The relationship between input mechanics, flow and auxiliary movements during videogame-play.

Study Report

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Abstract

Designing computer games is a mixture of art and science. One of the psychological concepts that greatly affects both videogame design and videogame-play is the mental state of flow. In this report we studied how motion sensing input mechanisms for game-play affect flow. We examined 62 people with an obstacle course game that had two input methods, an exaggerated method and a minimalistic method. An exaggerated method is an input method that requires an extensive use of a players body while a minimalistic input method only requires the application of fingers. Motion sensing input like the Wii controller and steering wheels for racing games are example of input methods that require exaggerated input. Keyboard and mouse or a run-of-the-mill gamepad controller are examples of minimal input methods. None of our data supports any relationship between input methods and flow.

We also examined the relationship between flow and auxiliary movements videogame-players often exhibit. We define auxiliary movements as movements performed by players that have no direct influence on game-play. We checked if such movements were an indication of flow, but there is no data to support that hypothesis either.

We then asked if exaggerated input could cause auxiliary movements. This seems t be the case as we had strong correlation between those two factors. What is more interesting is that the less people played games the stronger this effect was.

In the game, participants controlled the swing of a pendulum as it travelled forwards through an obstacle course. The goal was to avoid unbreakable objects (by halting the swing) and to follow strings of golden circles by adjusting the swings momentum and width.

We used the Flow Short Scale to see if participants reported flow and we measured body movements with an accelerometer attached to a players head.

Keywords

Flow. Videogames. Tilt. Accelerometer. Auxiliary movements. Minimal input method. Exaggerated input method. Angle amount. Sample angle.

Table of Contents

1. Introduction

The primary goal of any game designer (beknownst or not to said designer) is to create circumstances that enable players to experience flow, because while a player experiences flow, that player is having fun, feels capable and escapes reality; the basic goals of any computer game. Flow is a highly desirable state of mind to have in players and game designers strive to create conditions where flow can occur.

Input mechanics are the foundation of any videogame. Without input, there is no game. Today there is a new generation of input systems where players' motions in three dimensions can be translated as input.

With this study we are trying to determine if motion sensed input (exaggerated input) is likelier to induce a state of flow over minimalistic input (a pressing of a button).

Presumed clues that a videogame-player is experiencing flow are auxiliary movements a player performs during play that have no impact on the game. We also take a look at auxiliary movements and how they are related to exaggerated/minimalistic input and if they are indeed an indication of flow.

1.1. Null Hypothesis

1. *Exaggerated input methods in videogames are not likelier to induce flow over minimal input methods.*
2. *Auxiliary movement by players is not an indication of flow.*
3. *An exaggerated input method is not likelier to induce auxiliary movements.*

1.2. Alternative Hypothesis

1. *In videogames, exaggerated input methods are likelier to induce flow than minimal input methods.*
2. *Auxiliary movement by players indicates they are experiencing flow.*
3. *An exaggerated input method will induce auxiliary movements.*

2. Theoretical Considerations

2.1. Immersion

Immersion is the holy grail of videogame designers[3]. This is where the challenge of the game and its mechanics couple with world portrayal, story and the theme of the game to yield a holistic experience where players become immersed in the game. This is commonly called 'hooking' players. A player who becomes immersed in a game is a satisfied customer and a returning customer for the developer/publisher. Not only that; like other media, videogames' sales are strongly fueled by viva voce and have their qualities publicly subjected to grading systems and criticism. According to Weibel and Wissmath[1] "A main reason to play computer games is the pleasure of being immersed in a mediated world. Spatial presence and flow are considered key concepts to explain such immersive experiences." Our focus is on the flow construct.

2.2. Flow

The concept of flow was first introduced by Csikszentmihalyi and is a state of consciousness while performing an activity. It is described thusly: It is a feeling of intense, focused concentration. One's sense of time becomes distorted. One feels capable to meet the challenges of the task. There is a loss of self-consciousness. There is a sense of control over the activity and a feeling of enjoyment or reward for the engagement[2].

Flow is begotten under distinctive circumstances. The activity has to have clear objectives, must provide immediate feedback on performance and one must perceive the challenges of the activity to be within one's scope of skills. One can not force a state of flow, it is a state indigenous to circumstances, inclination and aptitude.

2.3. Auxiliary Movements

Unnecessary and involuntary movements during videogame-play are possibly a by-product of the flow experience. These movements often manifest in such a way, that if one was performing the videogame activity in real life, they would not only be effective but necessary. For instance, while turning in a racing game the player leans into the turn, as if being inside the virtual vehicle or while performing a difficult jump in a platformer game, the player lifts the remote as the jump-button is pressed in an attempt to influence the input. They can also be wholly unrelated to the activity per-se such as the clenching of the toes.

We were unable to find any research done on auxiliary movements while playing videogames. To our untrained eye, it seems this avenue is unpursued.

We find this phenomena intriguing and want to see if input methods can affect it. If the input method is resembles the actual activity within the game, will auxiliary movements be more frequent or distinct? Or does it not matter? We are not trying to figure out *why* this happens.

3. Conducting the Study

A detailed description of our plan for executing the study can be found in Appendix A.

3.1. Participants

A total of 68 participants took part in the study. Random people in a shopping mall of ages 12-58, where the average age was 23. 23 females and 45 males.

We introduced ourselves, our school and our department to each approached participant, explained our research obscurely and without details that could affect a participant's behaviour during the study.

Figure 1

3.2. Study Design

Before commencing play, participants answered a short questionnaire asking for age, gender, device familiarity, gaming frequency and an evaluation of their stress level. Then there were three levels of play, two minutes each, followed by the Flow Short Scale plus a single question regarding enjoyment. Participants were then thanked and rewarded with a soda pop.

3.3. Environment

We constructed a booth in the shopping mall in order to lessen distractions from by-passers. Participants were encased in three walls, sitting on a stool. Study moderators prevented other shoppers from interrupting their play.

Participants were fitted with a headband on which an accelerometer was attached.

Figures 2 & 3: This design was meant to be as disturbance free as possible considering our surroundings, shielding participants from shopper traffic as they participated in the study.

4. The Game

We designed the game ourselves. We wanted a game that was free of genre in order not to skew skill levels required to play (i.e. everyone was a beginner to the game). The game consists of a pendulum suspended in the middle of the screen and travels through a level. Participants had to swing the pendulum from left to right to hit oncoming targets and avoid obstacles.

We took care that the game satisfied all the preconditions for flow to be possible. The game gave immediate feedback on performance via score. Controls were responsive. The game's first two levels were pretty easy and the third provided a challenge, allowing participants to ramp up their game skill before tackling a challenge.

We had no questions or interruptions between levels (only a short pause) as we did not want to interrupt flow. Questionnaires were presented to participants before and after play.

4.1. Control Descriptions

4.1.1. Minimal Input Method

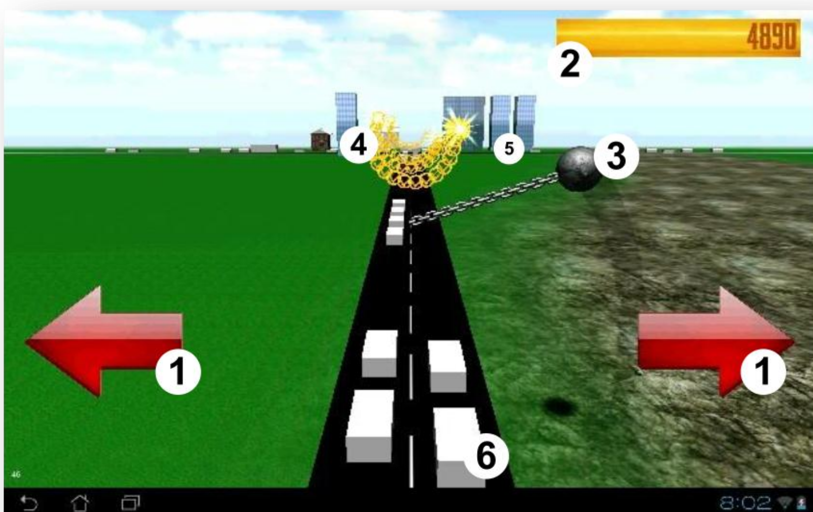

Figure 4

1 Pressing left arrow rotates the pendulum clockwise. Pressing the right arrow rotates the pendulum counter-clockwise. Pressing both arrows simultaneously will halt the pendulum in mid swing until you release either arrow.

2 Score.

3 The pendulum.
4 Golden rings. Making the pendulum follow a row of these is how you gain score.
5 Buildings are obstacles, crashing into them ruins your swing for a moment.
6 Cars. Fun to sweep into the air with your swinging pendulum!

4.1.2. Exaggerated Input Method

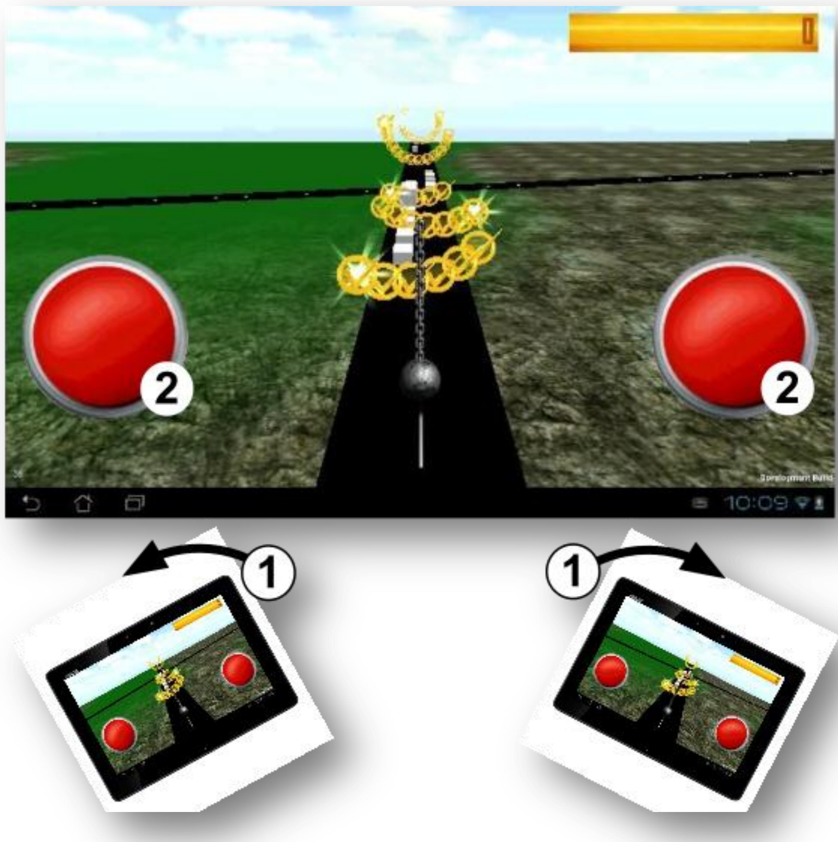

Figure 5

1 Tilting the device left or right has the same effect as pressing the left or right arrow in Control Layout 1.
2 Halt buttons. Pressing and holding these buttons will stop the pendulum in mid-swing until you release them again.

4.2. Measurements

We measured flow with the Flow Short Scale which is used in research concerning flow by Wiebel and Wissmathl[1], Engeser and Rheinberg[4] and Wiebel et al.[5].

While playing the game ...

- I felt just the right amount of challenge.
- My thoughts/activities ran fluidly and smoothly.
- I didn't notice time passing.
- I had no difficulty concentrating.
- My mind was completely clear.
- I was totally absorbed in what I was doing.
- The right thoughts/movements occurred of their own accord.
- I knew what I have to do each step of the way.
- I felt that I had everything under control.
- I was completely lost in thought.

We measured enjoyment with a single question:

- I enjoyed myself thoroughly.

For each question we used a seven point likert scale instead of the five point scale because we wanted more precise feedback.

Disagree			**Ambivalent**			**Agree**
1	**2**	**3**	**4**	**5**	**6**	**7**

We measured body movements with an accelerometer. We used the KineJump software which came with KineJump prototype to extract data from the accelerometer.

5. Data Processing

Accelerometer data for each user needed to be trimmed to fit the time frame that it took to play the game from beginning to end. I.e. the end needed to be cut off. Using the DSV Filter Library to isolate the right timeframe, the input data was then adjusted to meet the librarie's criteria. Thus a program was written performing tasks based on the following list.

- Numbers must adhere to the following regular expression:
  [0-9]+(\.[0-9]+)?
- Each column needs a header specifying a name followed by an indicator on its data type ('n' for a number and 's' for a string):
  [a-zA-Z0-9]+_[ns]
- The original, read, data must not be lost.
- Normalization.
- Interchangeable input delimiter.

The data was then run through the filter. An example filter statement:
timecode >= 0 and timecode < 120
(timecode <= 0 or timecode > 0 or x <= 0 or x > 0 or y <= 0 or y > 0 or z <= 0 or z > 0)

Here the timeframe is 0 - 120 seconds. Each datafile is then saved to a subfolder, "filtered/x" where x is a name, input by the user describing the filtered data.

5.1. Accelerometer Data Interpretation

The signal we received from the accelerometer is list of accelerometer samples which is a long list of 3 dimensional vectors denoting the direction and magnitude of acceleration at any given point in time. We needed to extract the sample angle (a participant's amount of left-right leaning in degrees at a specific point in time) from each of those accelerometer samples utilizing the acceleration of gravity as a way to measure it. We realized that the accelerometer's x-axis was not horizontal as we had expected but instead it was vertical, pointing upwards. Because of this, we instead used the y-axis which pointed sideways along the participant's left and right.

- Let G be a set 3 dimensional vectors denoting acceleration.
- Let A be a set of sample angles.
- Let $N(v) = \frac{v}{\sqrt{{v_x}^2+{v_y}^2+{v_z}^2}}$
  where $v$is a 3 dimensional vector
- For each vector $g \in G$ there is a $a \in A$.
  - where $a = 90 - acos(N(g)_y) * \frac{180}{\pi}$

5.2. Low-Pass Filter

We applied a low pass filter (filter that removes high frequencies from a signal) to the accelerometer signal before computing the angle amount from it (a participant's total amount of left-right leaning in degrees while playing the game). We used this filter to remove all noise above 3.2Hz because any movement faster than 3.2Hz is not practical to measure since we're not measuring convulsion.

The signal is 640 samples per second meaning the highest possible frequency is 320Hz. The filter is applied by smoothing the signal a total of 200 times iteratively by selecting 100 frequencies between 320Hz and 3.2Hz and smoothing the signal twice for each one.

5.2.1. The Algorithm: description of a single smoothing iteration

Each point *p* in the smoothed signal is computed by taking two points, *a* and *b*, on either side of *p* from the input signal, averaging their values and assigning the outcome to *p*. Each iteration has only one parameter; *range*. The range is an integer and it determines the sample interval between *a* and *b* in the input signal. In other words, the range is the inverse of what frequency should be removed from the signal.

$range = 320 / Hz\ to\ remove$

E.g.

- a range of 1 removes noise at 320Hz
- a range of 2 removes noise at 160Hz
- a range of 50 removes noise at 6.4Hz
- a range of 100 removes noise at 3.2Hz

As mentioned before, 100 frequencies are selected to be removed. Those frequencies are selected by incrementing the range by one every two iterations, between 1 and 100.

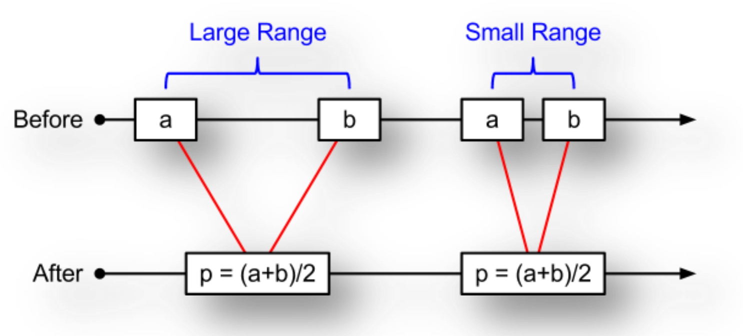

Figure 6: A single iteration averages two points from the input signal and assigns it to the point in-between them in the resulting signal.

The position of *a* and *b* is half the range away from the position of *p*. If *p* is at position 105 and the range is 2.4 then:

- *a* = [105 - 1.2] = [103.8]
- *b* = [105 + 1.2] = [106.2]

This yields two problems. One of them is shown below.

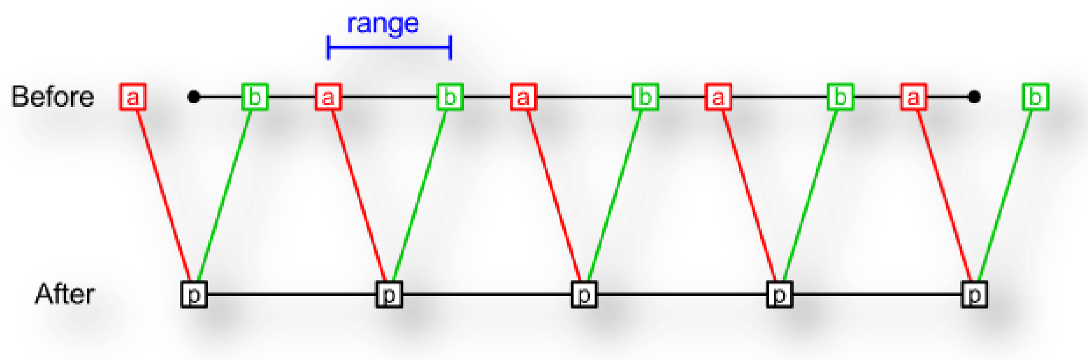

Figure 7: Notice that **a** is out of range on the left, and **b** is out of range on the right.

The other problem is that the signal isn't continuous, meaning there are no values in-between indices because the signal is a list of numbers.

5.2.2. Continuity

To make the original signal seem continuous and not just a list of numbers we simply interpolate between values when reading from the original signal.

If point *a* is at position [14¼], then it's value the sum of the following:

- 75% of the value at index [14]
- 25% of the value at index [15]

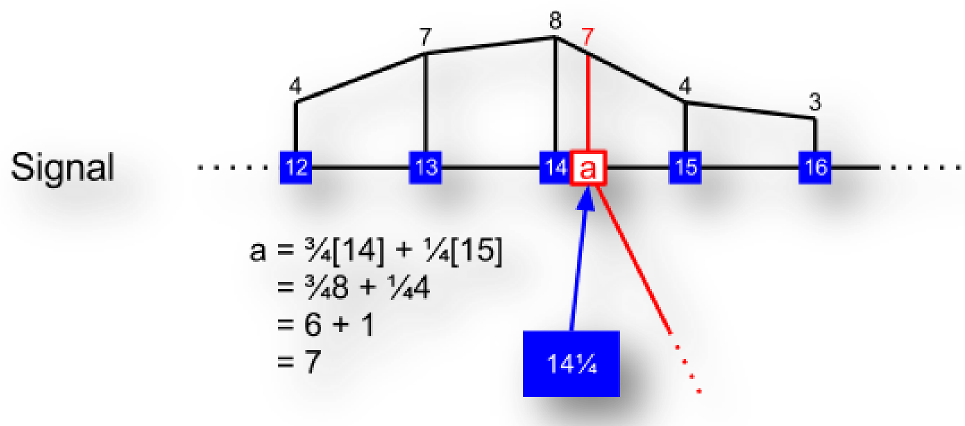

Figure 8: An example of how the interpolation works. In this case, the value at position 14.25 is 7

Finity

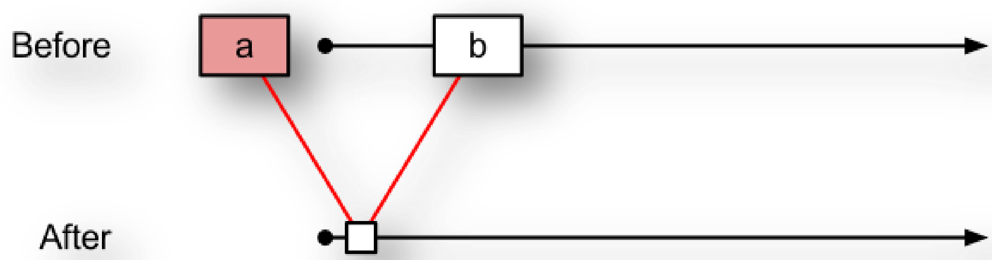

Figure 9: The signal is finite, it has a beginning and an end. This yields a problem at ends of the signal.

A solution to this problem is to interpolate how much a and b are away from p according to where p is in the signal.

Given the following

- n = index of the last point in the signal
- i = index of p
- delta = i / n
- value at = function to retrieve the value at a given position in the signal

Then

- $a = value\ at\ [i - range * delta]$
- $b = value\ at\ [i + range * (1 - delta)]$

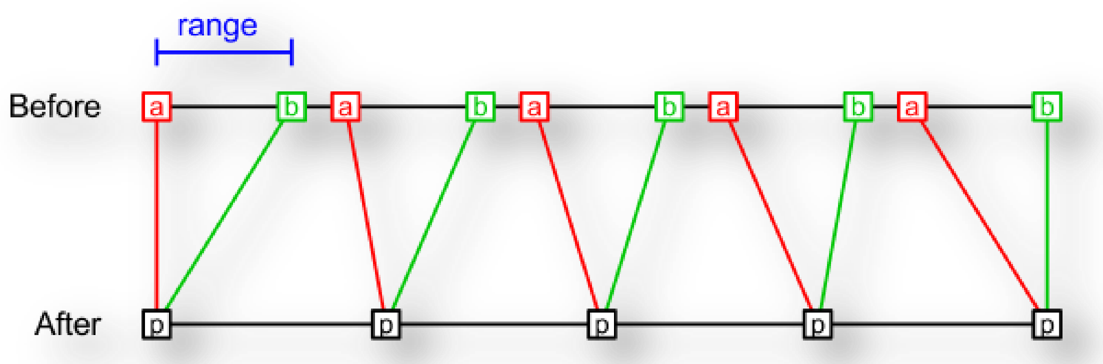

Figure 10: This diagram shows how each iteration is actually done.

This smoothing algorithm is applied 200 times removing all noise above 3.2Hz, consequently acting as a low-pass filter.

5.3. Angle Amount

To compute the angle amount from a signal of sample angles we find all critical values in the signal (values at points where the signal changes direction; where the derivative is 0). Then the angle amount is:

$$(c_0 - x_0) + \sum_{i=0}^{n-1} c_{i+1} - c_i$$

Where:

- x_0 is the first value in the signal.
- c_i is a critical value at index i starting at index 0.
- n is the number of critical values.

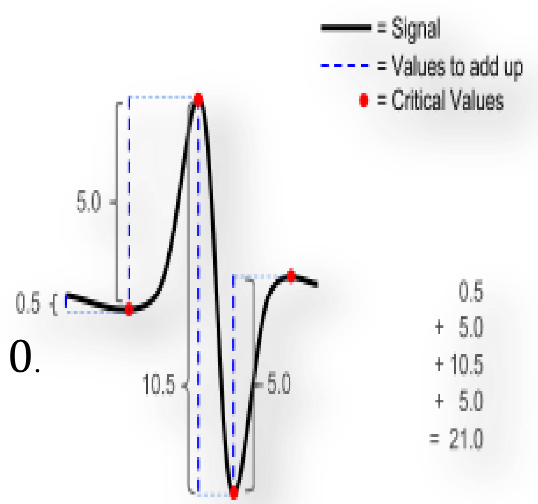

Figure 11: An example of how the computation of angle amount works

6. Discussion

The aim of this study was to investigate the relationship between auxiliary movements and flow, auxiliary movements and input methods and input methods and flow. It is of use for the gaming sector as the state of flow is a highly desirable effect to have on videogame-players. It is a tell-tale sign that the game is being enjoyed and thus is a success. Any information on how to induce flow (if at all possible by fixed means) is valuable to the design process of a game. The introduction of motion sensing input devices and their effect on flow has not --to our knowledge-- been studied before. We therefore felt we could investigate and detect if these input mechanics had an advantage over traditional game input (such as keyboards, mice and gamepads) on inducing flow.

The findings could be of practical use and results that would've indicated a positive relationship between exaggerated input and flow could've been used in game design. As expected though, there was no special relationship detected between input and flow (after all, people experience flow in a variety of situations).

When examining if auxiliary movements by gameplayers was affected by flow, an indication of flow or affected by exaggerated input we found no correlation between flow and auxiliary movements. We feel this avenue could be explored in more detail with participants who already are passionate gamers playing a game they already love. We noticed that as gaming frequency increased movement decreased (a correlation of -0.23). This seems interesting, perhaps auxiliary movements are miniature by frequent gamers because they are used to the effect? Perhaps, while the gaming experience is new, increased movement should be expected and should deplete over time as familiarity grows?

Also, curiosity compels us to ask *why* people perform auxiliary movements, do they enhance enjoyment, or performance? According to our data, they have a slight relationship with enjoyment (correlation between movements and enjoyment was 0.14) and have no effect at all on performance (correlation between movements and performance 0.01). So to us auxiliary movements remain a mystery.

7. Conclusions

We feel confident in reporting that there is no relationship between flow and input methods. Auxiliary movements relationship with flow remains a mystery but we discovered the the fact that an exaggerated input method results in auxiliary movements by players, especially inexperienced players.

7.1. Null Hypothesis 1

Exaggerated input methods in videogames are not likelier to induce flow over minimal input methods.

For this hypothesis we used t-testing for calculating correlation between two groups, those who used the buttons input method and those who used the tilting input method.

For 99% certainty the correlation coefficient between flow and the use of an exaggerated input method needs to be greater than 2.39 to be rejected.

The results was: -0.16 → ACCEPTED

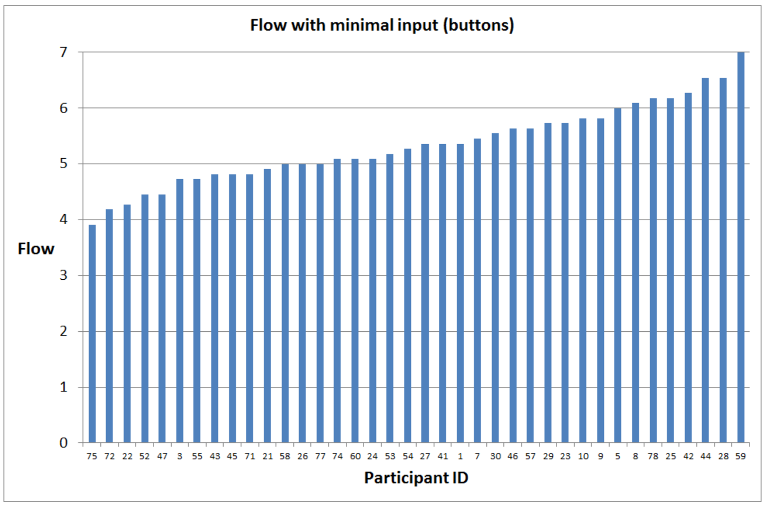

Figure 12

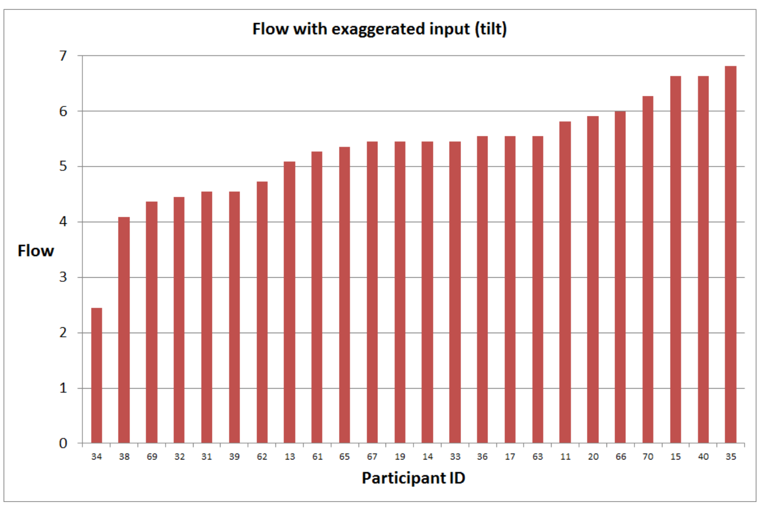

Figure 13

7.2. Null Hypothesis 2

Auxiliary movement by players is not an indication of flow.

For this hypothesis we used Pearson product-moment correlation coefficient for calculating correlation between flow and angle amount.

For 99% certainty the correlation coefficient between flow and angle amount needs to be greater than 0.26 to be rejected.

The results was: -0.08 → ACCEPTED

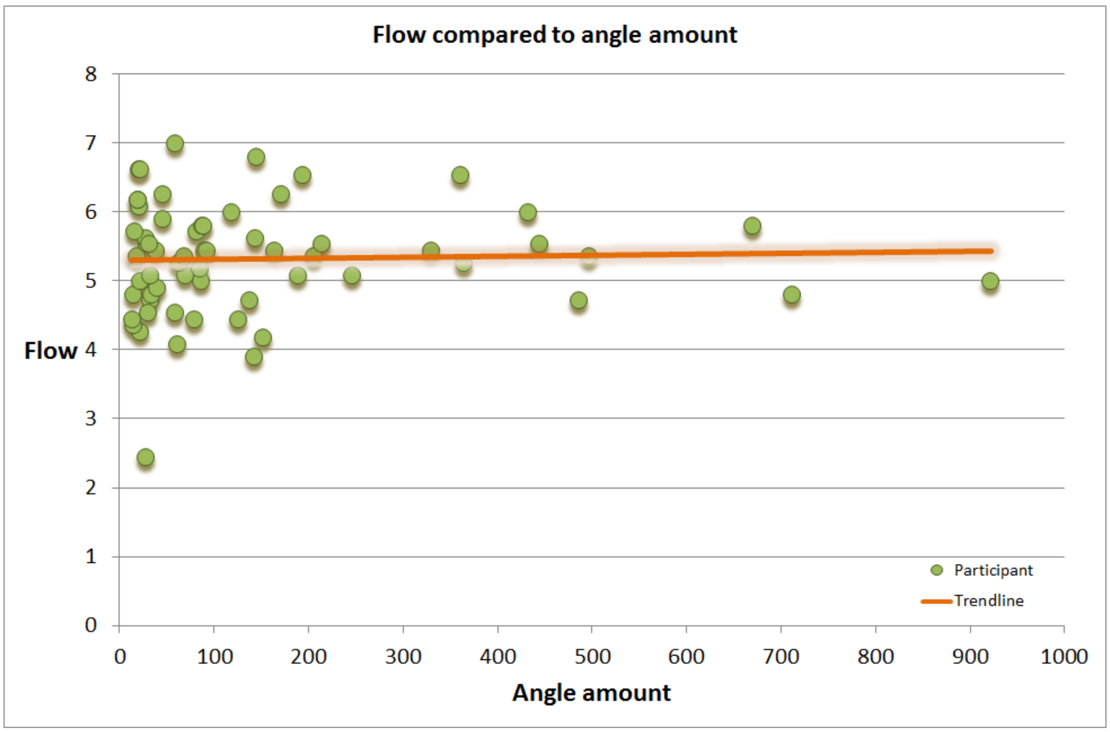

Figure 14

7.3. Null Hypothesis 3

An exaggerated input method is not likelier to induce auxiliary movements.

For this hypothesis we used t-testing for calculating correlation between two groups, those who used the buttons input method and those using the tilting input method.

For 99% certainty the correlation coefficient between angle amount and the use of an exaggerated input method needs to be greater than 2.39 to be rejected.

The results was 7.11 → REJECTED

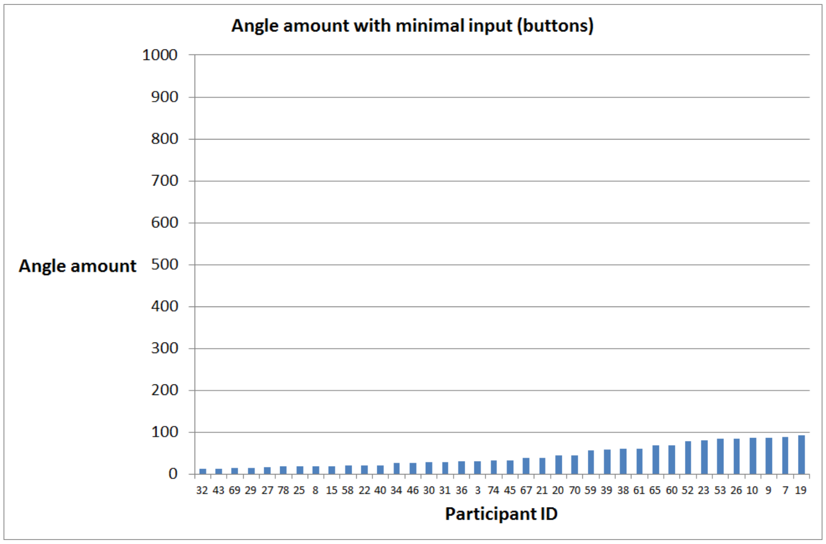

Figure 15

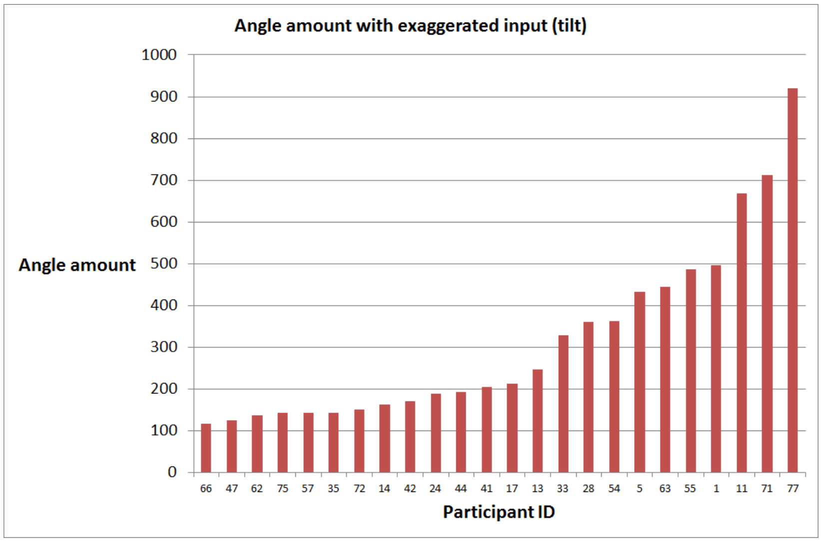

Figure 16

7.4. Alternative Hypothesis

1. *In videogames, exaggerated input methods are likelier to induce flow than minimal input methods.*

   The results was: -0.16 → REJECTED

2. *Auxiliary movement by players indicates they are experiencing flow.*

   The results was: -0.08 → REJECTED

3. *An exaggerated input method will induce auxiliary movements.*

   The results was 7.11 → ACCEPTED

8. Software list

Unity 3D and MonoDevelop	Game creation and data processing
Google Docs.	All documentation.
KineJump prototype.	Movement measurements.
MS Excel.	For graphing and calculating.
GCC compiler and Notepad++.	Data preprocessing.
MS Word.	Final layout for reports.
Trello.com	Kanban board.
DSV Filter Library.	C++ data processing library.

9. Special thanks

Sveinn Fannar Kristjánsson:

For lending us an Android phone for our study.

School of Science and Engineering, Sports Science department (Baldur and Einar):

Advice and lending us the accelerometer and Jumper Software.

Sýningarkerfi:

For providing us with a booth for our study.

Kringlan:

For providing us with a venue for the study.

Ölgerðin:

For giving us Mountain Dew to give away to participants.

G. Haukur Guðmundsson Physiotherapist

For advice on body movements.

Þorlákur Karlsson

For mathematical advice.

10. References

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11. Appendix A - Conducting the Study

Note! As a plan b, we also video recorded participants for analysis in case our accelerometer data would not be usable. No data from video analysis is used to produce conclusions in the study!

11.1. This Document

This document is meant to clarify every single thing that needs to be done whilst conducting the study. To run the study smoothly we have defined roles and phases. Roles to divvy labor and phases to define the overall process. We have three roles; The scout, the host and the technician and then we have three phases, Introduction phase, Preparation phase, Play phase and the Goodbye phase.

11.2. Phases

We defined phases to better understand what we needed to do. Categorizing our actions was very useful in order to envision the process of our study.

11.2.1. Introduction phase

When we approach strangers asking for their help with the study, we need to give them a brief overview of what is happening, who we are and what will be required of participants. That way, people know what they are accepting to do for us and lessens the prospect of irritability and misunderstanding. We need to introduce ...

- The school.
- Us.
- The project.
  - What it is. Try to avoid going into details so participants do not subconsciously affect the study.
  - How we're doing it.
    - Mention the camera.
    - Mention the strap on meter.
- Time involved.

A sample introductory spiel

Hello there!
We're a group of computer science students from HR in our final project.
We are researching behaviour of people playing a computer game.
We need people to play our game and answer 16 questions.
We strap on a little sensor to your head and video-record your movements while you play.
This takes around X minutes.
Would you like to participate?

11.2.2. Preparation phase

Once a person agrees to participate, we need to follow these steps.

- Tutorial. We need to introduce the goal of the game as well as the control methods. We already did a small test where we asked people to play our game without being taught how to play. It was disastrous in terms of player performance, and we need people to have a chance at success if we hope to induce flow.
- Once the previous participant is done playing we remove their strap, shake their hand and thank them for their contribution.
    - *It is alright to allow the waiting participant to play with the tutorial while we wait for the previous participants to finish.*
- We need to strap on the sensor.
    - *Note! We need to visibly clean the strap before placing it on people. This will diminish any sanitary concerns participants might harbor and put them at ease.*

11.2.3. Play phase

Before play can begin, now that our participant is strapped up and ready to go, we need to perform these steps …

- Ready the playtime.

    - Enter a new player into the game.
    - Note the ‘Participant ID’ that person is assigned in the game and flip the cardboard numbers to reflect a new participant’s ID.
- Wait for the participant to answer the first five questions.
    - **Important note!** Remind the participant that once the first five questions are answered, we need to intervene the process to calibrate the sensor and the camera before play can commence.
- Ready the recordings.
- Start the game.

11.2.4. Goodbye phase

- Remove the strap from a finished participant.
- Thank them for their help.

11.3. Roles

We defined roles in order to make it absolutely clear what everyone needs to be doing while we conduct the study. We defined three roles ...

11.3.1. The Scout

- The scout greets people and convinces them to join the study.
- The scout administrates the tutorial.

11.3.2. The Host

- The host removes the sensor of finished participants.
- The host straps the sensor on a new participant.
- The host prepares the game-machine.
- The host adjusts the cardboard numbers to the new participants' ID.
- The host explains the process:
    - First five questions.
    - Wait for us to synchronize.
    - Then three levels with short stops in between.
    - Then eleven questions.
- The host coordinates with the technician to synchronize data recording.
    - The host makes sure that the participant has finished the first questions and the 'START' button is visible on the game-machine.
    - The host asks if the participant is ready to play and if the technician is ready to record. Once both agree the host presses 'START' and signals the technician to start recording.
    - ***See the technician preprocess steps.***

11.3.3. The Technician

- **Postprocess.** Performed *after* someone has finished playing.
    - The technician stops the video camera recording.
    - The technician stops the AM recording and saves the results under that participants' ID.
    - The technician restarts Jumper, the AM program.
    - The technician needs to reconnect the AM sensor.
        - Press 'open' on the 'Choose serial port' window. It should be set to COM4.
        - Go to the 'Tools' menu and select 'Recording Graph'.
- **Preprocess.** Performed *before* someone plays.
    - The technician needs to wait for the signal from the host before doing anything.
        - **The host** makes sure that the participant has finished the first questions and the 'START' button is visible on the game-machine.

        - **The host** asks if the participant is ready to play and if the technician is ready to record. Once both agree **the host** presses 'START' and signals the technician to start recording.
- The technician starts the video camera recording.
- The technician WAITS for the beeps that signals play has begun before starting the AM recording.

11.4. Items we must bring

Reynir

- Clean and tidy clothes
- Chair for participants to sit on
- Stickers
- A screen to cover participants whilst they're being filmed
- Video camera
- Laptop
- Tripod
- Multiplugs for electricity x2
- Rubber under the chair
- Extra electricity sockets
- Skrúfjárn
- Tutorial device
- Sticky Tape
- Felt pens
- Accelerometer
- A coin
- The Booth

Ari

- Numerical cards
- Clean and tidy clothes
- Trashbin
- Pen
- Paper
- Cleaning kit
    - Something for the straps
    - Something for the touch devices
- Asus game device
- A poster denoting our school
- Lamp to highlight focus points for the camera
- Mountain Dew!

Daníel

- Clean and tidy clothes
- Laptop