BACHELOR THESIS PSYCHOLOGY

“LEARNING COMPLEX MOTOR PROCEDURES” –

CAN THE ABILITY TO LEARN DEXTERITY GAMES PREDICT A PERSON’S ABILITY TO LEARN A COMPLEX TASK?

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Abstract

Objectives: MIS seems to be more difficult to perform than open/regular surgery. Because of its differences to regular surgery it can lead to more risks and problems. These risks cannot be fully explained by cognitive or ergonomic factors. As previous studies suggest different correlations between the performance in MIS and specific cognitive factors can be found (Anastakis, Hamstra, & Matsumoto, 2000). Because of MIS's advantages it is important to research which factors might predict an ability of skills that are needed to perform well on MIS. The aim of this research is to study whether one dexterity task has predictive power for learning another dexterity task. Moreover, the question is asked if these predictions can be more accurate if the skills are viewed holistically rather than viewed as specified cognitive abilities.

Method: 40 participants took part in this study. Each participant repeated four different dexterity tasks for a specific amount of times. Per trial the time was measured and observations were noted down. The measured time was used to estimate individual learning curves.

Results: A Pearson pairwise correlation was exercised between the four different tasks per parameter. The parameter virtual previous experience and the learning parameter showed no strong correlation. In comparison a strong correlation could be detected between the Drawing maximum performance and the Origami maximum performance.

Conclusion: In conclusion it can be seen that it is only partly possible to predict the ability of a person to learn complex motor procedures by letting them perform dexterity tasks. It can be seen that the maximum performance of two tasks seemed to be associated. If a person has a talent in Drawing the person will also score high on the Origami task. It should be worked on these results in more detail to examine if other tasks are connected, or any specific underlying factors that might determine those tasks.

Keywords: Minimally Invasive Surgery (MIS), learning curve, dexterity tasks, holistic view, complex motor procedures

Content

1. General Introduction

Over the last few years much progress has been achieved in the area of surgery. *Minimally invasive surgery* (MIS) can be seen as the technique with the most powerful development including important changes in surgery skills. MIS is a sort of surgery that differs from regular surgery. The patient is operated on via a small key (keyhole surgery) or stab wound. Richard Martin Satava had the most impact on MIS and started the revolution of MIS (Gallagher & Smith, 2003). MIS offers many advantages regarding the superior cosmetic results or less postoperative pain (Matern & Waller, 2014). Not only does this method have many advantages, this surgery technique also poses problems. Because of its variations and differences to regular open surgery it seems to be more difficult to establish the skills that are needed for MIS. This results in a higher rate of risks and complications with new surgeons applying this surgery strategy (Gallagher & Smith, 2003). Also the circumstances and the setup of MIS surgery differs greatly from open surgery. Transforming the 2D image into the real 3D situation or the “fulcrum effect” (see section Advantages and Difficulties) is only one example of limits in MIS that demonstrates the difficulties and high demands that MIS poses not only to new surgeons.

Since MIS includes many advantages, but is also prone to risks because of its limits and differences to regular surgery, different studies tried to give an explanation of possible underlying factors. It differs from person to person how good they perform in MIS. This leads to individual differences. These differences might be explained by various aspects. According to Gallagher & Smith (2003) dealing with MIS technology is related to ergonomic, cognitive and training factors. Specific failures in MIS can be attributed to an insufficient ability to interact and use the equipment and instruments in MIS (ergonomic factor). Another problem is posed by the transfer of the 3D image while interacting with the instruments and seeing the situation on a screen (cognitive factor). Finally, training seems to have an influence on the performance in MIS. The ability to practice MIS without failure depends partly on issues of training. According to Gallagher & Smith (2003) there is a necessity for long term training and practice to succeed in MIS without failure.

Much research focused on the aspect of cognitive factors to explain the abilities of performing MIS. Different cognitive abilities were looked into to see if there was any specific correlation between a cognitive ability and MIS skills. An example of this is the cognitive aptitude test. This test includes different cognitive aspects such as visual spatial ability, perceptual skills, spatial memory, perceptual speed and reasoning. This test is used prior to a simulator training to assess the abilities of the individual and adapt the training program to a level that is needed. In conclusion it can be said that the cognitive aptitude test is only related partly/moderately to the learning curve of MIS (Groenier & Schraagen, 2014).

The results of different studies suggest different correlations between possible predicting underlying factors and MIS skills. These different results seem to be ambiguous and do not show the same correlations if they are replicated (see section Previous Studies). Also it has to be kept in mind that there is a possible ‘publication bias’ of studies that found no correlation/ significant results at all and therefore were not published. It seems that there is no consent about the link between the ability to perform MIS and the different results that are suggested by studies (Anastakis et al., 2000).

Due to these ambiguous results a different starting point should be considered to study a precondition to perform MIS successfully. A reboot could be one possible option that does not examine the cognitive factors as specific parts but takes into account the bigger picture/a combination of these factors (holistic view). If these complex skills are viewed holistically it may be possible to predict a person’s ability to learn complex tasks. The holistic approach supports the idea of taking a step back and determine if a task-based assessment procedure could work at all. There may be the probability that by not examining specific cognitive aspects, MIS skills could be represented as a whole and then further studied. Everyday dexterity tasks can serve as a possible assessment tool to present the holistic view. Tasks such as tying a knot or folding Origami include different cognitive components. These tasks can therefore test a combination of factors (motor skills, spatial ability and strategies that orchestrate these skills) rather than testing them one by one in abstract components (cognitive aptitude test). Individuals may perform on a high level on different tasks that may speak for a correlation of the underlying factors of these tasks. These underlying factors may be able to predict the ability of an individual to learn complex motor procedures such as MIS. Learning curves can then serve as an instrument that measures the acquiring of these motor skills and can indicate differences and correlations between tasks and individuals.

1.1 *MIS: Advantages and Difficulties*

MIS is regarded as a standard for different operations and has been used for more than ten years (Matern & Waller, 2014). This kind of surgery has been applied more and more frequently because of its advantages. In comparison to regular surgery, MIS is superior in cosmetic results. Because of the small stab wounds/ keyholes the scars are smaller. Also MIS causes less postoperative pain and therefore patients are released from hospital more quickly (shorter hospitalization) (Matern & Waller, 2014). Another important advantage that MIS entails is the aspect of a faster recovery compared to the recovery time of regular open surgery (Ponsky, 1991).

As opposed to the advantages that can be seen in MIS, this surgery technique also poses problems and difficulties that should be taken into account. According to Gallagher & Smith (2003) there is a higher risk of complications during the first 50 operations for new surgeons. The first 10 MIS operations include the highest risk factor. This higher risk factor and therefore greater complication rate can be related to the low amount of experience of surgeons. Another explanation is the general difference between MIS and regular surgery. One aspect that differentiates these kinds of surgeries is that the situation can only be grasped in a 2D image on a screen which has to be then transformed to the actual 3D situation. Another aspect that differs to the regular surgery environment is that the instruments respond in an inverted way. This leads to more prone scaling (Groenier & Schraagen, 2014). Moreover, because of the indirect way of interacting with the instruments the surgeons have to operate in a different posture. This is the reason why MIS can lead to physical discomfort of surgeons. Furthermore, there is a fixed axis to the movement of the instrument. This leads to a limited axis of operating (fixed to body wall), which is also called the 'fulcrum effect' (Groenier & Schraagen, 2014).

1.2 *Previous Studies*

Different studies focused on cognitive aptitude tests including multiple cognitive abilities that were tested in order to find out if they are related to MIS skills. Differences that could be detected in learning curves are on account of differences in the cognitive aptitude (Buckley, Kavanagh, Nugent, & Ryan, 2014; Groenier & Schraagen, 2014).

An example of a cognitive ability that has been tested is *visual spatial ability*. Previous studies showed that this cognitive factor is correlated with the performance in MIS (correlations between 0.42 to 0.46)(Keehner, Lippa, Montello, & Tendick, 2006; Luursema, Buzink, & Verwey, 2010). Visual spatial ability can be detected in different aspects during MIS. Transforming the 2D image mentally into the 3D real situation is part of visual spatial ability (Fried, Satava, & Weghorst, 2004). Also the orientation that is needed within the body itself is related to these skills (Cao, MacKenzie, & Payandeh, 1996). Visual spatial ability is not the only aspect that seems to have a correlation with MIS performance. Gallagher & Smith (2003) suggested that *psychomotor skills* are also related to MIS performance. Other studies also tested other cognitive abilities such as *spatial memory, reasoning, perceptual speed* (correlation varied between 0.16 to 0.46) (Keehner et al., 2006; Luursema et al., 2010).

All these abilities seem to be related to early stages of the learning phase of MIS skills (Keehner et al., 2006).

Even though the correlations and relations between these cognitive abilities and MIS skills have been found in studies, these results could not always be replicated by other studies. Anastakis et al. (2000) refers to different correlations in different studies. A recent study by Groenier & Schraagen (2014) demonstrates that these correlations cannot be replicated. This research focused on the cognitive factors spatial memory, visual spatial ability, perceptual speed, reasoning. No significant relations between the cognitive factors and the learning curves could be found (Groenier & Schraagen, 2014). It seems to be a discrepancy between the results of different studies and the suggested correlations. It could be possible that there are underlying factors that determine MIS skills, but are only visible if viewed holistically.

1.3 *Learning curve*

Learning curves were established in 1885 by Ebbinghaus and were then further developed into different types of learning curves. Learning curves describe in general how a person learns something. This is presented in a graph with experience on the horizontal axis and learning variable on the vertical axis. In these curves a rise can be detected to a limit. First the curve increases fast but then nothing more changes and it stabilizes at a certain level. The starting point of a learning curve can vary per person. It depends on the amount of experience that the individual has already undergone before. The limit of a learning curve can be reached in different ways. A steep curve describes a quick rise till the limit level and then stabilizes. In contrast a stable/shallow learning curve reaches the same limit but it takes longer to reach it. The limit levels, the starting points and the rise of the curve itself can be compared per individual and per task to detect correlations. These correlations and differences can then make a statement about the predisposition of people's ability to learn complex motor procedures. In this study the learning curves are going to be estimated with a non-linear mixed effects model with exponential, used as a regression model for learning curves. According to Heathcote, Brown, & Mewhort (2000) the main function of such a model is:

$$Y_{ptN} = Asym_{pt} + Ampl_{pt} exp(-Rate_{pt} N)$$

1.4 *Conclusion*

As seen above, laparoscopic surgery (MIS) has a more demanding learning curve compared to regular surgery (Palep, 2009). It can be seen that MIS is more difficult to perform than open/regular surgery. Because of its differences to regular surgery it can lead to more risks and problems. These risks cannot be fully explained by cognitive or ergonomic factors. As previous studies suggest different correlations between the performance in MIS and specific cognitive factors can be found (Anastakis et al., 2000). Because of MIS's advantages it is important to research which factors might predict an ability of skills that are needed to perform well on MIS.

1.5 *Research Question*

The aim of this research is to study whether one dexterity task has predictive power for learning another dexterity task. Moreover, the question is asked if these predictions can be more accurate if the skills are viewed holistically rather than viewed as specified cognitive abilities. A holistic view leads to the necessity to take a step back and to assess whether a task-based assessment procedure could work at all. According to previous studies in the literature it is expected that a holistic view might pose a better solution for predicting MIS skills than viewing skills in an isolated way.

To research this hypothesis, the learning curves of different dexterity tasks will be analysed. These dexterity tasks are not based on one cognitive factor but a combination of different skills. It may be possible that one participant performs well on all tasks while other participants always show the same pattern of failing specific tasks. Also two or more tasks could show to be associated because if participants perform high in the one task they also will have a talent for the other tasks. These results could then support a test that discovers a predisposition of skills that are needed to perform MIS successfully. Therefore, the research question is established if a person's ability to learn a complex task can be predicted by letting the person perform dexterity tasks.

2 Pilot Study

At the beginning of this study, five different candidate tasks were developed in connection to the reboot. These five tasks are different dexterity tasks which are going to be described in more detail. A pilot study is conducted to test the functionality of the setup of the tasks and to acquire feedback for further improvement. Four participants took part in the pilot study. Almost every task was done by every participant. Some of the researchers themselves did not take part because of previous experience while constructing the task and the instructions (Rubber Band, Origami). All tasks were repeated 20 times. During each of these trials the time was measured and the performance was noted. Furthermore, extra observations such as strategy changes, difficulties and general changes were noted. These notes were later on used for the improvement of the study.

The results of the time measurements were used to establish different graphs (see Figure 1, Figure 2). These graphs were used afterwards to detect if there was an improvement during the 20 trials and if there are any varieties between different learning curves (task dependent and participant depended). In relation with the observational notes a decision was made for four of the five tasks to be used in the actual study. A description of the tasks and improvements of the setups can be found beneath.

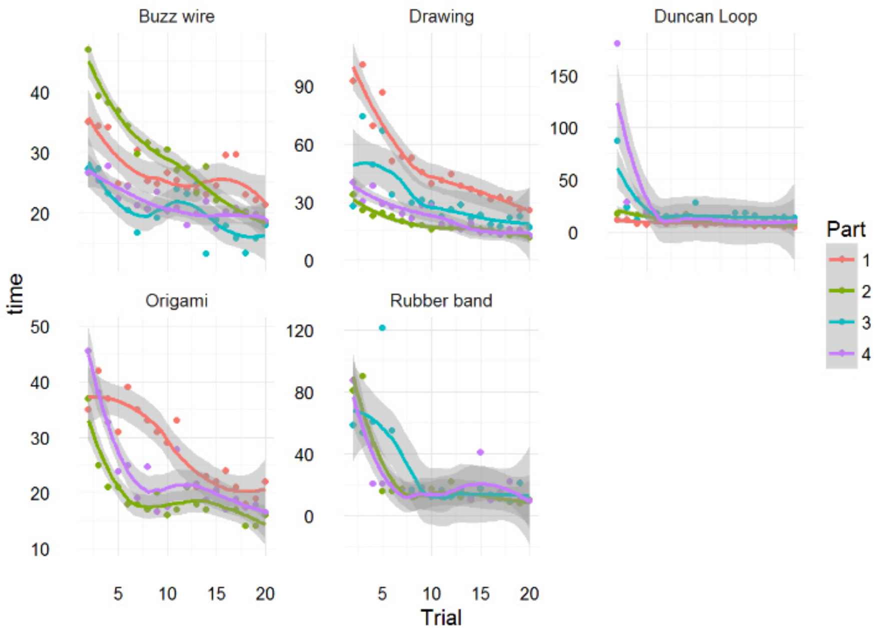

Figure 1. Comparison of learning curves between tasks

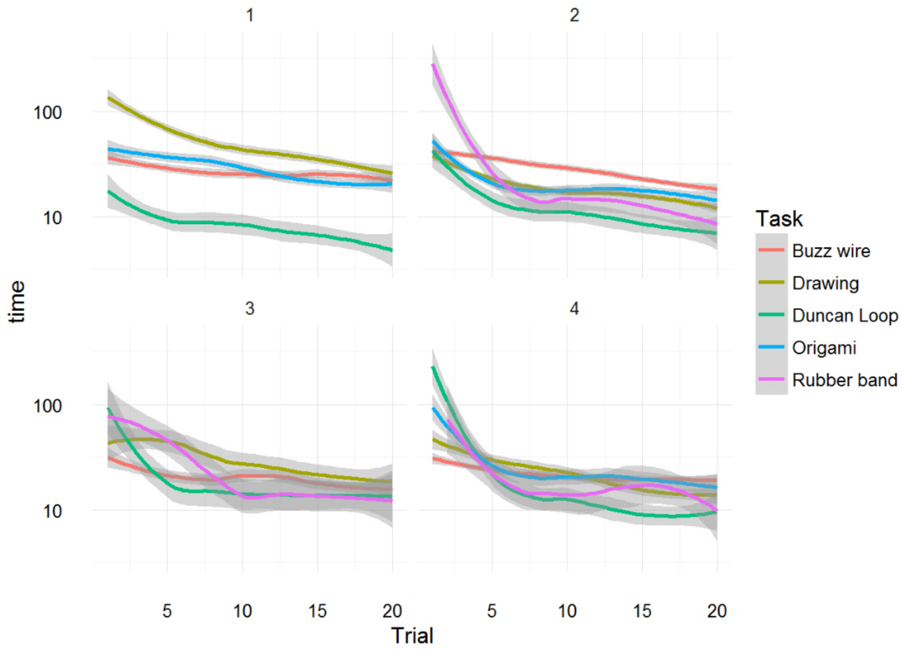

Figure 2. Comparison of learning curves between participants

2.1 *Origami*

Origami is a Japanese art of folding paper. It involves spatial thinking to be able to understand and interpret the given instructions. The given instructions with this candidate task were only visual. This means that the instructional steps are only shown by pictures and no further explanation. The instructions show how to fold a fox (see Appendix A). This is done by following the nine steps of the instructions.

The graphs of the Origami tasks show a decrease of time with each trial for every participant. At the end all learning curves stabilize. Some learning curves were not smooth but had extra peaks and then improved again and stabilized. Compared with the observational notes this can be related to the lack of motivation and sometimes also annoyance because of the repetition of the tasks. If the participant was informed about the amount of the trials left an improvement was visible. The performance per trial was difficult to measure. It was not always clear which criteria determine if the fox is good enough. Also the participants stated that they had difficulties estimating which aspect of the performance was prior (fast time or perfection of the Origami figure). Furthermore, the paper that was used in the pilot study was not perfectly cut and had only one color (compared to the paper used in the instruction with one side colored).

Taking all these aspects into account, the Origami task seemed to be suitable for the study. Individual differences could be detected and an improvement till stabilization was visible in almost every curve. Therefore, it was decided to pick this task and improve aspects that seemed to be problematic. It was decided to use normal paper but cut that paper professionally to prohibit any special difficulties.

2.2 *Rubber Band*

Creating figures out of Rubber Band includes spatial aspects to follow the instructions and transferring those to make the figure. The Rubber Band task consisted of a specific figure that needed to be replicated by using your hands and one Rubber Band. The figure chosen in this task was a double star. For this, two different kinds of instructions were used and tested. One set of instructions was a series of pictures with an explanation beneath every picture. While testing these instructions it seemed to be too complicated to follow the more spatial steps that needed to be performed. Because of these difficulties video instructions were also tested. This video was easier to understand but problems arose following the speed of the steps. Most participants could follow the steps to a specific moment and then had problems to go on or made a mistake. Because of the kind of instructions, it was difficult to go back, stop or re-watch a specific step. The participant needed to replay different parts of the video and sometimes needed to stop it to follow the instructions completely. This resulted in higher amounts of times per trial because the time to stop and go back in the video and then start again was also counted. More details can be seen in the graphs described beneath.

As seen in the graphs almost every participant had a low previous experience on this tasks because almost everyone started at their highest beginning level compared to other tasks. Each result of the different participants showed an improvement in time and the curves stabilized at the end. The observational notes suggested difficulties in the setup of the study. Because of the spatial dimension of the tasks it was difficult to decide on the kind of instructions that should be used. Instructions presented in different pictures were too complicated to follow. The video that was used was better to follow and therefore possible to understand but it seemed to be not practical during the pilot study. In conclusion the difficulties with the setup seemed to be too grave and it was therefore decided to erase this task from the actual study.

2.3 *Drawing*

The Drawing task was established based on the “fulcrum effect”. Because of the difficulties interacting with something that moves in the opposite direction it was decided to construct a task that can be related to that. The candidate task “Drawing” used a cardboard box to hide a paper on which a line of a figure should be traced that was only visible for the participant in the mirror.

The graphs established from the Drawing task results showed the greatest variances. There were different beginning levels and different kinds of improvements in time. According to the observational notes the participants had difficulties deciding on what was more important: The accuracy of the traced line or the time of the trial. Also the pen that was used could influence the performance of the participant. A thicker pen led to a more difficult level and therefore could lead to different results. In spite of these difficulties this task seemed to be suitable for the actual study and was therefore chosen.

2.4 *Buzz Wire*

The Buzz Wire task was based on a typical toy for children. It was made out of wood and a formed wire with different kinds of curves. If the wire was touched with the attached hook a red LED lighted up. This light was used to count the mistakes. During the trials it was difficult to count the mistakes because the LED lighted up too quickly. This resulted in invalid measurements of the amount of mistakes.

The learning curves of the Buzz Wire tasks are more stable and do not decrease as much as other learning curves. Still a decrease and stabilization in each learning curve of every participant could be detected. Difficulties resulted from the setup and the construction of the task itself. If the wire was touched it began to shiver. This added extra difficulty to the task that was not the same over every trial. Also a problem with the goal of the tasks itself could be seen. It was not clear enough what aspect the focus was on. If the participant just took the time as the most important factor a different strategy could be observed than when taking the amount of mistakes in consideration.

Considering all aspects, it was decided to use this task in the actual study. The setup off the Buzz Wire was changed to be more suited for the task. The wire used in the new apparatus was thicker and therefore more stable. Also, the amount of time the LED lighted up was extended so counting the mistakes was the same with all participants. Furthermore, three-dimensional aspects were added to the wire so that a greater decrease of the learning curve was possible with a higher entry level.

2.5 *Duncan Loop*

The Duncan Loop is a specific knot used in different areas such as fishing. Also in this task spatial dimension is needed to transfer the situation of the instructions to the actual situation.

For this task an instructional figure was used. Before the participant began the finished knot was shown to him/her to let them see what it should look like. For the task a white cord was used. A problem arose with the ending of the knots because they dissolved and then were disturbing for the participants.

The results of the Duncan Loop task showed a discrepancy between the participants. Two learning curves started at a very high level of previous experience compared to the two others. This seemed to be the result of earlier training and experience in sailing and scouting. Another anomaly that could be detected was the fast decrease and also fast stabilization of the learning curves. Just after five to ten trials almost every participant reached their maximum performance and maximum performance did not change anymore.

Although two participants had previous experience in this task and therefore had no significant learning curve, it was decided to use this task in the actual study. It seemed that this task was suited for the purpose of the study and that the results of those two participants might be an exception. The learning curves suggested that a maximum performance was already reached earlier and 20 trials were not needed. Therefore, it was decided to shorten the amount of trials to ten for the actual study.

2.6 *General aspects*

Also general feedback was conducted to improve the overall setup of the study. One question was how to deal with struggles and problems of the participants with the tasks. If the participant gets stuck (Duncan Loop: participant is stuck and is not able to recreate the loop with the instructions and needs extra help; Rubber Band: participant is not able to follow instructions and does not know at which step the mistake is) and is not able to go on or does something wrong and does not get where the mistake is, how should the researcher react in this situation. Therefore, an instructional handbook was created that gave the researchers rules on how to react in these kinds of situations. This handbook also included information about how to measure the performance because this seemed to be difficult for the researchers as well as for participants.

Also the motivational aspect of the study seems to have an influence on the performance. If the participants were informed about the number of trials left (last three trials) they wanted to improve their time and get the best results for the last trials. It should be thought about a general rule to handle this aspect.

Moreover, the performance of the participants during the tasks could be influenced by the order the tasks are completed. Some tasks need more concentration at the beginning to understand them (Rubber Band, Duncan Loop) than others (Drawing, Buzz Wire). If the participant is already exhausted by the three tasks before this might be visible in the results of the last task. Therefore, a randomized order of tasks should be used for each participant.

2.7 *Conclusion*

After evaluating and discussing all the collected data and observations, the decision was made to exclude one task from the study. The Rubber Band seemed to be not suited for this type of study. Because of the struggles with the kind of instructions it was more difficult to learn the trick. Under these circumstances it would be possible to measure a greater amount of the instructions than the learning of the task itself. The other four tasks were further developed according to the evaluation and feedback that was resolved from this pilot study. The description of this improvement and of the tasks themselves can be seen in the method section.

3 Method

3.1 *Design*

In this study a within-subject design was employed. The experiment consisted of one group that fulfilled all tasks in a randomized order. The tasks were the same with every participant.

3.2 *Participants*

A convenience sample of 40 participants (N=40) with an age range between 18 till 76 (M= 28.05; SD=14) was used in this study. 80% of the participants that took part in this study were female, 20% were male participants. The group of participants consisted of 14 German persons and 26 Dutch persons. The studies/jobs varied from 20% that had a job and 80% that studied. 90% of the participants indicated to be right handed, 2.5% stated to use both hands equally and 7.5% were left handed. There was no exclusion criterion for participating in this study.

3.3 *Materials*

Four different tasks are used in combination with a short questionnaire interview section at the end. The tasks were the Duncan Loop knot, Origami, Buzz Wire and a Drawing task. Furthermore, there are instructions specifically created for the researchers and for the participants.

3.3.1 Duncan Loop

The Duncan Loop task consisted of a 1.7-meter-long white cord with a width of three millimetres. The ends of the cord were closed so that the cord would not get open and loose. Otherwise the participant could get distracted and annoyed by a broken cord. An illustration is used to instruct the participants on the method and technique to knot the Duncan Loop (see Figure 3). A finished knot is shown to the participants before the trials begin to give them an idea what the knot should look like.

Figure 3. Duncan Loop instruction

3.3.2 Origami

For the Origami task 20 white squared papers, with a size of 21cm x 21cm, were used per participant. Per trial a new sheet of paper was used to diminish the effect of the previous folded edges. We chose this specific size of the paper because this way it was not too big (so it would be unpractical to fold it) and also not too small (so the measurements would depend on the size of the participant's hands). We chose a fox as a figure because this figure seemed to be on a basic level so that it was possible for almost everyone to follow the instructions but also not too difficult that it would take a long time to understand the procedure and extra help would be needed. The instructions consisted of eight coloured pictures that each described one folding step (see Figure 4). The folding line was shown by a grey dashed line in the instructions. The instructions were printed on an A4 paper and then were handed out to the participants at the beginning of the first trial.

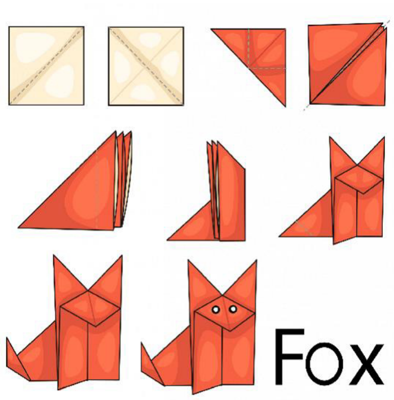

Figure 4. Fox Origami instruction

3.3.3 Buzz Wire

The Buzz Wire task is set up with different materials and can be dissembled for transportation. The base consists of a wooden plank with two small extra planks that hold the ends of the wire. The wire is formed with different sized curves and also has two three-dimensional aspects. The wire is stable enough so there is no extreme shaking if it is touched. A handle with an open loop of two centimetres is attached with a cable to the right side of the apparatus. Also the wire is connected to a cable on the right side which leads to a 9V-battery. A red LED light is interposed in this circle so every time the wire gets touched the red light will blink. The wire can be dissembled so the curves have a lower risk of deforming when transported and therefore are most likely to stay the same for every participant.

3.3.4 Drawing

The Drawing task consists of four different parts. A printed figure is used for Drawing. This figure displays a circle and square combined into one figure (see Figure 5). The figure is printed in two different sizes so a space of five millimetres can be used to trace a line in-between. The printed papers are numbered from one till 20 so the progress of the task can be followed afterwards. The participant uses a pen to draw this line. Because the goal of the task is to draw according to the reflected image in a mirror, a cardboard box is used. This box is used to hide the paper from the participant. The box has a round opening with a width of 20 centimetres. The site that is directed to the mirror is open. From the outside the box is coloured in white not to distract the participant with the original print of the box. The mirror that is used with this task has a size of 35 by 35 centimetres.

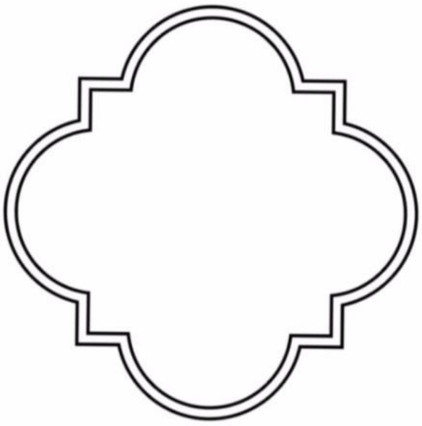

Figure 5. Fill out template for Drawing task

3.3.5 Measures and other materials

Furthermore, other materials were used during this study. An informed consent was used that assured that the participant understands the conditions of the study and their permission to take part in the study. Also four different sets of instructions were handed out to the participants per task. Each set explained what needed to be done. An instructional guide was established for the researchers. By directing the study with fixed instructions it could be made sure that the procedure per task stays the same with every participant. The guide presented the utilities that are used during the task, the procedure of the tasks and extra notification for the researcher to fill in the observational form (see Appendix). This form was made to capture and record observations during the study such as strategy changes, motivation of the participants, questions/difficulties of the participants. The needed time per trial is also noted down. Furthermore, the trial numbers 10 and 17 had red marks to remind the researcher to announce the amount of trials left. The time per trial was measured using a stop watch. Also the performance per trial was noted down.

Three options were possible for recording the performance of the tasks Drawing and Origami. A ‘V’ was noted down if the performance was good. A ‘X’ was given if the performance was not completed or sufficient enough. Also the possibility exists that the performance was sufficient but not good. Then a ‘V/X’ was noted down. There were also three options for the researcher to record the motivation per trial. An ‘O’ meant that the motivation of the participant was not clear to the researcher during the trial. An ‘M’ was noted down if the participants seemed motivated and on the opposite an ‘F’ if the participant seemed frustrated. With these records it would later be possible to track changings in the learning curves and give a possible explanation.

3.4 *Procedure*

3.4.1 Data collection

After testing the different tasks during the pilot study and improving them further, we sent the study to the ethical commission of the University of Twente for approval. After approval was given we invited the participants and asked if they wanted to take part in the study. These participants were then evenly divided between the four researchers.

Before the study, a randomized order of tasks per participants was established to assure that not every participant followed the same order of tasks. After every 10^{th} participant the first task was changed so that only 10 participants began with the same task. The order of the following tasks was different with every participant. With this structure we could assure that there are no effects because of the structure (same task at the end, no learning effect because of missing concentration). The scheme of the order of tasks also presented the participant number so every form could be traced back to the participant but the data could be handled anonymously afterwards.

The experiments took place in different settings. Most settings were chosen by the participants themselves (at home) or took place in cubicles at the University of Twente. We began the study by instructing the participant about general aspects of the study that could be found back on the informed consent. Before the actual start of the experiment this informed consent was signed by the participant and the researcher. Then the experiment began by asking the participant general questions. A few questions dealt with the demographic background of the participant (age, gender, nationality, job/study). Then we followed these questions with more specific questions that are important for the analysis of the dataset afterwards. Aspects such as left- or right handedness were asked to determine the preference of the participant.

Afterwards the actual tasks began. Per task we handed out a set of instructions to the participant (see materials for specific details). After letting the participant read those instructions we asked them if anything was not clear and if they needed further explanations. Then the trials began. The participant announced when he or she was ready and the clock should be started.

During the experiment the researchers observed the participants. Depending on the task we counted the amount of mistakes, we noted down any strategy changes, an impression of the motivation of the participant was also made and any other extra aspects were marked down. We filled all these aspects in the observation form. By writing down these observations during the trials, we could trace special occurrences in the data set later on and explain them in more detail.

After the tenth and the 17th trial the researcher announced the number of trials left to the participants to motivate them to improve themselves for the last few trials. By generalizing this comment, there are no differences in motivational effects per participant caused by the researcher. If the participant was finished with the trial the clock was stopped and the time was noted down in the form. Directly after every task, we asked the participant about their experience with the task. These answers are also noted down for further analysis of the dataset. Between every task we gave the participant a five-minute break, so that the participant would not get frustrated and had time to fuel up.

After completing all four tasks we interviewed the participant with a questionnaire to record their personal experience in general. The collected data (trial times, observations) that was noted down by each researcher, was then transferred to an excel document where all data from the 40 participants was grouped together. This data set was then used for further analysis.

3.4.2 Data analysis

The results of each trial are then used to estimate learning curves. Before, the data set was cleaned. No major cleaning needed to be done, only mistakes in the documentation of the data were corrected and changed. To estimate the curves a non-linear mixed effects model with exponential is used as a regression model for learning curves. According to Heathcote, Brown, & Mewhort (2000) the main function of such a model is:

$$Y_{ptN} = Asym_{pt} + Ampl_{pt} exp(-Rate_{pt} N)$$

The parameter Asymptote means the level of maximum performance which is reached asymptotically with continued practice. The Amplitude parameter describes the amount of improvement. It shows the difference between the performance before the first trial and the Asymptote. The last parameter is the Rate parameter which displays the overall speed of learning.

Due to this formula above the problem arises that the amplitude parameter is ambiguous. If the amplitude is low this might indicate that there is a low potential for good maximum performance. Furthermore, this might suggest that the amount of learning is little because the person had previous practice. This is the reason why it is chosen for a different parametrization of the exponential model, that models (virtual) previous experience. The alternative parameter Previous experience is shifted on the x axis in the new reparametrized model. The learning curve of a participant with a high amount of previous experience is shifted to the left, which makes it appear flatter in the observed range.

$$Y_{ptN} = Asym_{pt}(1 + exp(-Rate_{pt}(N + Prev_{pt})))$$

Three different parameters need to be analysed. First the virtual previous experience parameter that indicates the entry performance. Second the learning parameter that summarizes the rise of the learning curve. The last parameter is the asymptote parameter that shows the estimated maximum performance. The learning curves of all four tasks were divided into these three parameters. The statistical program SPSS 22 was then used to analyse these variables in more detail. To assess the relations between all scale variables a pairwise Pearson correlation was calculated for all three variables.

4 Results

4.1 Descriptive statistics

4.1.1 Virtual previous experience

The boxplot shows that the virtual initial performance was the lowest with the Duncan Loop task. Two participants seemed to already have experience and had therefore a high performance in comparisons with the others. The tasks Origami and Drawing are on the same level in previous learning, although the Drawing task has a wider spectrum from minimum and maximum previous learning. Furthermore, those two tasks had the highest initial performance. In between lies the Buzz Wire task.

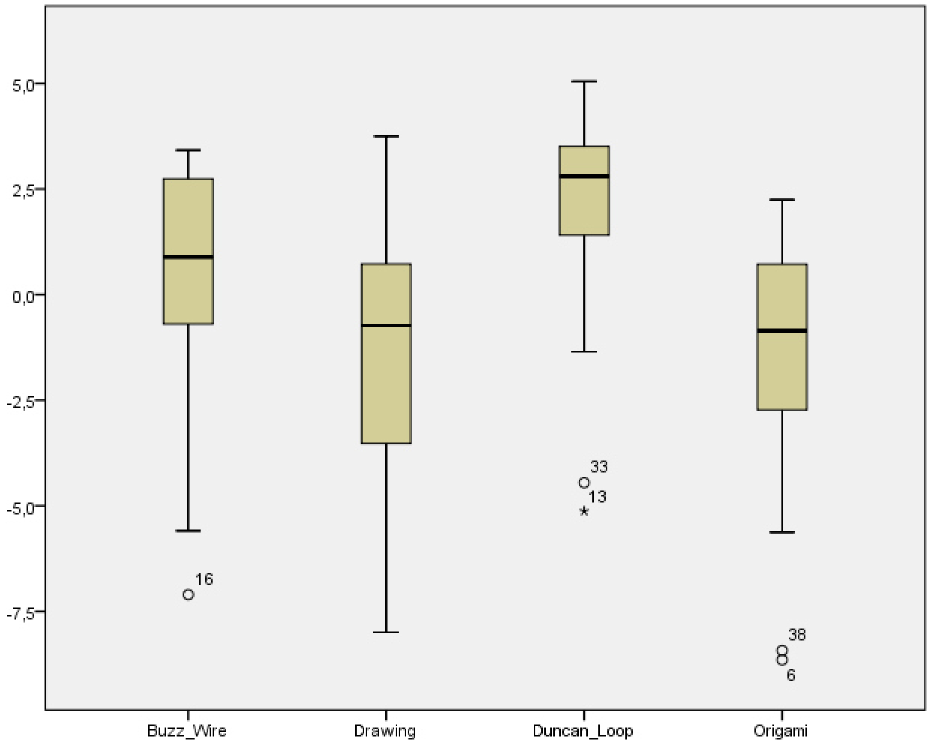

Figure 6. Boxplot of the parameter Virtual previous experience

Table 1.

Descriptive Statistics virtual previous training

	M	SD	Minimum	Maximum
Buzz Wire	0,52	2,56	-7,10	3,42
Drawing	-1,38	2,91	-7,99	3,75
Duncan Loop	2,21	2,23	-5,12	5,05
Origami	-1,34	2,62	-8,65	2,25

4.1.2 Learning

The learning parameter indicates an estimated slope of the learning curve. It can be said that the smaller the value of this parameter the faster the participant was able to learn the task. It seems that in general the Buzz Wire task was learned the quickest. This task is followed by Drawing, then Origami and finally the Duncan Loop task. The lower and upper bounds of the standard deviation are on the same level for every task with the exception of the Duncan Loop task. It seems that the speed of learning differed more in this task compared to the others.

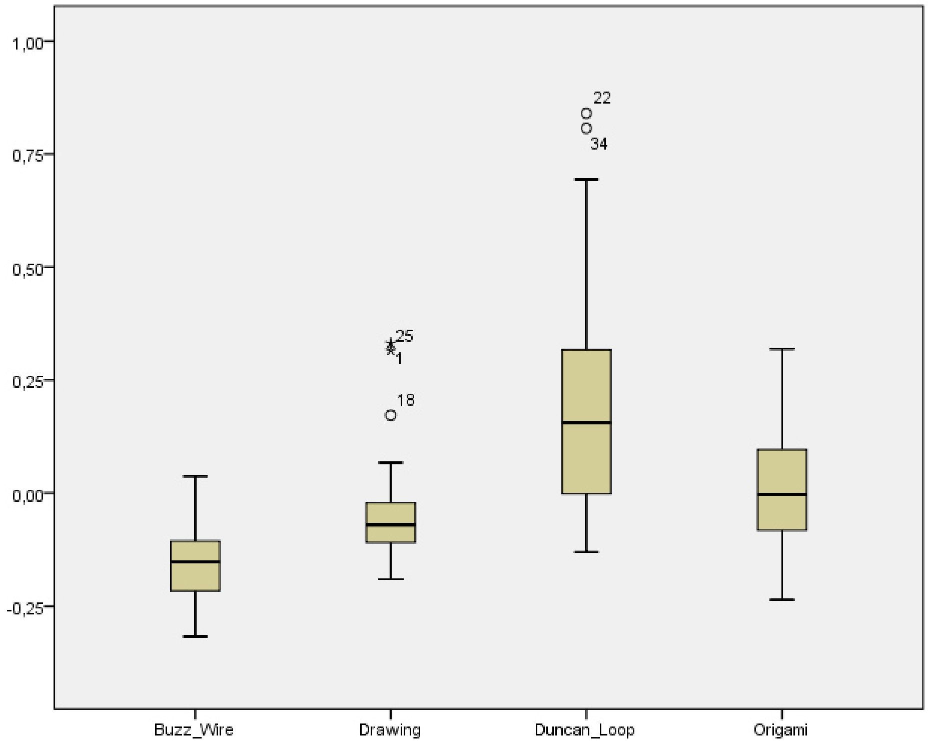

Figure 7. Descriptive statistics boxplot of the parameter learning

Table 2.

Descriptive statistics learning parameter

	M	SD	Minimum	Maximum
Buzz Wire	-.15	.07	-.32	.04
Drawing	-.05	.11	-.19	.33
Duncan Loop	.19	.24	-.13	.84
Origami	.01	.13	-.24	.32

4.1.3 Asymptote

The lower the value the higher is the estimated maximum performance (Asymptote). This means that the best mean performance can be detected with the Duncan Loop task. The other three tasks are approximately on the same level. The lowest end-performance can be seen with the Drawing task. Also there are a few outliers that had a lower end performance. These outliers can be seen in every task.

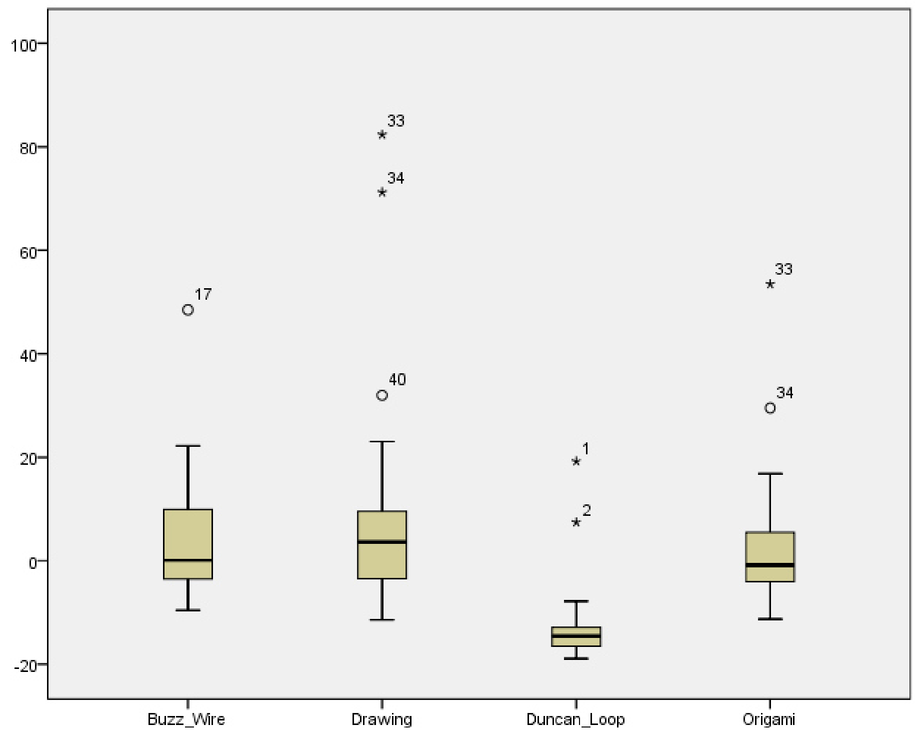

Figure 8. Descriptive statistics boxplot of the Asymptote parameter

Table 3.

Descriptive Statistics asymptote

	M	SD	Minimum	Maximum
Buzz Wire	3,84	11,01	-9,61	48,50
Drawing	7,75	18,85	-11,43	82,34
Duncan Loop	-13,30	6,85	-18,95	19,26
Origami	2,21	11,52	-11,26	53,46

4.2 Correlation analysis

A Pearson correlation coefficient was calculated to assess the relationship between each of the three different tasks. For each parameter (virtual previous experience, learning, asymptote) a pairwise correlation was exercised between the four different tasks.

4.2.1 Virtual previous experience parameter

No strong correlation could be detected for virtual previous experience (see Table 4). Three correlations are in-between a confidence interval that has an upper end that can be defined as moderate correlations. These possible moderate correlations can be seen between the variables Drawing and Buzz Wire, Duncan Loop and Drawing, Duncan Loop and Origami (see Table 4). This means that these correlations might be higher and therefore speak for a relation between those variables. But these correlations could also lie on the lower end of the interval and therefore be not meaningful. Contrary one moderate negative correlation can be detected between the tasks Duncan Loop and Buzz Wire (r = -.29, n = 40) 95% CI [-.52, .02]. This negative correlation might describe that the previous experiences between those two tasks are not related.

Table 4.
Pearson Correlation Coefficient of virtual previous experience variables between four tasks

	Correlation Coefficients			
	Buzz Wire	Drawing	Duncan Loop	Origami
Buzz Wire	1	-	-	-
Drawing	0 [-.43,.40]	1	-	-
Duncan Loop	-.29 [-.52, .02]	.03 [-.16, .29]	1	-
Origami	-.06 [-.39, .17]	.17 [-.13, .43]	.03 [-.25, .45]	1

4.2.2 Learning parameter

There was also no strong correlation visible of the learning parameter between the four tasks (see Table 5). Also with this parameter some correlation lay in between a confidence interval that has an upper bound that indicates a higher correlation that can be described as moderate. These confidence intervals are between the tasks Drawing and Buzz Wire, Duncan Loop and Buzz Wire, Drawing and Duncan Loop, Drawing and Origami, Duncan Loop and Origami. In comparison to the confidence intervals these upper bounds are higher than with the confidence intervals of virtual previous experience.

Table 5.
Pearson Correlation Coefficient of learning variables between four tasks

	Correlation Coefficients			
	Buzz Wire	Drawing	Duncan Loop	Origami
Buzz Wire	1	-	-	-
Drawing	.39 [.13, .62]	1	-	-
Duncan Loop	.26 [.10, .50]	.11 [-.16, .43]	1	-

Origami	.02 [-.22, .25]	.16 [-.11, .46]	.08 [-.38, .52]	1

4.2.3 Asymptote parameter

In contrast to the other parameters a strong correlation between the asymptote parameter of Origami and Drawing could be detected (r = 0.852, n = 40) 95% CI [0.68, 1.02]. A scatterplot summarizes this result (see Figure 9). A talent in Origami is correlated with a talent in Drawing. Also a moderate correlation with the upper bound of the confidence interval between the tasks Origami and Duncan Loop can be detected.

Table 6.
Pearson Correlation Coefficient of maximum performances between four tasks

	Correlation Coefficients			
	Buzz Wire	Drawing	Duncan Loop	Origami
Buzz Wire	1	-	-	-
Drawing	.07 [.18, .36]	1	-	-
Duncan Loop	.04 [-.26, .26]	.03 [-.12, .28]	1	-
Origami	.03 [-.17, .38]	.85 [.44, .93]	.17 [-.06, .42]	1

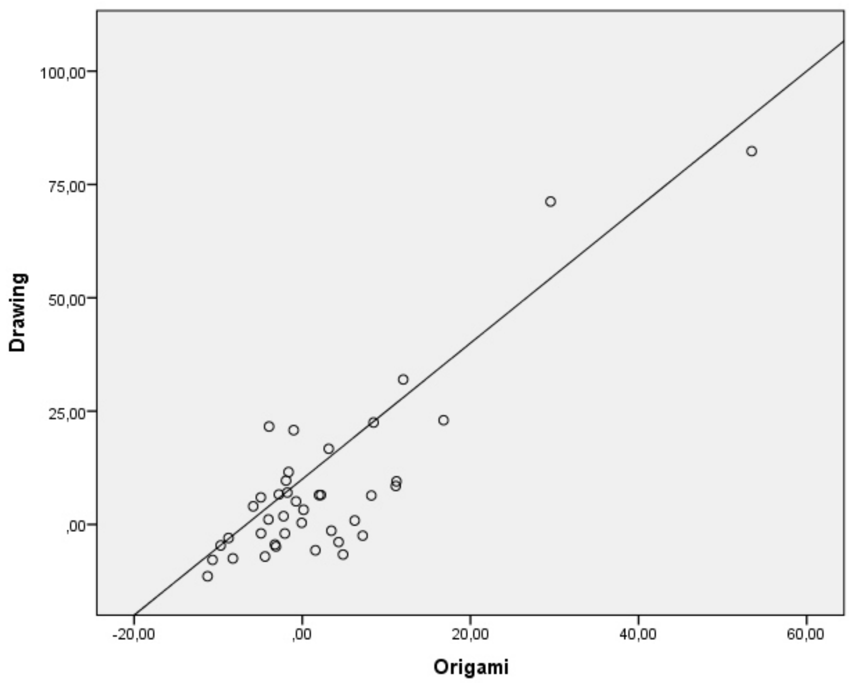

Figure 9

Correlation between the Origami maximum performance and the Drawing maximum performance

5 Discussion

The aim of this research has been to study if one dexterity task has predictive power for learning another dexterity task. Moreover, the question was asked if these predictions are more accurate if the skills are viewed holistically rather than viewed as specified cognitive abilities. The tasks that were chosen in this study were Origami, Drawing, Duncan Loop and Buzz Wire. The results indicated different correlations with every variable (virtual previous experience, learning, asymptote). Only one pair showed a strong correlation in the maximum performance. It seemed that Drawing and Origami are connected. If the connection was seen in the maximum performance, it means that a person that performed high in the Drawing task also had a talent for Origami and vice versa.

Also another correlation was seen between Drawing and Buzz Wire when it comes to the learning parameter. According to Bolboaca & Jäntschi (2006) a correlation can be described as strong if it is above 0.8. The correlation between those variables was only 0.39. Correlations lower than 0.5 are defined as weak correlations (Bolboaca & Jäntschi, 2006). That is the reason why only the correlation between Drawing and Origami is chosen as a strong correlation and should be further worked on. Furthermore, these differences in correlation can have grave consequences. If the correlation is only moderate, this might influence the practical use in different areas later on. If this correlation is used as a basis in tests for future surgeons it is important that the correlation the test is based on is strong enough. Otherwise surgeons might be wrongly chosen as suited because the test was based on random noise in the study. This might resolve in dangerous incidents during surgery with the possibility of death. Moreover, there is also the possibility that surgeons have a talent and are suitable for MIS but are disregarded because of misguided tests. Both possibilities result in high costs that could be prevented.

The question arises if these results can still display a holistic view to predict MIS skills with dexterity tasks rather than with specific cognitive ability tasks and tests. The results showed that only one correlation was strong enough between two tasks. The other tasks did not seem to be related with each other. This might speak for at least three underlying factors. The correlating tasks could have one factor or more than one factor in common, whereas the other tasks have at least two other factors in common. It is difficult to still view those two related tasks as holistic because the correlation might be based on only one common factor. This one common factor might not display a holistic view.

The Pearson correlations were calculated between three different aspects of the learning curves. First the correlations were studied within the four different task variables of the virtual previous experience aspect. These variables present the balanced entrance level for each task. Only weak correlations were detected between the tasks. This implies that the virtual starting level was different with every task and cannot be associated. This means that every participant had a different initial performance level that was not related to any other initial performance level. For MIS this might mean that the previous experience does not play a role in estimating the future performance. Therefore, a repetition of tasks is needed (not only during the assessment tests) to detect the potential of future surgeons. This resolves in higher costs for the training/test because more time is needed for repeating the tasks.

Furthermore, the correlations for the learning parameters were calculated. The results displayed weak to moderate correlations that spoke against a holistic view. For further research it might be interesting to study why these tasks are not related/correlated. It might be possible that the motivation of the participants and/or the variety of strategies used had an influence and explains these results. In general, the learning variables indicate the rise in each learning curve for different tasks. If there is no correlation detectable, that might indicate that it is not possible to estimate the time needed to learn a task like MIS. It might be that surgeons in training acquire the skills fast. This means that the training will be cheaper. But also the opposite can be true that future surgeons have a talent for MIS but acquiring those skills takes a longer training time and therefore results in higher costs. Based on the results it can be stated that repetition of task is an essential factor, not only for the training later on but also for future ability tests. The perfect level of repetition needs to be found that is high enough but also not too high and exhausting (time and money consuming) to serve as an optimal model that estimates the maximum performance.

The last variables that were studied were the maximum performances. The maximum performance represents the highest level that could be reached in a task. As described above one strong correlation was detected (Drawing/ Origami). It can be said that the maximum performance remains stable and does not change much. Therefore, this variable can be related to the future maximum performance of surgeons. The correlation between those four variables indicates an important aspect. If a person has a talent in one task (Origami) the person also has potential for the other related task (Drawing).

If only the correlation between Drawing and Origami is strong enough to be used later on it is important to consider further developments for this study. Only one strong correlation was found. This means that only two tasks are correlated. It may be possible that other tasks exist that are also related to this task. In this study only four tasks were tested. But more dexterity tasks exist that might show a correlation and therefore support the holistic view.

If there are no other dexterity tasks that are connected to Drawing and Origami, the underlying factors should be analysed in more detail. An exploratory factor analysis might present the amount of underlying factors. This factor analysis could be based on the general performance of the participants. A mean performance could be calculated that shows the average performance of each participant. Then it should be looked into the common aspects to find out what the underlying factor/s between Origami and Drawing might be. It might be possible that mental rotation is one underlying aspect (of a combination of different underlying skills) that might be important in both tasks. For Origami the participants had to rotate the instructions in their mind to build a figure in 3D. Also the Drawing task displays aspects of mental rotation. To follow the line, the reflection in the mirror has to be rotated. Furthermore, it could be tested if a person scores high on both, a mental rotation task and the two dexterity tasks. Other studies also could be used to determine possible underlying factors that might be associated with these tasks.

Previous studies focused more on specific cognitive abilities rather than on tasks that determined MIS skills as holistic. As described in the introduction the results of these studies were ambiguous (Anastakis et al., 2000; Wanzel, Hamstra, Anastakis, & Matsumoto, 2002). But it seems that some factors might account for part of the variance in MIS skills. According to the systematic review by Maan, Maan, & Darzi, (2012) the abilities visual-spatial and psychomotor seem to be suited for the usage of assessing candidates for future surgeons. Moreover, Kramp, Det, Hoff, & Veeger, (2016) suggested also perceptual ability to be an important factor. Also the systematic review by Langlois, Bellemare, & Toulouse, (2015) considered spatial ability to be important for assessing future candidates.

Therefore, it might be possible that these factors are related to the dexterity tasks used in this study. The cognitive aspect spatial-ability describes the capacity of someone to reason, remember and mentally manipulate spatial relations. Mental rotation tests are, for example, used to assess this specific cognitive ability. In a mental rotation test it needs to be decided if an image is a rotated copy of the original image. Mental rotation is also needed for the Drawing task to be able to rotate the reflected image in the mirror to follow the figure in the correct direction.

Furthermore, according to Boakes, (2009); ÇAKMAK, (2009) it seems that Origami tasks are not only related to spatial abilities but Origami instructions are able to improve spatial abilities in students. If spatial ability is connected to Origami and also to MIS skills, this cognitive factor might be the underlying factor in both tasks that partly determines someone's skills for MIS.

In the article by Kaufman, Wiegand, & Tunick, (1987) the psychomotor skill is described as mix out of different components such as manual dexterity, balance and limb speed. Manual dexterity accounts for a part of all dexterity tasks in this study. Especially the Buzz Wire task can be described by this definition. To perform well on this task not only manual dexterity is needed but also balance not to touch the wire, and speed to score high on the performance trial time.

According to Kaufman et al., (1987) spatial perception is a skill that is related to psychomotor skills. This perception skill can be described as an ability to judge the relations between and within objects in space and make statements about their size. This skill also includes someone to be able to manipulate an object mentally and visualize the effects (Kaufman et al., 1987). Almost every task needs to be mentally manipulated. The instructions of the Duncan Loop task need to be transformed to fit in the real situation. The same goes for the Origami instructions. Two dimensional images need to be manipulated to the real three dimensional situations. It follows that all three factors that might account for some variance of MIS skills can also be seen in this study. The dexterity tasks might all include some aspect of these cognitive skills. But it still might be possible that the predictive value of the cognitive abilities as well as the predictive value of the dexterity task is strongly enough related to the real MIS skills.

Maan et al., (2012) indicated that a simulator- based assessment includes the strongest predictive value to determine if someone is suited for MIS surgery. Therefore, another aspect that could be further studied is if the tasks are really related to the performance of MIS. Therefore, laparoscopic simulators could be used that measure the performance. Then these results could be compared to results of the performance of the dexterity tasks. If these results correlate it can be assured that the dexterity tasks are valid and predict the correct skills. This chance might be small because the tasks are not correlated with each other. So if the results suggest that there is no relation between those tasks and the simulator, a simulator-based assessment might be the only option to really assess someone's skills for MIS. This would speak for the possibility that these specific skills can only be predicted by testing the skills themselves.

There are also aspects that should be taken into account that may have jeopardized the results of this study. The tasks and instructions were very specific. It might be possible that the performance measurements are influenced by the instructions themselves. It might be possible that the instructions were not clear enough or too difficult/easy/specific for the participant. Furthermore, different types of persons have different preferences for the kind of instructions. According to Jonassen & Grabowski, (2012) individuals are different in processing new information and applying it. This leads to different kinds of preferences for different kinds of instructions. This also means that the result and outcome of a task depends on the kind of instructions (Jonassen & Grabowski, 2012). It might be that the kinds of instructions used in the study were not best suited for the participants. Therefore, they performed not as well as they could have and the results present a different aspect than the skills themselves. For example, some participants might develop skills more quickly if they can read the instructions rather than follow an instructional figure (Duncan Loop, Origami).

Moreover, it can be seen that the confidence intervals are relatively wide. This might be because this study included a lot of noise because of little control over the experiment itself. Some aspects could not be controlled during the task. Although an observational scheme was used and an instructional handbook was established there was still variance between the participants. Some participants needed extra help or were not motivated to fulfil the tasks and therefore completed them superficially. All these aspects influenced the results of the tasks and should be kept in mind for further analyses and usage of these results.

6 Conclusion

In conclusion it can be seen that it is only partly possible to predict the ability of a person to learn complex motor procedures by letting them perform dexterity tasks. It can be seen that the maximum performance of two tasks seemed to be associated. If a person has a talent in Drawing the person will also score high on the Origami task. It should be worked on these results in more detail to examine if there are other tasks connected, or any specific underlying factors that might determine those tasks. Furthermore, it is important to have a general look at the association with the real MIS skills with a simulator-based assessment. It should be always kept in mind that a possible future assessment test is valid and reliable to pick only those candidates that are suited for MIS. Otherwise the consequences might be fatal and people might die because of surgeons not being able to perform MIS correctly. If it is not possible to detect any relation, it could be possible that MIS skills are only predictable by MIS skills themselves.

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8 Appendix

8.1 Appendix A: Rulebook/ Instruction

GENERAL QUESTIONS:

General Question (at the begin of the study):
Age:
Gender:
Nationality:
Study/Profession:
Ben je links- of rechtshandig of wisselt dit? (denk aan: schrijven, knippen, snijden, gooien)
Are you left- or righthanded or does that change? (think about: writing, using sciccors, cutting, throwing)
Bist du Links- oder Rechtshänder oder wechselt? (denke an: schreiben, schneiden, werfen)
Hoe vind jij het om met je handen te werken? (denk aan knutselen/ reperaties)
How do you feel about working with your hands? (think about crafts/repairs)
Wie findest du es mit den handwerklich zu arbeiten/ handarbeiten? (basteln/ etwas reparieren)
Beleef je frustratie momenten als jij met je handen werk?
Do you get easily frustrated while working with your hands?
Bist du schnell frustriert wenn du Handarbeiten machst?

Experience Question (directly after task):
Heb je ervaring met (afgelopen taak)? Geef eventueel voorbeelden
Do you have previous experience with (this task)? If needed, give examples
Hast du schon vorher Erfahrungen gesammelt die mit dieser Aufgabe zusammenhängen?

Questions at end of the test (pay attention to the order of the tasks the participant got during the study):
Welke taken vond je leuk? Welke taken vond je moeilijk?
Which task did you like? Which tasks were hard?
Welche Aufgabe hast du als schwierigste empfunden?

Ask about the performance (this question should be answered after every task).
How would you estimate your performance at the beginning? (on a scale from 1-7, 7 is good performance, 1 is bad performance)
Final performance

ORIGAMI (instructor)

Needed:

- 25 origami papers (special papers for our research) / 5 extra if somethings go wrong
- Pieces of tape
- Printed instruction
- Printed picture instruction of fox figure
- stopwatch

Order of events:

Introduction to task:

- Tape the picture instruction to the table in front of the participant so that the participant is not able to turn the paper
- Give a short introduction to the tasks and what needs to be accomplished
- Hand the material out to the participant
- Explain the procedure/ let the participant read the instruction
- Ask for any ambiguities or problems about the procedure
- Answer question

During task:

- Ask the participant if he is ready to start
- Then start the time
- Fill in the form during the task (see instructions for origami form)
- If the participant notifies you that he/she is finished stop the time and note it down in the form
- Start again
- Let the participant know after 10 trials the half is finished
- Let the participant know when the last 3 trials start
- Repeat this till the participant reached 20 trials

After tasks:

- Ask the participant if he had any previous experience with origami -> note the answer down in the form
- Give the participant a short break of 5 minutes till the next tasks is started

Origami form:

Performance:

- Does the fox look alike the original V/X

Strategy:

- Participant follows every step of the instructions/ participant does not look at instructions any longer
- Changes steps/ leaves steps out

Motivation:

- Motivated: M
- Frustrated: F
- Not clear: O

Comments from researcher:

- Were any questions answered
- Received the participant extra help/support

Others:

- Was there anything extra that was notified that does not fit in the other categories

Instructions for Participant

ORIGAMI
Take a piece of paper and follow the steps of the instructions below to build the fox. Try to make the fox look like the fox in the instruction, however you must do this as fast as possible. When you are ready the clock will start. And when you finish, announce this to the researcher so the time can be stopped. You are going to make 20 foxes. If you have any questions you can direct these to the examiner.

MIRROR DRAWING (instructor)

Needed:

- Mirror
- Box
- Pen
- Stopwatch
- Printed instruction
- Printed shape

Order of events:

Introduction to task:

- Tape the picture instruction to the table in front of the participant so that the participant is not able to turn the paper
- Put the mirror in position
- Give a short introduction to the tasks and what needs to be accomplished
- Hand the material out to the participant
- Explain the procedure/ let the participant read the instruction
- Ask for any ambiguities or problems about the procedure
- Answer questions

During task:

- Ask the participant if he is ready to start
- Then start the time
- Fill in the form during the task (see instructions for mirror drawing form)
- If the participant notifies you that he/she is finished stop the time and note it down in the form
- Start again
- Let the participant know after 10 trials the half is finished
- Let the participant know when the last 3 trials start
- Repeat this till the participant has reached 20 trials

After tasks:

- Ask the participant if he had any previous experience with drawing through a mirror -> note the answer down in the form
- Give the participant a short break of 5 minutes till the next tasks starts

Mirror Drawing form:

Performance:

- Did the participant draw between the lines? V/X

Strategy:

- Participant follows every step of the instructions
- Changes steps/ leaves steps out

  - Participant starts at a different point.

Motivation:
  - Motivated: M
  - Frustrated: F
  - Not clear: O

Comments from researcher:
  - Were any questions answered
  - Did the participant receive extra help/support?

Others:
  - Was there anything extra that was notified that does not fit in the other categories

Instructions for Participant

MIRROR DRAWING

In this experiment you will be tracing a shape, but instead of looking at your hands, you are going to look in a mirror. Try to stay in between the lines and to finish as fast as possible. You must start at the same point every time. If you have any questions you can direct these to the examiner.

DUNCAN LOOP (instructor)

Needed:
- Rope
- Stopwatch
- Printed instruction

Order of events:

Introduction to task:
- Tape the picture instruction to the table in front of the participant so that the participant is not able to turn the paper
- Attach the rope to something
- Give a short introduction to the tasks and what needs to be accomplished
- Hand the material out to the participant
- Explain the procedure/ let the participant read the instruction
- Ask for any ambiguities or problems about the procedure
- Answer questions

During task:
- Ask the participant if he is ready to start
- Then start the time
- Fill in the form during the task (see instructions for mirror drawing form)
- If the participant notifies you that he/she is finished stop the time and note it down in the form
- Start again
- Let the participant know after 10 trials the half is finished
- Let the participant know when the last 3 trials start
- Repeat this till the participant has reached 20 trials

After tasks:

- Ask the participant if he had any previous experience with knotting (scouting/sailing etc.) -> note the answer down in the form
- Give the participant a short break of 5 minutes till the next tasks starts

Duncan Loop form:

Performance:

  - Is the knot correct? V/X

Strategy:

  - Participant follows every step of the instructions
  - Changes steps/ leaves steps out
  - Participant starts at a different point.
  - Holds the rope in a different way

Motivation:

  - Motivated: M
  - Frustrated: F
  - Not clear: O

Comments from researcher:

  - Were any questions answered
  - Did the participant receive extra help/support?

Others:

  - Was there anything extra that was notified that does not fit in the other categories

Instructions for Participant

DUNCAN LOOP

Take the rope and try to replicate the knot shown on the paper. Make sure you follow the instruction and do this as fast as possible. When you are ready the clock will start. And when you finish, announce this to the researcher so the time can be stopped. You are going to make this knot 10 times. If you have any questions you can direct these to the examiner.

BUZZ WIRE (instructor)

Needed:

- Buzz Wire
- Stopwatch
- Pen

Order of events

- Determine position of the Buzz Wire
- Give a short introduction, make clear that time on task and performance are measured
- Ask for problems and answer questions

During task

- Ask the participant if he/she is ready
- If he/she agrees, the researcher answers ‘start’
- Researcher fill the form during the task (note change in strategies), monitor behaviour
- If the participant says “stop”, researcher writes down time needed to accomplish the task
- Let participant repeat the task
- Inform participant after 10 trials are completed
- Let the participant know when only 3 trials are left
- In total 20 trials needed to be completed by the participant

After tasks are completed

- Do you have previous experience with the Buzz Wire task? (when was the last time you performed this task)

Buzz Wire Form

Performance:

  - Count errors

Strategy:

  - Changes in holding position
  - Changes in holding the wire
  - Changes in mental techniques? (closing eyes before experiment?)

Motivation:

  - Motivated: M
  - Frustrated: F
  - Not clear: O

Comments from researcher:

  - Were any questions answered
  - Did the participant receive extra help/support?

Others:

  - Was there anything extra that was notified that does not fit in the other categories

Instructions for Participant

BUZZ WIRE

In this experiment you will completing a Buzz Wire task (bibber spiraal/heisser Draht). Take the staff and try to follow the wire as fast as possible. Time on task and errors will be measured.

8.2 Appendix B: Observation scheme

Participant number: Researcher:

Task:

Trial number	Time	Errors	Coding	Comments
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				
16				
17				
18				
19				
20				

8.3 Appendix C: Randomized order of task for participants

Participant	Buzz Wire	Drawing	Knot	Origami
1.00	1	2	3	4
2.00	1	2	4	3
3.00	1	3	2	4
4.00	1	3	4	2
5.00	1	4	2	3
6.00	1	4	3	2
7.00	1	2	3	4
8.00	1	2	4	3
9.00	1	3	2	4
10.00	1	3	4	2
11.00	1	4	2	3
12.00	1	4	3	2
13.00	1	2	3	4
14.00	1	2	4	3
15.00	1	3	2	4
16.00	1	3	4	2
17.00	1	4	2	3
18.00	1	4	3	2
19.00	1	2	3	4
20.00	1	2	4	3
	Knot	Origami	Drawing	Buzz Wire
21.00	1	2	3	4
22.00	1	2	4	3
23.00	1	3	2	4
24.00	1	3	4	2
25.00	1	4	2	3
26.00	1	4	3	2
27.00	1	2	3	4
28.00	1	2	4	3
29.00	1	3	2	4

30.00	1	3	4	2
31.00	1	4	2	3
32.00	1	4	3	2
33.00	1	2	3	4
34.00	1	2	4	3
35.00	1	3	2	4
36.00	1	3	4	2
37.00	1	4	2	3
38.00	1	4	3	2
39.00	1	2	3	4
40.00	1	2	4	3
	Drawing	Buzz Wire	Origami	Knot
41.00	1	2	3	4
42.00	1	2	4	3
43.00	1	3	2	4
44.00	1	3	4	2
45.00	1	4	2	3
46.00	1	4	3	2
47.00	1	2	3	4
48.00	1	2	4	3
49.00	1	3	2	4
50.00	1	3	4	2
51.00	1	4	2	3
52.00	1	4	3	2
53.00	1	2	3	4
54.00	1	2	4	3
55.00	1	3	2	4
56.00	1	3	4	2
57.00	1	4	2	3
58.00	1	4	3	2
59.00	1	2	3	4

60.00	1	2	4	3
	Origami	Knot	Buzz Wire	Drawig
61.00	1	2	3	4

62.00	1	2	4	3
63.00	1	3	2	4
64.00	1	3	4	2
65.00	1	4	2	3
66.00	1	4	3	2
67.00	1	2	3	4
68.00	1	2	4	3
69.00	1	3	2	4
70.00	1	3	4	2
71.00	1	4	2	3
72.00	1	4	3	2
73.00	1	2	3	4
74.00	1	2	4	3
75.00	1	3	2	4
76.00	1	3	4	2
77.00	1	4	2	3
78.00	1	4	3	2
79.00	1	2	3	4
80.00	1	2	4	3

8.4 Appendix D: Informed consent

Informed Consent

Approval for Scientific Research

I declare that I was completely informed about the nature and the method of this study. I understand that the purpose of this study is to research the learning performance of motoric abilities using several dexterity tasks. The experiment takes 120 minutes and my performance will be measured (needed time to accomplish a dexterity task and performance errors).

The following issues are clearly explained to me:

- In case that research results will be used in scientific publications, this will be completely anonymous.
- My demographic data will not be viewed by third parties without my explicit approval.
- I agree to voluntarily take part in this study. I am aware that I can stop at any time with this research without giving a valid reason. I can withdraw my participation 24 hours after the examination. In this case, all collected data will be destroyed.
- I have right to receive results at the end of the experimental analysis.

Filing a complaint regarding this research, can be done by contacting the Secretary of the Ethics Committee of the Faculty of Behavioural Sciences of the University of Twente (telephone: 053-4893611, email: j.n.verenjans-vanderweerd@utwente.nl PO Box 217, 7500 AE Enschede).

If I want to have more information regarding this research, I can contact Verena Kaschub (telephone: 004915739624240; email: v.l.kaschub@student.utwente.nl).

Date:

First name and Surname (participant): ___________________________

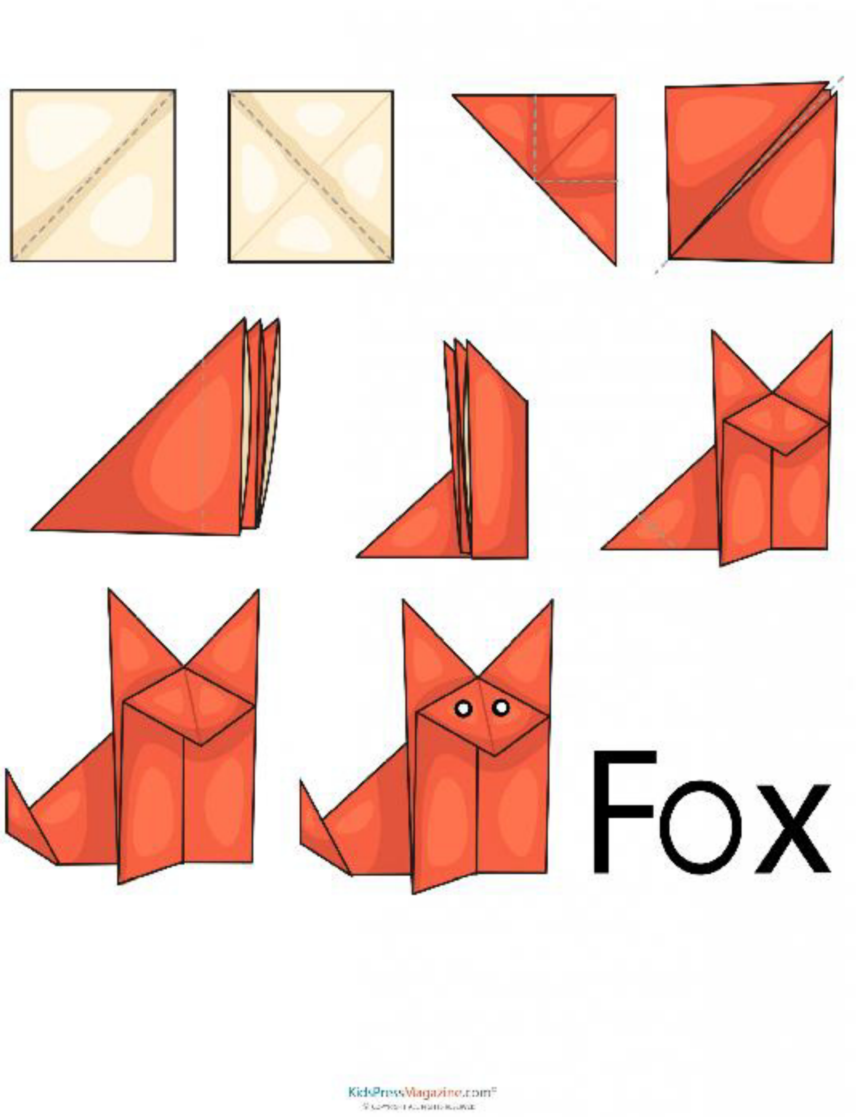
Signature:_____________________

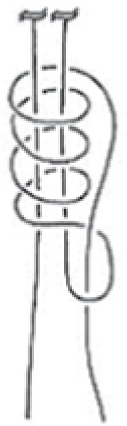
Date:

First name and Surname (researcher): Verena Kaschub

Signature:_____________________

8.5 Appendix E: Instruction (Origami Duncan Loop) / Drawing figure





Duncan
loop

8.6 Appendix F: SPSS syntax of analysis

```
DATASET ACTIVATE DataSet3.
BOOTSTRAP
  /SAMPLING METHOD=SIMPLE
  /VARIABLES INPUT=Buzz_Wire Drawing Duncan_Loop Origami
  /CRITERIA CILEVEL=95 CITYPE=PERCENTILE  NSAMPLES=1000
  /MISSING USERMISSING=EXCLUDE.
CORRELATIONS
  /VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.

BOOTSTRAP
  /SAMPLING METHOD=SIMPLE
  /VARIABLES INPUT=Buzz_Wire Drawing Duncan_Loop Origami
  /CRITERIA CILEVEL=95 CITYPE=PERCENTILE  NSAMPLES=1000
  /MISSING USERMISSING=EXCLUDE.
DESCRIPTIVES VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /STATISTICS=MEAN STDDEV MIN MAX.

EXAMINE VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /COMPARE VARIABLE
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL
  /MISSING=LISTWISE.

BOOTSTRAP
  /SAMPLING METHOD=SIMPLE
  /VARIABLES INPUT=Buzz_Wire Drawing Duncan_Loop Origami
  /CRITERIA CILEVEL=95 CITYPE=PERCENTILE  NSAMPLES=1000
  /MISSING USERMISSING=EXCLUDE.
CORRELATIONS
  /VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /PRINT=TWOTAIL NOSIG
```

```
  /MISSING=PAIRWISE.

BOOTSTRAP
  /SAMPLING METHOD=SIMPLE
  /VARIABLES INPUT=Buzz_Wire Drawing Duncan_Loop Origami
  /CRITERIA CILEVEL=95 CITYPE=PERCENTILE  NSAMPLES=1000
  /MISSING USERMISSING=EXCLUDE.
DESCRIPTIVES VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /STATISTICS=MEAN STDDEV MIN MAX.

EXAMINE VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /COMPARE VARIABLE
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL
  /MISSING=LISTWISE.

DATASET ACTIVATE DataSet1.
BOOTSTRAP
  /SAMPLING METHOD=SIMPLE
  /VARIABLES INPUT=Buzz_Wire Drawing Duncan_Loop Origami
  /CRITERIA CILEVEL=95 CITYPE=PERCENTILE  NSAMPLES=1000
  /MISSING USERMISSING=EXCLUDE.
CORRELATIONS
  /VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /PRINT=TWOTAIL NOSIG
  /MISSING=PAIRWISE.

BOOTSTRAP
  /SAMPLING METHOD=SIMPLE
  /VARIABLES INPUT=Buzz_Wire Drawing Duncan_Loop Origami
  /CRITERIA CILEVEL=95 CITYPE=PERCENTILE  NSAMPLES=1000
  /MISSING USERMISSING=EXCLUDE.
DESCRIPTIVES VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /STATISTICS=MEAN STDDEV MIN MAX.

EXAMINE VARIABLES=Buzz_Wire Drawing Duncan_Loop Origami
  /COMPARE VARIABLE
  /PLOT=BOXPLOT
  /STATISTICS=NONE
  /NOTOTAL
  /MISSING=LISTWISE.

* Diagrammerstellung.
GGRAPH
  /GRAPHDATASET NAME="graphdataset" VARIABLES=Origami Drawing
MISSING=LISTWISE REPORTMISSING=NO
  /GRAPHSPEC SOURCE=INLINE.
BEGIN GPL
  SOURCE: s=userSource(id("graphdataset"))
  DATA: Origami=col(source(s), name("Origami"))
```

```
  DATA: Drawing=col(source(s), name("Drawing"))
  GUIDE: axis(dim(1), label("Origami"))
  GUIDE: axis(dim(2), label("Drawing"))
  ELEMENT: point(position(Origami*Drawing))
END GPL.
```

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