hindering the identification of causes and quantification of effect sizes. This drawback is eliminated in experiments considering a systematic variation of factors of interest, such as the level of magnification of a surgical microscope or the physical properties of the handle of a scalpel. By our knowledge, only few attempts have been made to investigate systematically sensomotor performance in a real or realistic microsurgical setting. Since transferability of experimental results to practice depends on the fidelity of the experimental setting as compared to the setting in practice, questions about effects of various factors on sensomotor performance in practice can hardly be answered based on findings reported in the literature.

We developed a platform by means of which senomotor performance is investigated experimentally in a realistic microsurgical environment. Sensomotor performance is assessed in participants completing the pointing task according to Fitts (Fitts 1954) and while using microsurgical equipment. In this contribution, we will describe the method and the apparatus and we will report results of a pilot experiment, such as the effects of handedness and of pointing direction on sensomotor performance, supporting the suitability of our set-up. Apart from assessing effects of individual factors in sensomotor performance, developed apparatus may be used in design of microsurgical tools, such as in the design of handles of grippers.

2. Theoretical framework

Donders (1986) postulated the proportionality between the time taken to compete a sensomotor task and the amount of information processed in the task. Driven by Donders postulate, Fitts (1954) related the difficulty of a sensomotor pointing task to the time required to complete the task. Fitts investigated abovementioned relation by means of a one-dimensional pointing experiment (see illustrations in Seow 2005) in which participants were required to use a pencil to point at target of a given size, which was at a given distance. Since Fitts' seminal work, variants of his experiment have been reported in the literature. Variations concerned, among others, in the dimensionality of the task, in the orientation of pointing and in the definition of the size of a target, e.g. considering the endpoints of the pointing movements instead of the true size of the target (Wright et al., 2013).

In the first step of our development, we will neglect multidimensional effects and process recorded data assuming a one-dimensional pointing task. Also, we will use the physical size of the target as a measure for its size.

3. Instrumentation

Developments of the instrument aim to realize a platform, enabling investigation of effects of various factors on performance in a microsurgical task. In this first attempt, factors to be investigated are limited to the orientation of pointing and to the dominance of the hand used to perform the pointing task. Effects of magnification are summarized briefly in this report and will be reported in detail in a forthcoming publication (Menozzi M et al. 2016).

The platform (fig. 1) offers similar conditions as are present in a typical microsurgical task. The main components of the platform were a surgical field, a handheld microsurgical tool and a microscope used to magnify the surgical field. The handheld microsurgical tool consisted out of a ball stylus and a micro switch in bayonet housing, and was mounted on a commercial available microsurgical handle. Participants activated the micro switch in order to indicate the completion of the pointing task. The microscope was equipped with a camera for recording the magnified image. Recorded image was displayed on the monitor of a PC, which also processed the image in order to locate the tip of the handheld microsurgical tool. A purpose written program, which was installed on the PC, introduced targets into the image recorded by the camera of the microscope. Targets varied randomly in size and location (orientation and distance) on the monitor. Therefore, the platform enables to run pointing experiments as described by Fitts but in a setting, similar as found in a microsurgical task.

4. Method

Participants were sat comfortably at developed platform. They were asked to perform the Fitts task using the handheld microsurgical tool for five different levels of nominal magnification of the microscope: 6x; 10x, 16x, 25x and 40x. For each level of magnification, a total of 20 trials were recorded with the dominant and another 20 trials with the subdominant hand. The PC recorded the movement times as well as the number of attempts to hit the target. Movement times and number of attempts to hit the target were stored with target location and target dimension into a log file. Analysis of recorded data encompassed computation of frequency of trials in which the target was hit at the first attempt as well as computation of processing speed in s / bits according to Fitts (throughput values IP will be discussed in a forthcoming publication). Frequency of trials in which the target was hit at a first attempt, are analyzed in terms of installed magnification and in terms of direction of pointing.

Figure 1. *Developed platform enabling the investigation of various factors affecting sensomotor performance in a microsurgical task. Foto reprinted with permission from Abt NA 2014*

5. Results

A total of 13 participants took part in the study. Eleven participants completed similar microsurgical tasks at a monthly or daily basis and two were less experienced. Due to incomplete data sets, data of three participants were excluded from further processing. The remaining 10 participants were seven men and three women with an average age of 35.3 y (SD=5.0 y). Nine of the 10 participants were right handed (right hand is the dominant hand).

Effects of magnification and of hand dominance on average (across participants) frequency of trials, in which the target was hit at the first attempt, are reported on the left hand graph of fig. 2. Highest frequency is achieved when installing a magnification of 10x. The right hand graph in fig. 2 shows the variation of processing performance with magnification when carrying out the pointing task with the dominant and with the subdominant hand. An inspection by eye reveals an optimum performance when the pointing task is carried out with the dominant hand and a magnification of 10x is installed. Further details on the effect of magnification will be reported in a forthcoming publication (Menozzi M et al., 2016).

Variation of performance was investigated by means of an ANOVA, in which the two within factors magnification (five levels) and dominance (two levels) were considered. Greenhouse-Geisser corrected results reveal a significant effect of magnification ($F(4, 1) = 3.94$, $p=0.043$) but no ($p=0.228$) significant effect of hand dominance nor an effect of interaction ($p=0.877$) between magnification and hand dominance on performance. According to partial eta squared, the effect size of magnification is strong ($\eta^2=0.305$). Performance varied significantly between subjects ($F(9)=404.54$, $p=0.000$, partial $\eta^2=0.978$).

Two post hoc ANOVA were run considering separately the datasets of the two hand dominances. This enable to include participants with incomplete data sets. Post hoc ANOVA revealed a significant effect of magnification in tasks completed with the dominant hand ($F(4, 59)=4.011$, $p=0.006$) but no effect when tasks were completed with the subdominant hand ($F(4, 58)=2.163$, $p=0.084$).

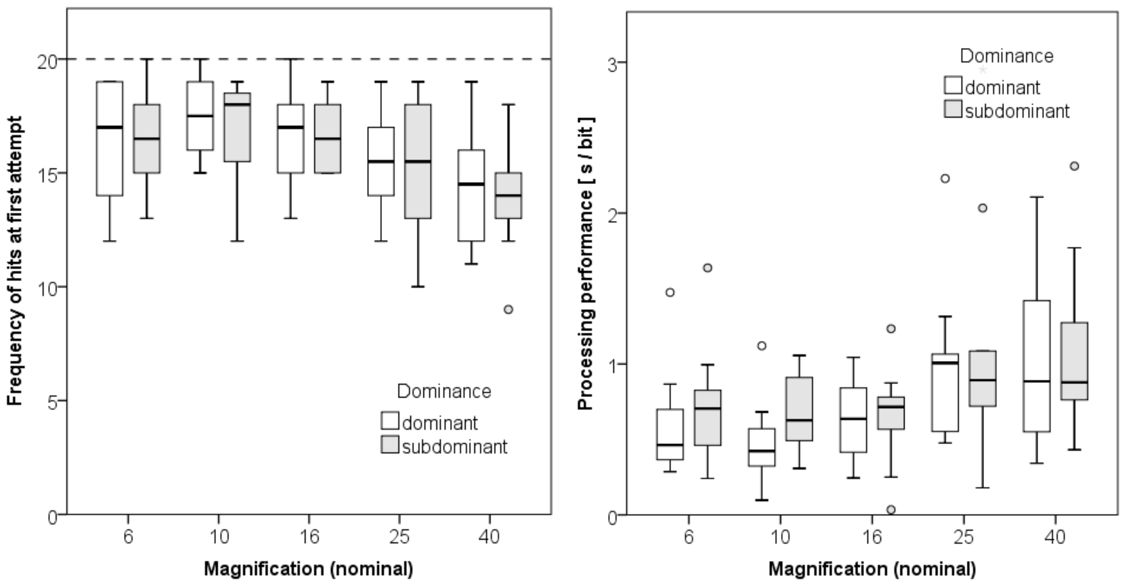

Figure 2. *Left Graph: Average frequency of trials on which the target was hit at the first attempt as function of magnification and of hand dominance. The dashed line indicates the maximum frequency (20). Right graph: Effect of magnification and of hand dominance on processing performance (in seconds / bit). 10 subjects.*

Figure 3 reports an analysis of percentages of hits at first attempt per quadrant in the pointing space. Hereby the first quadrant Q1 extends from 315° (=-45°) to + 45°, Q2 from 45° to 135°, Q3 from 135° to 225° and Q4 from 315° to 45°. Reported percentages are averages across participants and installed magnifications.

Considering that in nine out of 10 participants the dominant hand was the right one, data reported in fig. 3 indicate that, percentages are better for pushing rather than for pulling movements. Movements in quadrant 1 may require pulling of the right (right is dominant hand in nine out of the 10 participants) arm whereas movements in quadrant 3 are more of pushing type. Similarly, one may explain results when considering the subdominant (mostly left) hand. Differences between right and left hand in quadrant 2 and 4 may result from difference in comfort for ulnar and radial abduction of the wrist.

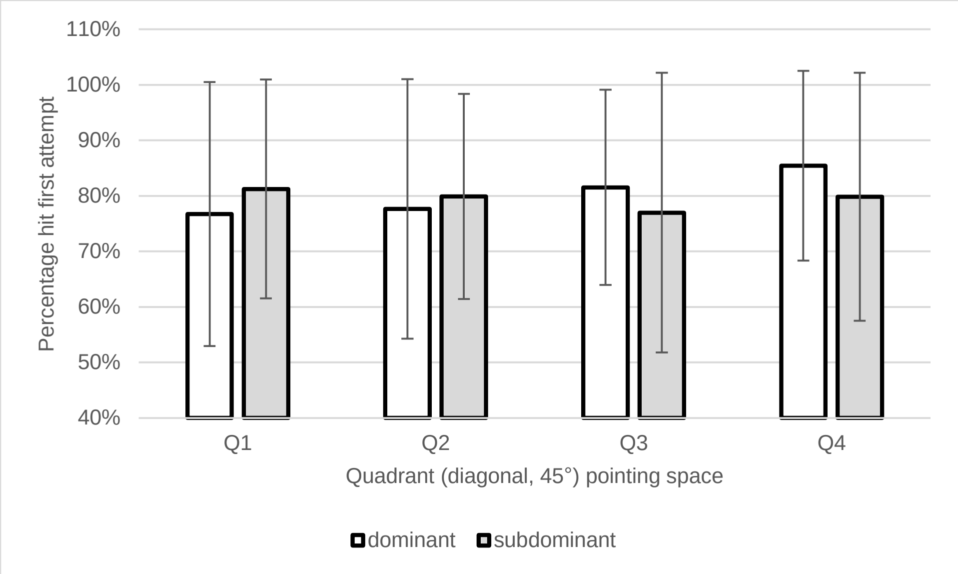

Figure 3. *Average percentages (across participants and magnifications) of hits at first attempt per quadrant in the pointing space and as function of hand dominance. Hereby the first quadrant Q1 extends from 315° (=-45°) to + 45°, Q2 from 45° to 135°, Q3 from 135° to 225° and Q4 from 315° to 45°. 10 subjects. Error bars denote 1 SD.*

6. Discussion and conclusion

As expected, magnification has a significant impact on the outcome in a microsurgical task. An inspection of fig. 2 by eye reveals an optimal magnification of 10x (nominal). Interestingly, at a magnification of 10x, the frequency of hits at a first attempt is higher in the subdominant hand than in the dominant hand. However, best performance in terms of information processing as according to Fitts' framework is achieved, when installing a magnification of 10x and using the dominant hand. A magnification beyond 10x seems to decrease performance of information processing.

From the point of view of the hand-arm-motor-system, pushing movements seem to be easier to accomplish than pulling movements. In both, the right and the left hand-arm systems, pulling movements may include in part an ulnar abduction of the wrist, which probably could be less comfortable than a radial abduction of the wrist (although the radial abduction covers a smaller range than ulnar abductions).

Based on presented results as well as on the author's experience gained while conducting the experiment we may conclude that developed platform is a valuable means to assess human factors and ergonomics in a microsurgical setting.

7. References

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Acknowledgement. The authors would like to thank Alcon Grieshaber Schaffhausen for lending part of the equipment used to perform the experiments.