Effect of dominant vs non-dominant hand on eye-hand coordination tracing exercise improvement in 17 year olds.

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Research Question

How does using the dominant hand compared to the non-dominant hand affect 17 year olds' time taken to complete an eye-hand coordination tracing exercise over 5 trials ?

Background information

The aim of this study is to find out if the use of our dominant hand or non-dominant hand has any effect on the improvement seen through an eye-hand coordination tracing exercise. Test subjects will be required to complete the star pattern tracing exercise 5 times with each hand (10 times in total) while looking in a mirror. The mirror reflects what is drawn backwards, tricking the brain into thinking the hand has to go the opposite direction to follow the pattern when it should not. I will be looking at their improvement in the time taken to complete the exercise over these 5 trials.

Memory is the process by which experiences and knowledge are encoded, stored and retrieved. The left hand is related to the brain's right hemisphere - which deals with emotions and intuition - while right hand is connected to the left hemisphere, dealing with intellectual skills. Though genetics seem to be the main determinant of handedness[12], not all scientists agree, some claiming that measures of behaviour and anatomy are the main determinant. The asymmetry of our brain reflects our handedness.[13] Whilst handedness affects the precision of hand movement, it has no impact on the capacity to foresee its consequences. This has been demonstrated by an investigation using two eye-hand coordination tasks to determine the effect of handedness on motor control.[6] However, according to a bimanual coordination research, there was a bigger improvement seen by the non-dominant hand in right-handers while no significant effect was seen in left-handers[4]. It has also been proven that left-handed children had more chances of having a developmental coordination disorder compared to the general population.[1]

The different parts of the brain involved for eye-hand coordination include the hippocampus where episodic memories are made and stored to be used later. It connects senses to memories. It also includes the cerebellum which deals with the coordination and regulation of movement. Additionally, the eyes themselves, the spinal cord, the cerebral cortex and the peripheral nervous system are also all required in order for eye-hand coordination to occur.[11] It is a very complex mechanism. Short term memory is where a sensation is stored right after experiencing it. It will only remain there for about 30 seconds. Important information is shifted to long term memory as it keeps being repeated. Long term memory can store information without limit.[7, 9]

In terms of improvement, the learning curve theory states that the more a task is practiced, the less time and effort will be required to complete it.[5]

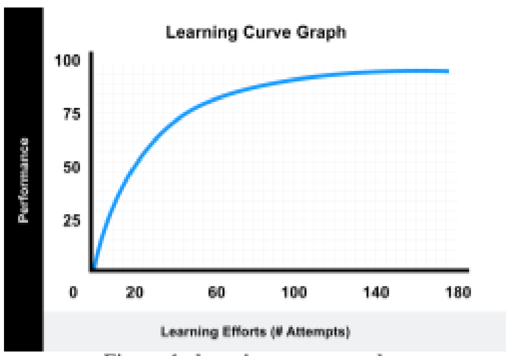


Figure 1 - learning curve graph

This experiment relates to Option A - neurobiology - (visual processing) in the biology higher level course syllabus. It is about cognitive and biological psychology as it covers both learning and memory.

I will be using the t-test method and standard deviation to look at the significance of the differences between dominant and non-dominant hands.

Personal engagement

I am very interested in the biology of humans and am very keen on understanding the way we function, especially our brain. I remembered doing exercises called Brain Gym as a child in order to improve my coordination as I would struggle with it. This sparked the idea of conducting an experiment with a coordination exercise which I later decided to do on eye-to-hand coordination. The idea of looking for the effect of dominant and non-dominant hand on improvement in coordination came from trying to write my name and other simple words with my non-dominant hand in an art class a few years back. I remembered struggling a lot to complete the task and thought it would be interesting to look at the difference in improvement depending on which hand we use. I had also recently heard about being able to improve our non-dominant hand's coordination by doing simple tasks with it such as brushing your teeth. This made me want to investigate how much practice is needed in order to start seeing improvement in coordination. This study was adapted from procedures previously published for a highschool experiment which I made more specific. As this option in the syllabus was not chosen by our teacher, I had to learn this section by myself in order to have the appropriate knowledge to conduct this study and evaluate the data.

Variables

<u>Independent variable:</u> Use of dominant and non-dominant hand to complete the exercise.
<u>Dependent variable:</u> Improvement over 5 trials per hand. Improvement will be the change in time taken in seconds to complete the exercise.

<u>Control variables:</u>

Controlled variable	**How**	**Why**
Age	Will only test 17 year old students. A consent form needs to be signed.	Age might affect the time of improvement.
Coffee or not	No caffeine. Will be asking and making sure people did not drink coffee in the last 3 hours.	Caffeine can lead to shaking and may affect mental performance, hence affecting the coordination process.
Environment	Laboratory classroom, sitting down with no music, only background noises from the class.	Music could be a distraction for the test subjects and having different environments with different kinds of sounds could affect the test subjects' concentration, hence affecting the results.
Distance of mirror from test subject (cm)	Placed 40cm away from the person with the help of a ruler and a stand.	If the mirror is too far away, it will be harder to see the paper's reflection in it, increasing the difficulty of the exercise and vice-versa.
Time between each trial (s)	60 seconds of break will be allowed between each trial. This will be measured with the stop-watch.	If the break times between trials varies, the results might be affected due to inconsistency.
Red ink	Red inked pen will be provided to the test subjects.	Red is a vibrant colour, making it easier for the test subjects to see what they are drawing on the piece of paper through the mirror. Using another colour could affect the results as they might not be as visible, increasing the difficulty of the exercise.

Precision/accuracy of the tracing	Line traced must go through each single circle of the shape to make sure everyone has similar accuracy.	If the accuracy of the tracing is not the same for everyone, some might not care about the precision and trace the shape much faster than others who will try their best to be precise.
Order of hand used for the exercise	The dominant hand will always be used to complete the first 5 trials, followed by the non-dominant hand.	The first hand could provide enough practice to the brain for the second hand to have less of a hard time completing the exercise. Controlling it will allow any potential effect to the second hand to be easily identified.

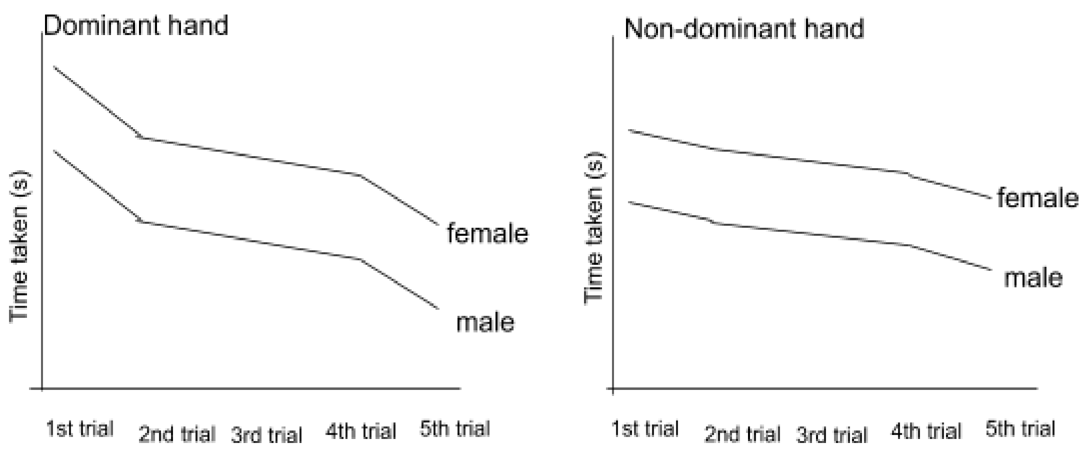
Uncontrolled variables

- Emotional and physical state of the subjects: Factors like the subject's tiredness, digestion and emotional state could all have a negative impact on their concentration, affecting their performance on the tracing exercise.
- Which hand is dominant (left-handed or right-handed): It might have an impact on the results as there could be a difference in learning and improvement depending on people's dominant hand. I will note the test subjects' dominant hand and check for any significant difference between right-handed and left-handed people.
- Sex of test subjects: It may affect the results as there could be a difference in improvement between the two sexes. I will take note of the test subjects' sexes and will be checking for any differences between the two.

Hypothesis

There will be more improvement seen on the dominant hand than the non-dominant. This is because our non-dominant hand is less solicited than our dominant and will hence be less efficient in learning fast.

Sketch diagrams for hypothesis - *figure 2*:



Null hypothesis

There will be no difference in improvement between using the dominant hand and the non-dominant hand.

Apparatus

- Mirror
- Sticky tape
- Stop-watch ±0.005s (±0.205s if human uncertainty of reaction time to press the stopwatch of ±0.200s (average reaction time to press stopwatch) is taken into account)
- Metal clamp stand
- Metre ruler ±0.5mm (smallest unit of mm, uncertainty is therefore half of a mm)
- Piece of tissue paper
- Red ink pen
- Pieces of paper (half an A4 sheet x 10) with the coordination exercise printed on each (for one person)
- Consent form

Diagram of experiment set-up

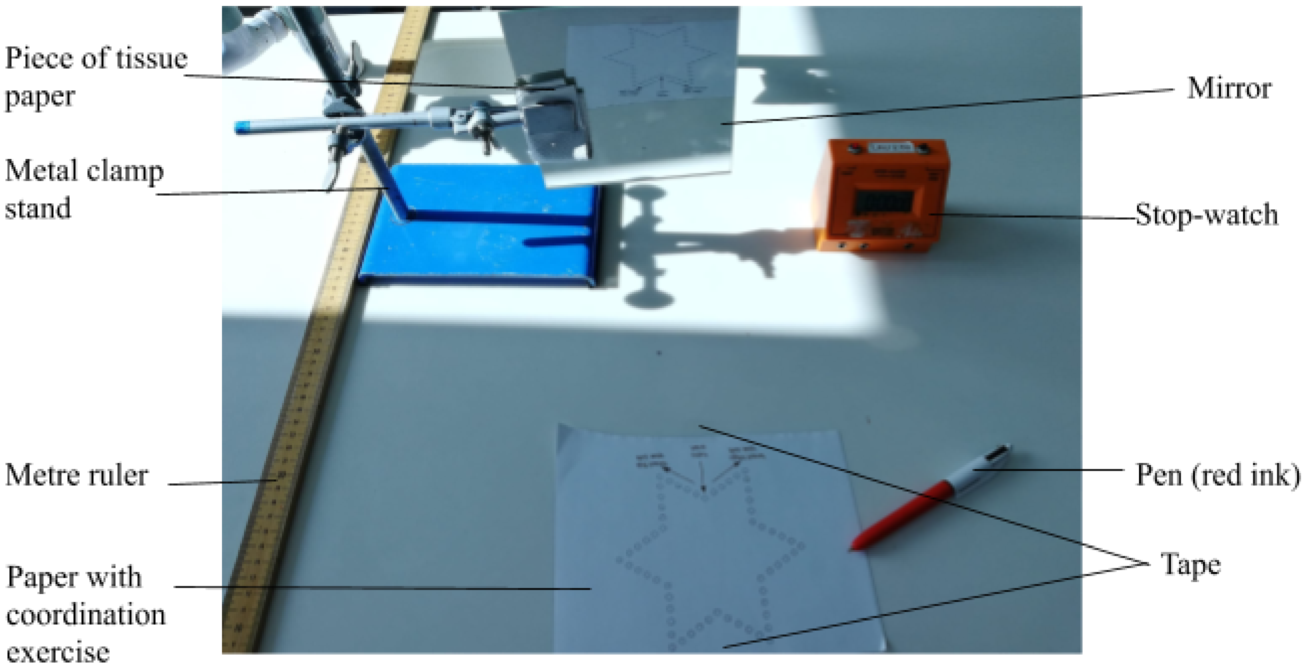
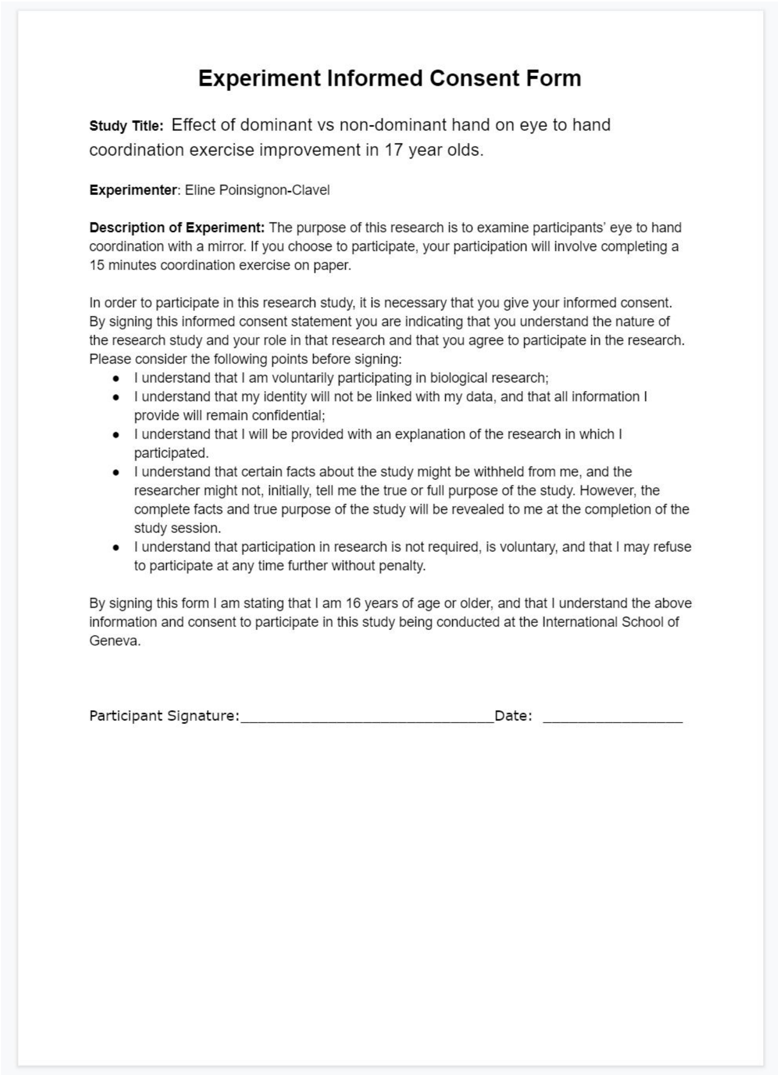


Figure 3 - apparatus diagram

Consent form - *figure 4*:



Experiment Informed Consent Form

Study Title: Effect of dominant vs non-dominant hand on eye to hand coordination exercise improvement in 17 year olds.

Experimenter: Eline Poinsignon-Clavel

Description of Experiment: The purpose of this research is to examine participants' eye to hand coordination with a mirror. If you choose to participate, your participation will involve completing a 15 minutes coordination exercise on paper.

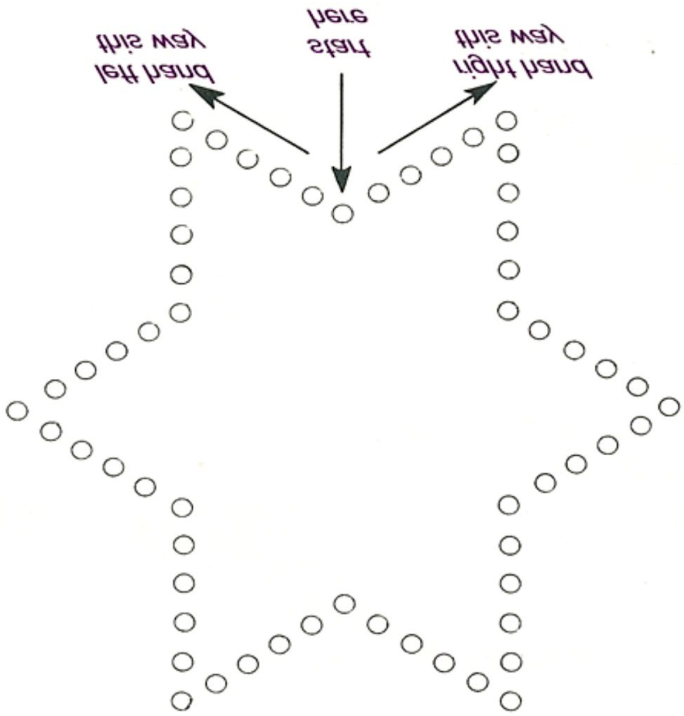
In order to participate in this research study, it is necessary that you give your informed consent. By signing this informed consent statement you are indicating that you understand the nature of the research study and your role in that research and that you agree to participate in the research. Please consider the following points before signing:

- I understand that I am voluntarily participating in biological research;
- I understand that my identity will not be linked with my data, and that all information I provide will remain confidential;
- I understand that I will be provided with an explanation of the research in which I participated.
- I understand that certain facts about the study might be withheld from me, and the researcher might not, initially, tell me the true or full purpose of the study. However, the complete facts and true purpose of the study will be revealed to me at the completion of the study session.
- I understand that participation in research is not required, is voluntary, and that I may refuse to participate at any time further without penalty.

By signing this form I am stating that I am 16 years of age or older, and that I understand the above information and consent to participate in this study being conducted at the International School of Geneva.

Participant Signature:______________________________Date: ________________

Coordination exercise - *figure 5*:



Methodology

Pilot study:

Before starting to collect data for this study, I decided to conduct a pilot study in order to make sure everything was in order and to check if eventual changes needed to be made. This helped me realise I had to change the methodology I had originally made.

The break time between each trial was changed from 5 minutes to 1 minute as there seemed to be no need for such a long break in between each trial and made the experiment an hour long. This was too long for most people to complete and was not necessary to the experiment, so I decided to reduce its length to 1 minute to make the experiment more accessible for test subjects (only about 25 minutes).

The number of metal clamp stands needed decreased from 2 to 1 as there was no need for a second clamp stand. It would also take too much space which was not necessary.

1. Place the metal clamp stand 40cm away from the edge of the table with the help of a metre ruler. Make sure that the edge of the mirror is exactly at 40cm instead of the edge of the clamp stand.
2. Use adhesive tape to secure the piece of paper with the exercise onto the table so that it is at a comfortable place for the test subject to draw on. Ask the test subject if it is correctly placed. This is to make sure the piece of paper does not move while the exercise is being carried on.
3. Take a piece of tissue paper and fold it several times to place it around the side of the mirror where it will be held by the clamp. This is to make sure the mirror will be properly held as it creates friction and will prevent the mirror from slipping off from the clamp.
4. Place the mirror vertically with the piece of tissue paper in the clamp stand and tighten the clamp as much as possible while making sure the mirror is being held straight.
5. Orientate the mirror accordingly so that it shows the full piece of paper stuck onto the table from a sitting position. Ask the test subject if they can fully see the exercise paper.
6. Prepare the stop-watch so it can accurately measure the time taken by the test subject for each trial.
7. Start the exercise with the dominant hand and follow the instructions on the exercise paper (figure 3: place the pen point on the “start here” circle; if right-handed, start by going to the right; if left-handed, start by going to the left). The test subject must only look through the mirror and cannot look directly at the paper. Only a red ink pen can be used to trace the shape. It is important that the test subject goes through each circle of the shape, however messy the line may be, in order to have the same amount of accuracy for everyone.
8. When the test subject is ready, the observer will start the stop-watch and stop it once the test subject has completed the outline. Note the time taken down into the data table
9. The paper is then replaced with a new, empty one and the subject will repeat the trial with the same hand. Step 8 is repeated for all 5 trials of this hand.
10. Once the 5 trials have been completed, repeat from step 7 with the non-dominant hand.

Safety and ethical issues

This experiment does not require any dangerous chemicals or instrument and will not have any negative effect on the test subjects. It is however, not environmentally friendly as the exercise paper had to be printed for every single trial. A lot of paper was therefore used for this investigation. I tried solving this problem by printing two exercises per paper to minimise the number of pages needed.

Test subjects are required to fill in a consent form in order to give their permission for their results to be used for this assessment and make sure they are fully aware of what will be expected of them during the experiment.

Raw data sample (for dominant hand)

	Time taken with dominant hand (sec)				
Sex	Trial 1	Trial 2	Trial 3	Trial 4	Trial 5
female	88.78	65.34	60.54	50.47	52.56
female	139.63	71.23	84.32	70.66	62.23
female	51.53	38.65	36.24	31.97	24.74
female	59.92	40.78	35.31	36.62	33.83
female	37.39	36.38	31.87	28.12	28.85
female	91.42	67.29	44.72	44.35	38.59
female	150.46	94.73	87.34	87.38	73.17
female	41.17	32.91	29.06	26.01	23.31
female	53.25	45.35	39.41	34.83	31.30
female LH	79.12	65.33	51.63	61.56	48.81
female	68.23	52.85	43.54	39.78	35.65
female	73.45	57.77	44.92	37.71	30.62
average	77.86	55.72	49.08	45.79	40.31
SD	35.813	18.116	19.201	18.638	15.629
male LH	101.63	77.23	84.35	44.24	36.26
male LH	109.83	65.53	53.81	54.41	53.83
male	93.38	85.84	73.85	62.94	52.64
male LH	81.09	122.12	84.32	67.03	65.38
male	115.26	80.43	49.65	43.16	31.84
male	103.45	85.87	68.65	53.93	46.17
male	109.48	67.56	50.99	47.74	52.21
male	95.53	83.47	69.36	56.79	49.38
male	107.67	91.88	78.66	63.46	50.51
male	88.37	75.15	62.82	51.30	39.83
male	91.54	76.45	62.93	57.33	47.42
male	98.56	84.64	77.03	64.93	51.53
average	99.65	83.01	68.04	55.61	48.08
SD	10.098	14.512	12.230	8.012	8.869

Figure 6 - raw data sample

A total of 23 test subjects (11 females, 12 males) were tested. Four were left-handed (3 males, 1 female), and 19 were right-handed (10 females, 9 males). The table shows the raw data for the time taken with dominant hand for males and females along with the averages and standard deviations (SD) for each trial. Some people's time increased to later decrease, still showing improvement but with partial worsening along the way. We can see that the standard deviation for the first trial of females (35.813) is much larger than the one for males (10.098), indicating that this data is less reliable. This is because there was a greater range of data in females than in males. However, the time taken to complete the exercise does not matter in itself as the focus of this study is to look at the difference in improvement, hence the change in time taken over several trials.

Processed data

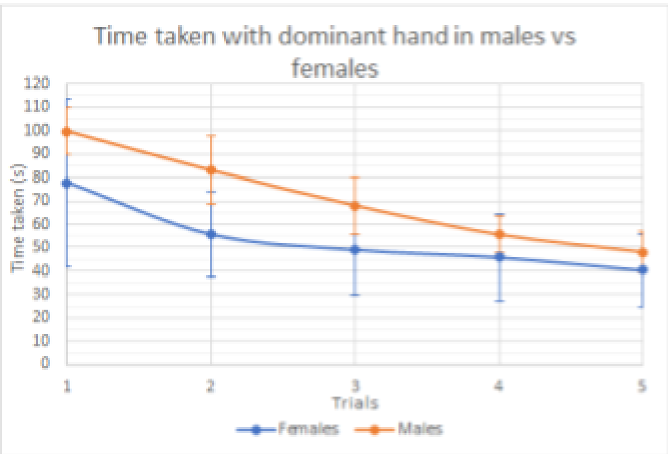


Figure 7 - graph for dominant hand

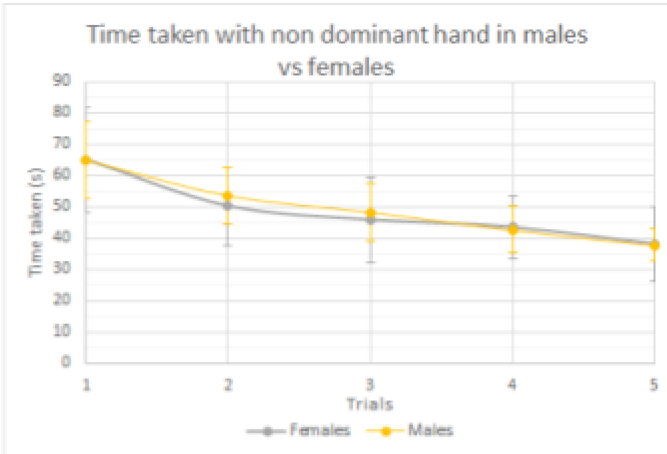


Figure 8 - graph for non-dominant hand

I made two graphs for each hand comparing the data for males and females in order to see if there is a statistical difference between the two sexes. This was to know whether I could mix both sexes in the final graph or keep them separated. Even though non-dominant hand has more similar results between males and females (as shown by the smaller gap compared to dominant hand), the trend for the two sexes is the same for both graphs and the error bars overlap each other for each trial. This means that the two different sexes can be mixed for the final graph as they have very similar trends.

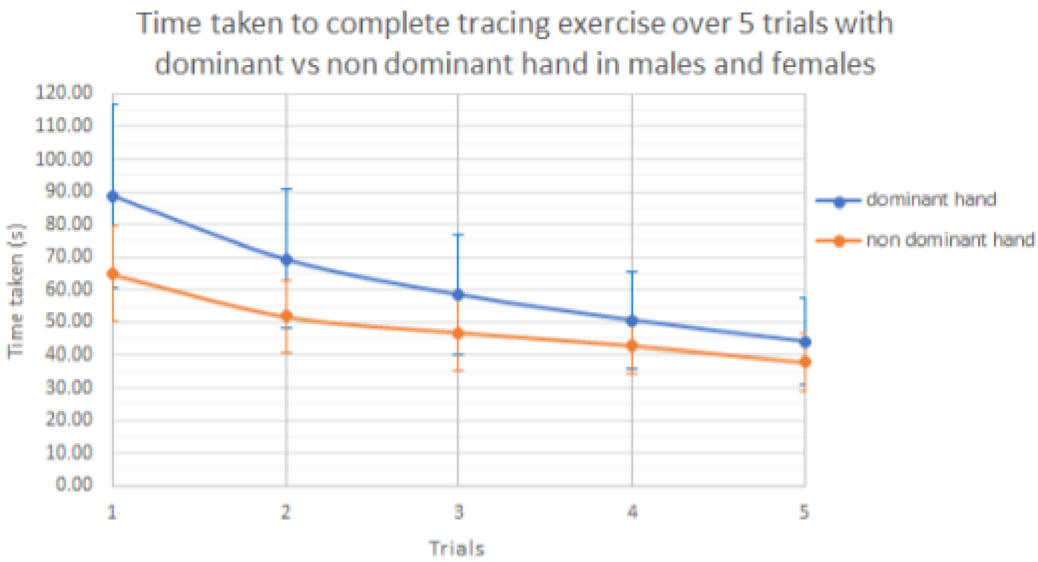


Figure 9 - graph for improvement of dominant vs non-dominant hand

In this final graph, we can see that there was clear improvement over the 5 trials as the time taken to complete the tracing exercise decreases. There is a stronger improvement from the first to second trial than in all other trials as both lines are steeper there. The dominant hand line being above the non-dominant hand's, we can observe that the time taken to complete the exercise with the dominant hand was longer. This could be because the non-dominant hand was always second to the dominant hand, meaning that the brain had already had practice on the exercise and did not need as much time as the initial. However, it does not matter as the goal of this experiment is to look at the improvement overtime and not the time taken. We can see that there was a more pronounced improvement in the dominant hand as the line is steeper than the non-dominant hand. However, some test subjects - which can be considered as outliers - had a more significant improvement with their non-dominant hand as they took more time on their first try with their non-dominant hand. This was observed through inspection of the raw data. We can also observe a slight stagnation of improvement in the non-dominant hand between trial 2 and 4 as the line gets flatter.

The error bars are visibly larger on the dominant hand curve than the non-dominant, the largest being the first trial of the dominant hand. This is because the results were more varied, indicating lower accuracy and unreliability of the results and line of the graph. They also overlap with previous and subsequent error bars, meaning the data is too spread for effective discrimination. The reason for these could be that, the dominant hand being the first hand to try the exercise, people were completely new to it and some people might have gotten used to the exercise at different speeds leading to varying results. For the non-dominant hand, everyone had gotten used to the exercise, leading to less varying results. It could also be because some people were slower or faster than others all throughout the experiment, meaning they were above or below the line through the whole graph.

As the error bars of both lines overlap at every point, it can be stated that my results are not accurate enough. While the trend seems significant, a larger data sample size would hence be required to make this graph more accurate and relevant.

We can conclude that as the person gets more practice (trials), the time taken to complete the exercise decreases (improvement is observed). More improvement was seen with the dominant hand than with the non-dominant hand.

Figure 10 - graph for left-handed subjects

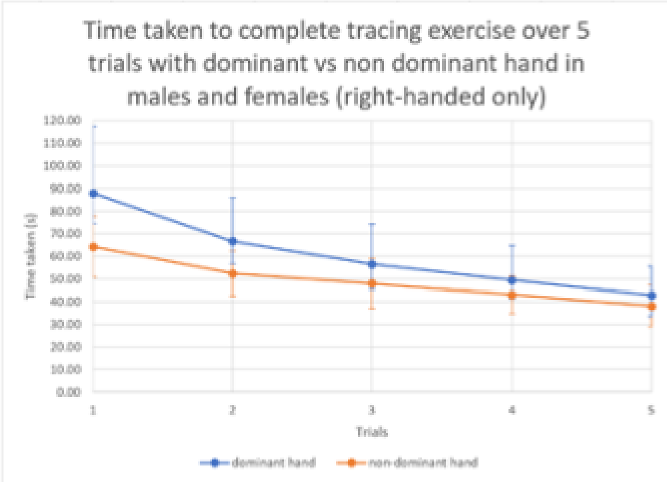


Figure 11 - graph for right-handed subjects

I decided to make a graph for each handedness in order to see if there was a difference in trend between the two. As we can see, both handedness had a bigger improvement on their dominant hand as the difference in the first and last trial is largest. However, left-handed (LH) subjects had a bigger improvement in the time taken between their dominant and non-dominant hands as shown by the larger gap in between both lines, compared to right-handed subjects. Though the trend for both handedness is the same, there is a larger difference between both hands in LH people. This is because LH subjects did not perform as well as right-handed subjects with their dominant hands. We can observe an increase on the fourth trial for LH, showing a slight worsening of a few seconds over this trial. However, this did not prevent the fifth trial to show more improvement from the third trial, also showing overall improvement from the first trial.

Observations during the experiment

- Some people were taking their time at first and became more competitive as they went on through the exercise
- Some people were taking their time, being very precise and making their tracing clean while some were only trying to go as fast as possible
- Some people lifted their pens from the papers, some did not
- Most people were laughing at the first try as it was challenging and confusing. This could have affected their concentration
- Some were very competitive against others doing the exercise at the same time
- Data collecting was extremely time consuming as each person required about 25 minutes to complete the whole experiment.
- LH males seemed faster with their non-dominant hand

Calculations

In order to calculate if the difference between the two hands is statistically significant, I have decided to use the t-test method. This is because it compares the dominant and non-dominant hand and the actual difference between their averages. I used the average of both males and females for each trial for each hand which I already calculated and added to the raw data table. The t test method does not take into account the improvement overtime, but it provides evidence for the difference between the use of dominant and non-dominant hand. I used the website GraphPad[3] to find the t value as well as the degree of freedom: $t = 1.4766$ $df = 8$

According to the critical values for t test table, a degree of freedom of 8 requires a critical value of 2.306[10] for a 5% probability that the data overlaps due to chance (95% confidence). The t value is smaller than that critical value. This is because the data sets overlap too much due to a widespread of data. The null hypothesis can therefore be accepted as there is no significant statistical difference between the two hands.

Conclusion

My aim with this investigation was to research whether the use of the dominant hand, as opposed to the non-dominant hand, had an impact on the improvement of eye-hand coordination.

To my surprise, the use of the non-dominant hand resulted in less time taken to complete the tracing exercise. This could be due to the bigger improvement seen by the non-dominant hand in right-handers discovered in the research on bimanual coordination research mentioned in background information. There was however more improvement observed in the dominant hand for the majority of people. This coincides with my hypothesis. It could nonetheless be due to the fact that the dominant hand was always the first hand performing the exercise, hence being confronted with something completely new which was quickly learned as it is the hand which is most solicited. This relates back to the learning curve theory, therefore explaining why less improvement was observed with the second hand (non-dominant). Additionally, no difference in trend for improvement was observed between males and females.

To answer my research question, using the dominant hand has a positive effect on improvement in eye-hand coordination tracing exercise in 17 year olds; there is more improvement when using the dominant hand over the non-dominant hand.

Evaluation

I conducted a pilot study in order to test my methodology and look for any needed improvements which are listed in the exploration.

The improvement of coordination was measured by looking at the time taken to fulfil the exercise. For this, a timer of two decimal places was used. Using a timer means that human error must also be taken into account as there is a delay between the moment the exercise is completed and the time the timer is stopped due to human reaction time. The timer's accuracy and the human reaction time lead to a certain degree of uncertainty (±0.205s) as explained in the exploration. Instead of investigating improvement by measuring time, I could have measured the accuracy of the lines drawn to research if they became more precise.

Limitation	**Why is it a limitation?**	**How can it be improved?**
Data sample was not big enough	Data is therefore not reliable	Test more people (100 test subjects)
Only one set of data for LH females compared to three for males. Not many LH people overall.	Data for left-handed subjects was representative of the ratio of LH to RH people in the world, but not helpful in having enough data for LH subjects.	Ask for a certain number of LH test subjects (~20 out of 100)
Test subject's personality	Affect accuracy of tracing if they are more conscientious or rather messy and competitive.	Classify them by personality (subjective) and compare them. Could also only test a certain personality.
No rule given on whether pen could be lifted or not	Could have affected results as some did and some did not. Lifting the pen could be less time consuming than having to trace back with the pen on the paper.	Determine whether the pen can be lifted from the paper or not and keep it as a controlled.
Had to trust test subjects to not cheat	I trust the test subjects to not directly look at the paper during the exercise and supervised them, but this does not allow for enough accuracy.	Find materials needed to make a special boy with one side open where its content could only be looked at from the mirror's reflection.

Emotional and physical state of test subjects	Tiredness, digestion and emotional state could all have a negative impact on their concentration, affecting their performance on the tracing exercise.	Make the environment as controlled as possible (location, senses stimuli like sounds or caffeine). Asking all test subjects to come feeling well rested.

Strengths

All test subjects were asked to use a red inked ballpoint pen in order to keep the color constant and make the ink more visible on paper. I made sure the exercise was completed with a similar level of accuracy by every test subject in order to make it as fair as possible as some might spend more time tracing accurately than others. The data was precise enough for this investigation as it does not require a lot of precision in data results since we are comparing the improvement overtime. I also took note of what people's handedness were in case it might have an effect on the investigation.

Further research

In order to further our understanding of the topic, the independent variable could be changed. For example, we could investigate the effect of music by making people always use their dominant hand and making them try the tracing exercise 5 times without music, and again with music. This could be more distracting for some, but it could also help others focus better. Another option could be to look at the difference between using regular and irregular shapes. For example, one would be the same star shape used in this experiment, and the other would be an asymmetrical shape without proper structure. In addition, the effect of handedness could be investigated by comparing left handed and right handed people. Each person would complete the exercise five times with each hand and the difference in time taken could be investigated. Lastly, a group of students could be asked to drink coffee 30 minutes before the experiment while another group does not drink anything else than water 4 hours prior to the experiment. The effect of caffeine on eye-hand coordination could hence be investigated.

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Figure list