Improving Bimanual Coordination through the development of a computer game
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Introduction - Background Research

This photo probably means I’ve been doing piano for about 10 years now and I remember regularly asking my mum the question, “Why did you make me do it?”. My mum, along with my piano teachers, used to always tell me that it was actually good for my brain, and that I should just do it because I’ll regret not playing the piano later on in life when I’m older and it is harder to learn.

When I got older, I learnt that their answers came from studies that have shown music’s influence on the brain. Mum used to also tell me, that using both my hands equally develops both sides of my brain and that it was connected to elevated IQ. When I was younger, I was quite satisfied by the fact that it ‘made me smarter’ but now that we have to do a mandatory year 10 science project, I thought that it would be a good time to investigate the science behind this and to see if non-pianists could receive this benefit too. From personal experience, I know piano can be somewhat tiring and boring in order to obtain the skills you need for quality playing. This has often proved true during 4-hour practice sessions in preparation for my Amus-A.

I wanted to see if the brain development can be achieved another way, using similar skills needed for piano playing. This allows for my friends who didn’t have the opportunity to play piano since they were 6, to also have the chance to receive the extra brain-training that comes from piano.

It has been suggested that the brains of pianists are more developed than that of the average person. This was assumed because of the need of strong independence in both hands, thus working
both the left and right hemispheres of the brain. The brain’s central sulcus, for most people, is deeper on the right or left side and this determines one’s dominant hand. This has also been explained like this: “The expansion of hand motor cortex in the dominant hemisphere may provide extra space for the cortical encoding of a greater motor skill repertoire of the preferred hand” (Volkmann, Schnitzler, Witte, Freund 1998). Scientific research has shown pianists’ central sulcus is better rounded and the brain barely registered a more dominant side, which is very uncommon in non-musicians. Studies suggest the pianist brain also works more efficiently when communicating to the frontal lobe (responsible for integrating information in order to make decisions) therefore allowing them to more easily go through methodical thinking and have the freedom to use their creativity.

There is, of course, the added factor of music greatly contributing to the significant brain development of the pianist. The brain not only has the left and right hemisphere, it is also divided into the analytical brain and the subjective-artistic brain. To maximize its full potential, both halves of the brain must be exercised equally. “Thus, it is theorized that the artistic child optimizes the brain’s bilateralism, which increases his intelligence (Lehr, 1998)”.

Research shows that the left brain analyses the music’s structure and the right brain concentrates on the melody, like we have another language to communicate through. This proves that music does indeed work the brain as a whole, and has a major part in the musician’s brain development. There have been many more studies on music and its influence on the brain’s development, and particularly its definite effect in the classroom.
This investigation however, focuses on the first idea put forward by my mum: the need of strong independence in both hands. The type of movement used to play piano is called ‘Bimanual Coordination’.

There are 3 standard types of arm movement:

1. **Unimanual** movement – Only one of the arms are moving (eg. writing)
2. **Symmetric** bimanual movement – both arms completing the same action (or mirroring each other) simultaneously (eg. hand clapping)
3. **Asymmetric** bimanual movement – both hands completing different tasks simultaneously (eg. playing the piano, tying shoelaces).

Bimanual Coordination involves using both hands simultaneously to perform a task, making the brain control multiple movements at the same time. This type of movement would be assumed to be the factor benefiting to the advancement of brain development in pianists. Personally, it took me until 4th grade to be competent in using both hands without consciously having to control each hand. Pianists are masters of asymmetric bimanual coordination and this would prove to be harder to pull off then symmetric bimanual coordination. Many of our everyday activities require some form of bimanual coordination and research on the topic has increased over the years. Several reasons are stated in *Brain Mapping: An Encyclopedic Reference*:

1. Complex bimanual skills form an entry point for the study of higher cognitive functions in perception and action, even including executive functions such as task switching, multitasking, and inhibition
2. Bimanual tasks are helpful tools to reveal motor developmental trajectories and deficits as a result of various brain disorders (Swinnen, 2002)
3. Such tasks are valuable instruments to study associations between brain structure and behaviour with a prominent role assigned to the corpus callosum (Gooijers & Swinnen, 2014).

Studies related to the brain often connects different activities with different areas of the brain. Studies have not been able to pin-point a specialised area in the brain specifically for Bimanual Coordination. There have been increasing arguments of neural recruitment associated with bimanual movements rather than a specialized brain area, like a “contextually dependent dynamic
scaffold” involving other areas of the brain. It changes depending on various internal and external factors which displays the brain’s ability to adapt and change vii. This text has also mentioned research that “shows correlations with performance on bimanual coordination tasks in young and older adults and in pathological conditions, such as traumatic brain injury and multiple sclerosis”.

This investigation takes this knowledge of proven increase in brain development associated with the asymmetric bimanual coordination practiced by pianists, and its implications even without music. The development of this game creates a user-friendly platform that tests students to ascertain if their left and right hand independence can be improved away from a piano. I wanted to do this so other people won’t be deprived of the benefits for the brain just because they couldn’t afford or access a piano.

My IT teacher had once mentioned his so called ‘improvement’ in typing after he did piano for some time. He assumed there may be some form of skill transfer since they’re both working the hands independently from the other. In this experiment, touch-typists and drummers are therefore also taken into consideration as they regularly perform movements involving asymmetric bimanual coordination. There may be some skill transfer between the activities. There have been other investigations and some have come to the conclusion that there is some transfer of coordination but it is determined by the “abstract directional codes that become part of the memory representation for bimanual coordination” (Temprado & Swinnen, 2005) viii.

The digital game is something every kid can easily learn and access in the modern world so this makes it readily available. It allows for much data to be collected automatically without much hassle by automatically sending it to an online cloud. I tried to find any other game/program that does require the use for 2 computer mice but google only came up with results that talked about different types of computer equipment, connecting 2 mice to a computer, and other related topics but NONE about an actual existing game that requires the use of 2 computer mice. There were some chat forums that talked about the idea of using 2 mice to improve multiplayer games but this wouldn’t require the same person to use both their hands independently. It looks like my game’s the first!

The 3 levels of the game with the bullets going: Left Down and Right.
Method and Materials

PART A – MAKING THE GAME

Equipment Needed:

- A computer
- Two Computer Mice
- Keyboard
- Visual Basic
- Corel PhotoPaint
- A working Internet Connection

1. Brainstorm concept and aim behind the game
   - to improve bimanual coordination
2. Start planning the game layout
   - Similar to *Space Invasions*, two mice represent two shields defending off bullets being shot by spaceships, 3 levels with the same difficulty (bullets going left (set in space), down (city skyline), right (street view))
3. Identify the information needed to be recorded from the game results
   - time the game was played, participations base64 identification code, number of left hand misses, number of right hand misses, order of levels played, score of 3 different levels
4. Find existing programming that allows for 2 computer mice to work simultaneously
5. Collect the images and animations used for the game
   - the background of the 3 levels (space, city skyline, streetview), half the earth, light sabers, spaceships, bullets, mushroom explosion
6. Use Visual Basic (VB) to program the game with “Windows Presentation Framework” as the framework
7. Import images and animations into VB
- If required, using Corel PhotoPaint, edit the image to the required colour before importing by using the “replace colour” tool. In this case we needed blue and yellow shields and bullets to represent the different RH and LH mouse.

8. Program Level 1
- Insert background images; program movement of spaceships; bullets movement and disappearance; shields; mushroom explosion; number of lives; point score system

9. Copy programming for Level 1 three times: for Level 2 and 3, and the practice. Change the images to appropriate images and edit some of the programming to fit the level direction.

10. Create a free account on Sparkfun and set up a cloud where all the data from the game will be sent to automatically when each game is finished.

11. Create the windows that appear before the participants start the game. Window:
   i. Asking for your username (eg. Bob Will’s username will be bobw)
   ii. Explains the concept of the game.
   iii. Asks you to check that you have two computer mice connected to the computer.
   iv. If yes, it will come up with a blue and yellow box representing RH mouse and LH mouse and requires you to check they both work simultaneously.

12. Combine all the different parts of the game together

13. Try the finished product a few times to make sure it all works Upload the game onto the school computer system so that all computers can access the program

PART B – SETTING UP THE GAME

Equipment Needed:
- A computer (model that has been checked to be compatible with the program)
- 2 computer mice
- A keyboard

14. Turn on the computer and Log in
15. Find the program on the school system and start the game
16. Follow the instructions, as explained in Part A.
17. If the two computer mouse proves to work simultaneously, exit the game [Alt F4] and click and drag the program onto the desktop to create a shortcut to the game
18. Log out of the computer and load the game on all the computer models of the like.
19. Leave a spare computer mouse at each computer that is compatible with the program, ready to be used by participants.

PART C – PLAYING THE GAME

Equipment Needed:
- A computer (model that has been checked to be compatible with the program)
• 2 computer mice
• A keyboard

20. Turn on the computer designated for the game
21. Log in using your school account
22. Click on the *Bimanual Invasions* icon on the desktop (represented by a rocket)
23. Enter in your username constructed by your first name and the first letter of your last name (*eg. bobw*). Use the same username each time.
24. Continue to follow the instructions (explained in Part B). If it all works, continue to play the game. If there are any glitches, press [Alt F4] and start again.
25. Play the practice level then wait the countdown to begin the other 3 levels (down/left/right in a random order).
26. After a few attempts, the practice level may be ignored and not attempted
27. Once the last level is completed, and a box saying “Data transmitted successfully”, Press [Enter] or [Alt F4] to exit the program.
28. Leave the computer for the next participant or log out of the computer.

**DATA ANALYSIS**

A table was automatically created in the *Sparkfun* cloud that collected the data in the game (see in Logbook). The data collected was: the participants base64 generated identification code, the order they did the levels including the practice level (*eg. DRLD*), the down (level) score, left score, right score, down left-hand misses, left left-hand misses, right left-hand misses, date it was played, and the timestamp (from International date line).

This information was downloaded as a spreadsheet and from then on, it was worked on and edited in Excel. I added a ‘total score’ column, adding the participants score from all 3 levels, and a ‘total difference in misses’ column (Bimanual Coordination difference – Bi-Co). The cloud only records the left hand misses, but there are 10 lives in the game so the formula to discover the number of right hand misses was:

\[= 10 - \text{(left hand misses)}\]

The ‘total difference in misses’ column records the difference between the misses in the right-hand and left-hand and the formula used was:

\[= 2 \times \text{(left hand misses)} - 10.\]

For massed and distributed practice, I went through the table where I had highlighted all the mass practice attempts. There were 10 participants that had all their attempts spread out (distributed practice). So we also chose 10 participants that had played it consecutively each day for 2/3 days (massed practice). These participants were chosen at random based on the dates of
their attempt and their score not taken in consideration. There were more participants that did massed practice and the final 10 were the ones with lots of data – more attempts. This is where the data points for Experiment 2 come from.

For skill transfer I’m comparing the gradients of the average progress between the 1st-3rd attempt for people in the difference experience levels. This is done by totaling all the scores for everyone in Level 1 piano, for example, then averaging it based on how many participants in that level.

Variables

OF THE GAME:

Independent

- The direction the bullets were going

Dependent

- The game score for each level
- The number of misses from each hand

Controlled

- 10 lives per level
- 3 levels per game
- Randomised order of the 3 directions (down/left/right)
- 2 mice required for each level

OF THE PARTICIPANT

Independent

- Participants that are male and female
- Participants that are left or right handed
- Participants that played it x-number of times
- Participants that played it distributed (spread out) or massed in a time frame.
- Participants that are at different level of experience as a pianist
- Participants that are at different level of experience as a drummer
- Participants that are at different level of experience as a touch-typist
Dependent

- Their game score
- The number of misses from each hand

Controlled

- Has access to a computer that is compatible with the game
- Plays the game with both of their own hands (without assistance of a friend to play one hand)

Risk Assessment

<table>
<thead>
<tr>
<th>Risk</th>
<th>Level of risk</th>
<th>Control</th>
<th>Solution if occurs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Glare from sunlight on computer screen</td>
<td>Low</td>
<td>Blinds will be closed and computer screens adjusted</td>
<td>Ask participant to close and rest their eyes. If it still hurts, call the teacher/school nurse for assistance.</td>
</tr>
<tr>
<td>Food and water near computers – accidental spill would be hazardous</td>
<td>Medium</td>
<td>Food and water will be banned from the vicinity</td>
<td>Immediately call the teacher and inform them on what’s happened.</td>
</tr>
<tr>
<td>Tripping on the cables</td>
<td>Medium</td>
<td>The cables will be set up neatly and if it is on the floor within reach, it will be covered by a protector</td>
<td>Set the person aside, fix the cables and warn the others and call the teacher to inform them. Call for first aid if needed.</td>
</tr>
<tr>
<td>Physical implementations: posture, eyestrain, muscle strain</td>
<td>Low</td>
<td>The time required for each session should not extend 10 minutes so it should not overuse any part of the body. The set up for each computer will be checked so it is ergonomically suitable</td>
<td>Allow the participant to rest and stretch. Call for the teacher if ongoing pain.</td>
</tr>
</tbody>
</table>
**Experiment 1**

**AIM**

To investigate if Bimanual Coordination can be improved away from eg. a piano.

**HYPOTHESIS**

By the end of the investigation, subjects will have improved Bimanual Coordination, which is reflected through improved scores in *Bimanual Invasions*.

- Improvement will be more rapid in the beginning, then slow down the more times they attempt the game.

**RESULTS**

Figure 1: Graphs showing a subject’s total game score and bimanual coordination difference overall (Total), and the 3 levels: Down, left and right direction.
<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Y/N</th>
<th>Subject No.</th>
<th>Y/N</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
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<td>26</td>
<td>Y</td>
</tr>
<tr>
<td>2</td>
<td>Y</td>
<td>27</td>
<td>N</td>
</tr>
<tr>
<td>3</td>
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<td>Y</td>
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<td>Y</td>
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<td>11</td>
<td>Y</td>
<td>36</td>
<td>Y</td>
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<tr>
<td>12</td>
<td>Y</td>
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<td>Y</td>
</tr>
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<td>Y</td>
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<td>Y</td>
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<td>Y</td>
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<td>Y</td>
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</tr>
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<td>Y</td>
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<td>N</td>
</tr>
<tr>
<td>22</td>
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<td>Y</td>
<td>49</td>
<td>Y</td>
</tr>
<tr>
<td>25</td>
<td>Y</td>
<td>50</td>
<td>Y</td>
</tr>
</tbody>
</table>

Total Improvement in game score (trendline is positive)

| Total YES: | 41 | TOTAL NO: | 9 |
| Percentage: | 82% |        | 18% |
IMPROVING BIMANUAL COORDINATION THROUGH THE DEVELOPMENT OF A COMPUTER GAME

Gradient of improvement

<table>
<thead>
<tr>
<th>No. Attempt</th>
<th>Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>$y = 1543x + 5467.3$</td>
</tr>
<tr>
<td>4</td>
<td>$y = 1194.4x + 6083.3$</td>
</tr>
<tr>
<td>5</td>
<td>$y = 1219.1x + 6003.5$</td>
</tr>
<tr>
<td>6</td>
<td>$y = 952.45x + 4824.8$</td>
</tr>
<tr>
<td>7</td>
<td>$y = 1145.9x + 3516.3$</td>
</tr>
</tbody>
</table>
RESULTS ANALYSIS

Figure 1 is a sample of the 4 combo graphs I made for each participant:

1. A total of all their scores and bimanual coordination differences from ALL the levels
2. Their score and bimanual coordination difference in the DOWN level
3. Their score and bimanual coordination difference in the LEFT level
4. Their score and bimanual coordination difference in the RIGHT level

All the graphs for all the participants can be seen in my logbook.

Subject 2 shows significant improvement overall (representative of 80% of the sample group as shown in Figure 2), and improvement in the individual levels too. The bimanual coordination difference is decreasing overall, and quite stable in the different directions.

Figure 3’s graphs were created by splitting up the participants into groups who did it 3x, 4x, 5x, 6x and 7x. Their results for each of the x-number of attempts that they did (eg. 1st attempt – 3rd attempt for those who did it 3x), were all totaled up and then averaged based on the number of people in that group:

<table>
<thead>
<tr>
<th>x-trials</th>
<th>No. of P</th>
</tr>
</thead>
<tbody>
<tr>
<td>3x</td>
<td>50</td>
</tr>
<tr>
<td>4x</td>
<td>36</td>
</tr>
<tr>
<td>5x</td>
<td>23</td>
</tr>
<tr>
<td>6x</td>
<td>14</td>
</tr>
<tr>
<td>7x</td>
<td>7</td>
</tr>
</tbody>
</table>

A trendline or ‘line of best fit’ was added to show the overall progress of their game score and their gradients compiled into the table shown in Figure 2.

Figure 4 is a graph comparing the preferred level from all the participants. This was determined based off a survey handed out after participants had attempted the game a few times – it is not necessarily their best level. As can be seen, for all participants, the females, and the males, the most preferred level is the bullets going right.

Figure 5 is a table showing the percentage of better RH or LH accuracy in the sample group. I added up all of the subject’s left misses for the one attempt, then totaled all the attempts and then averaged them. This was also done for right hand. The lower number was more accurate.

Figure 6 just shows the statistics of the number of RH and LH people in the sample group.

DISCUSSION

As can be seen, 82% of the sample group did indeed improve their performance in the game during their time period that they played it. Because the game only has 10 lives, the theory is that the longer you last in the game, before losing all your lives, the better you are at it. With this game in particular, it requires both hands to move equally in order to deflect the missiles. This means improvement in their game score means they are getting better at it and are therefore improving in their control of independently moving their two hands. With Subject 2, their bimanual coordination difference is decreasing overall, which shows improvement in their bimanual
coordination. This means this participant’s hands are gaining the skill and becoming more equal in dominance in the game (less difference between the hands).

With the rest of the participants however, many of their Bi-Co score didn’t follow the trend of either decreasing or increasing. Since their game score improved, this doesn’t mean their bimanual coordination didn’t improve. The problem seems to be that they only played it a few times so it may not have been enough time for their skill to start being automatic. The improving game score shows they were learning the skill and getting better at moving both their hands to defect the missiles, but with only a little practice under their belt, most would’ve still pretty much relied on their dominant hand still.

Figure 2 does not take into account how many times the participant attempted the game, but merely if their total scores improved over their attempts (as shown by the trendline). Because this was a game, it is likely, and expected, that there would’ve been some participants who did not try their best. This is probably the case with those who did not improve. It should be mentioned, however, that subject 46 and subject 47 had quite a straight trendline with minimal decline. Subject 26’s scores were not constant, neither positive nor negative, and kept going up and down, and subject 27 did not show much change either way. These participants I will count as outliers as they most probably did not put much effort into actually playing the game.

Figure 3 also shows definite improvement when participating in the game. Assuming these outliers are spread out among the different groups who did it x-number of times, they do not show to make significant difference to the results as the graphs still show significant improvement for all the groups. Therefore, they can be counted as outliers and an ‘exception to the rule’.

Looking at the table that compares the gradients for Figure 3, you can see that the largest gradient is in the group that only played it 3x. This group actually had the largest number of participants so it is not because of the fact that they had less people to average it out. It is not exactly consistent and in order, but the more times they did it, the smaller the gradient became. With these results, it is probably not in order because of the irregular number of participants in each group, which was because of change in circumstances where the participants could not fulfill the controlled 27 attempts I originally planned.

Looking at the data points in Figure 3, there seems to be a trend where the first few attempts have a greater improvement then it starts to plateau the more times they do it. This supports my teacher’s hypothesis because he thinks: if someone is just developing their bimanual coordination skill, they would improve more rapidly in the beginning then the rate of improvement will slow down as they begin to obtain the skill. It is good to see though, that even if that is the case, improvement never fully stopped even if it wasn’t as rapid as the first 3 attempts.
CONCLUSION

These results, from attempting the game *Bimanual Invasions*, show definite improvement and therefore show that Bimanual Coordination can be improved away from a piano.
Experiment 2

AIM

To investigate if distributed practice (having spread out game attempts) or massed practice (attempting the game a few times in a row) is more effective in improving one’s bimanual coordination (improves faster).

HYPOTHESIS

Massed practice will result in faster improvement

RESULTS

<table>
<thead>
<tr>
<th>no.</th>
<th>MASSED first score</th>
<th>MASSED last score</th>
<th>DISTRIBUTED first score</th>
<th>DISTRIBUTED last score</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4596.46</td>
<td>2603.62</td>
<td>9950</td>
<td>16550</td>
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<td>15017.99</td>
<td>12830</td>
<td>12470</td>
</tr>
<tr>
<td>TOTAL</td>
<td>75368.5</td>
<td>114418.68</td>
<td>94103.8</td>
<td>135629.3</td>
</tr>
</tbody>
</table>

Figure 6: Table with the first and last score based on the trendline

Figure 7: Scatter graph with trendline showing the total first and last scores.
RESULTS ANALYSIS

The total of the first and last scores for distributed practice were about 20,000 points higher than massed practice at both the beginning and the end:

DISCUSSION

As can be seen from the graph, distributed practice showed to have higher results than massed practice. The elevated scores also prove to be consistent from the first to the last score. The gradient for distributed practice is also a little more inclined than massed, showing a slightly faster improvement but not that it makes a massive difference because they both still improved significantly from their first attempt to their last.

If this was to be graphed against time, massed practice would show to have a more rapid improvement (steeper gradient) because it occurred under a shorter period of time. So it would look more effective. This graph is not based on time but their first and last attempt. Even though massed would have a steeper gradient if based on time, based on attempt, it is slightly lower than distributed. This means distributed shows to better maintain improvement rather than massed. Even if it was based on time, the scores would stay the same and distributed would still have a more elevated score.

CONCLUSION

Distributed practice shows to be slightly more effective and better maintains improvement than massed, but practicing it in either manner will show significant improvement.
Experiment 3

AIM

To investigate if there is any skill transfer between different activities that practice bimanual coordination such as touch typing, piano playing, and drumming.

HYPOTHESIS

Pianists, touch typists, and drummers will show some skill transfer in their game results – start off with a better score and improve faster than the control.

RESULTS

<table>
<thead>
<tr>
<th>Skill</th>
<th>No. of P</th>
<th>AV Pianists</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piano - N/A</td>
<td>30</td>
<td>N/A</td>
<td>6003.333333</td>
<td>8500</td>
<td>4500</td>
<td>6450</td>
<td>5500</td>
</tr>
<tr>
<td>Piano - 1</td>
<td>5</td>
<td>8566.666667</td>
<td>11300</td>
<td>8100</td>
<td>8250</td>
<td>7440</td>
<td>12833.333333</td>
</tr>
<tr>
<td>Piano - 2</td>
<td>1</td>
<td>8570</td>
<td>13060</td>
<td>6100</td>
<td>7600</td>
<td>10640</td>
<td>15433.333333</td>
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<tr>
<td>Piano - 3</td>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Piano - 4</td>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Piano - 5</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drums - N/A</td>
<td>45</td>
<td></td>
<td>7171.11111</td>
<td>2750</td>
<td>2400</td>
<td>2350</td>
<td></td>
</tr>
<tr>
<td>Drums - 1</td>
<td>2</td>
<td>9495.55556</td>
<td>5300</td>
<td>12500</td>
<td>3850</td>
<td></td>
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</tr>
<tr>
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<td>1</td>
<td>10200</td>
<td>7450</td>
<td>11000</td>
<td>2350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Drums - 3</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typing - 1</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Typing - 2</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Typing - 3</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Typing - 4</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Typing - 5</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 8: (above) The number of participants in each level for each activity. (right) Average score for x-attempts for the participants in that level. Graphed in Figures 9-11.
Comparing skill transfer between different experience levels of pianists

Figure 9a: Scatter graph comparing first 3 attempts of different experience levels of pianists. Rubric for levels in Results analysis.

Comparing progress of different experience levels of pianists

Comparing skill transfer between different experience levels of drummers

Figure 10a: Scatter graph comparing first 3 attempts of different experience levels of drummers. Rubric for levels in Results analysis.

Comparing progress of different experience levels of drummers

Figure 10b: Table comparing gradients of 10a. (Right table) shows it in order of lowest – highest gradient
RESULT ANALYSIS

1. For pianist level rubric:
   a. Don’t play = N/A
   b. Beginner = 1
   c. 1st – 2nd grade = 2
   d. 3rd – 4th = 3
   e. 5th – 6th = 4
   f. 7th and over = 5
   - The first scores were quite close together in range but level 5 was the highest.
   - The first scores, and gradients, were increasing but not necessarily in the order of levels. In both cases though, level 5 still remained the highest.
   - The first scores went in this order from lowest-highest: 2, 4, N/A, 3, 1, 5. They stayed in the same order until the third attempt. The only difference was that N/A ended up higher than 3.

2. For drummers level rubric:
   a. Don’t play = N/A
   b. Level of expertise from 1-5
- N/A started of significantly better than 1, 2 and 3 that were all bunched up.
- The first scores order was: 3, N/A, 1, then 2. They were the same at the end but level 2 overlapped the others until it ended up being the highest.
- Level 3 started the lowest and had the lowest gradient. Level 2 had the highest gradient.

3. For touch-typists level rubric (using words/per minute):
   a. <20 = 1
   b. 20-30 = 2
   c. 30-40 = 3
   d. 40-50 = 4
   e. >50 = 5

   - The starting order went like this: 1,5,2,3,4.
   - And ended like this: 1,2,5,3,4. This means that 2 and 5 swapped but the others stayed the same.
   - Level 5 had the highest gradient by a significant slope comparing to the next best (3) and 2 had the lowest gradient by about the same slope difference to 1 as 3 and 5.

DISCUSSION

For all 3 of the activities, it should be observed that the sample group for each level within an activity were not all equal. The reason for this will be discussed in the overall discussion.

Although I’ve added in the graphs and data for the drummers, I will not count the results as reliable data that I will use to support my hypothesis. This is because there were only 5 participants who were drummers so there were 2 participants for level 1, 1 for level 2, and 2 for level 3. Therefore, the results are not reliable because there wasn’t a large enough sample group to repeat the experiment a few times. I will only focus on pianists and touch-typing.

Surprisingly, for both the pianists and touch-typing, the gradients were not in any particular order. My hypothesis was that skill transfer would mean they would improve faster (A higher gradient) but this wasn’t the case. For both activities however, the level 5s did have the highest gradient but the sample group for this group was smaller than the others. If I redo this experiment I will try to get more for the higher sample groups so the data is more reliable as my hypothesis can be tested against more people.

I was expecting that if my hypothesis was correct, the general order of the gradients would be lowest-highest, with N/A on the bottom and 5 at the top. But if my hypothesis was incorrect, I was at least expecting that it would be in the general order of highest-lowest where those with less possibility of skill transfer would improve more rapidly. But the gradients appear to be in random order and neither of my expectations.

For touch-typing, the order went 1,5,2,3,4 which was close to my expectation if skill transfer was to occur. Level 5 is probably near the bottom because if skill transfer is indeed occurring, they
would already have more of the bimanual skill than those of the lower levels and cannot improve as much. Lower starters have more room for improvement and so dramatically improve compared to participants who already extensively use bimanual motion. This graph does show some skill transfer between touch-typing and *Bimanual Invasions*. The better the participant was in touch-typing, the better they were when they first did the game since they already had the skill. The gradients however, were not in a particular order, as already mentioned.

**CONCLUSION**

Acquiring Bimanual Coordination from other activities does give advantages to ones performance in *Bimanual Invasions* thus showing some form of skill transfer. They start with a higher score, the more experienced they are, but the rate of improvement does not seem to be linked to previous experience.

**Overall Discussion**

All three of these experiments overlap in their results. This is because the same group of 50 participants are used for each experiment. Originally, I intended about 150 participants to be able to play the game, and for them to play it 27 times. This would mean by results would be more accurate than the current results because the more people who do it, the more the experiment is repeated and this increases the accuracy of the results. This obviously did not go to plan due to many disruptions to the school timetable.

The results from this preliminary investigation is therefore quantitative because I am recording numerical changes. With the number of setbacks that disrupted many planned participants from actually participating, I had to use the information I had. I asked this group of 50 whether they participated in the other bimanual coordination activities rather than go and look for people who participated in them. This is why the sample group was not equal for the different levels and the drummers skill transfer was not taken into account as there wasn’t enough people to repeat the experiment over and over to make it accurate.

Therefore, this can be seen as a preliminary investigation where if I had to redo it I would take more time to ensure more even numbers for the sample group. This may be done by looking for people in each activity instead of taking any participant and asking if they meet some of the variables I was looking for.

As can be seen throughout all 3 experiments, playing *Bimanual Invasions* does increase one’s bimanual coordination skill. This is true whether the participant played it 3x or 7x, massed or distributed attempts, or had any previous development of the skill. With all the variables I looked at, the trend is clear: the computer game was successful in improving ones bimanual coordination.
### Table 1: Subject More Accurate Hand

<table>
<thead>
<tr>
<th>Subject No.</th>
<th>Hand</th>
<th>Subject No.</th>
<th>Hand</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RH</td>
<td>26</td>
<td>RH</td>
</tr>
<tr>
<td>2</td>
<td>RH</td>
<td>27</td>
<td>RH</td>
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<tr>
<td>3</td>
<td>RH</td>
<td>28</td>
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<td>4</td>
<td>RH</td>
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</tr>
<tr>
<td>5</td>
<td>RH</td>
<td>30</td>
<td>RH</td>
</tr>
<tr>
<td>6</td>
<td>RH</td>
<td>31</td>
<td>SAME</td>
</tr>
<tr>
<td>7</td>
<td>RH</td>
<td>32</td>
<td>LH</td>
</tr>
<tr>
<td>8</td>
<td>RH</td>
<td>33</td>
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</tr>
<tr>
<td>9</td>
<td>LH</td>
<td>34</td>
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<td>36</td>
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<tr>
<td>12</td>
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<tr>
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<td>LH</td>
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<td>RH</td>
<td>50</td>
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</table>

<table>
<thead>
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<th>NO. RH:</th>
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<th>NO. LH:</th>
<th>9</th>
<th>NO. SAME:</th>
<th>2</th>
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</thead>
<tbody>
<tr>
<td>%</td>
<td>78%</td>
<td></td>
<td>18%</td>
<td></td>
<td>4%</td>
</tr>
</tbody>
</table>

### Table 2: RH/LH Handed in Sample Group

<table>
<thead>
<tr>
<th>RH/LH</th>
<th>No. of P</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>RH</td>
<td>46</td>
<td>92%</td>
</tr>
<tr>
<td>LH</td>
<td>4</td>
<td>8%</td>
</tr>
</tbody>
</table>

Figure 12: Table showing percentage of better RH or LH accuracy in sample group.

Figure 13: Table showing percentage of RH and LH participants in sample group.
Although not part of the original aim, it was interesting to see the trend in the preferred level among the participants. Figure 12 shows how many of the participants were actually more accurate in their RH or LH and this can be compared to their actual dominant hand in Figure 13. In the 4 graphs I made for each participant, we can see the columns for the Bimanual Coordination Difference go above 0 (positive) or below 0 (negative). If it was positive, their Left hand had more misses, therefore their Right Hand was more accurate. If it was negative, their Right Hand had more misses, therefore their Left hand was more accurate.

I totaled each participant’s total LH misses and RH misses then averaged them based on how many attempts they had. Then I evaluated the more accurate hand by picking the one with the lesser number of misses. As I mentioned in the first experiment, the number of attempts for the game was too few for the skill to start being automatic and their hands naturally becoming more equal in coordination. Up to this point, participants still have to consciously think about it, though it is in the process of developing. This is probably why most still depend on their dominant hand and this can be seen where 92% of the sample group were Right-handed and 78% of the group were more accurate in their hand.

Further investigation

There is the chance that conclusions from this investigation may be relevant to people who have trouble distinguishing between their left and right, which is said to be a ‘complex neuro-psychological process’\(^x\), and the disorders as mentioned above. Practising with this game over a period of time may help their brain recognise left and right as they focus on defecting the bullets.
Conclusion

In conclusion, *Bimanual Invasions* is a user-friendly platform that when practiced over a period of time will improve anyone’s bimanual coordination no matter what level and previous experience you are at.

Acknowledgements

I want to thank my mum and dad for putting me in piano lessons since I was 6 because they saw the potential benefits in doing so. Thankyou for giving me the idea after years of my questioning on why I had to keep playing piano. Thankyou mum for funding the computer mice that I bought.

Thankyou to my science teacher and adult sponsor who guided me through the whole process. Thankyou for tweaking my plans so that they would work and helping me analyse my data when I was overwhelmed for looking at over 200 graphs and 280 data entries to go through.

Thankyou to my other teacher who helped me proofread this report and made sure it was all ready.

A massive thankyou to my IT teacher who had many, many late nights in order to finish the game on time so I could get going with my investigation. It wouldn’t have been possible without his help.

A really big thankyou to all my friends and school mates who participated in the game and put up with me asking you to play every lunch time!! Thankyou to my friend who helped me rally everyone and teach them how to access the game at the library.

Bibliography

