# Analysis of Impression in Exercise while Watching Avatar Movement

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***Abstract*—This paper analyzes impression in an user exercise while watching an avatar movement that performs interaction where actions of human are imitated by using the skeleton model obtained from Kinect sensor. In the interaction, the perception of the level of delay, impression of delay and habituation to the delayed movement of the avatar are investigated through some exercising experiments where the human raises and lowers both arms. For changing the level of delay, we prepare parameter sets with five grades of filter of Kinect library, and also prepare the " precedent movement" and "synchronic movement" to extract the inherent impression for the delayed motion. From the results of the questionnaire for subjects who experience the delayed movement of the avatar, those visual impression are analyzed by One-Way Repeated-Measures ANOVA. The novel habituation based on a certain level in the experience was discussed as follows: For the perception of the level of delay, it became clear that at parameter 3 and above, about 40 % of subject sensed "delayed movement". For the impression of delay, it came to light that the subjects feel uncomfortable with the "delayed movement". For the habituation to the delayed, we found that while the "delayed movement" gave a different impression than the "synchronic movement" and the "precedent movement", it cannot be said that impression differed in the "synchronic movement" and the "precedent movement"**

***Keywords–avatar movement; visual impression; exercise; delayed movement; post hoc analysis; habituation.***

## I. INTRODUCTION

This paper analyzes impression in an user exercise while watching an avatar movement that imitates the user movements, and is the extended version of the paper [1].

Avatar can be projected on a screen in real time by applying humanoid Computer Graphics (CG) on the skeleton model extracted from the human motion capture. By watching the avatar, the user can evaluate one's own motion in real time while moving.

However, in the real-time display of the avatar, in fact, time delay occurs during the process of extracting information from body motion and information process of applying it to humanoid CG. In other words, time delay occurs while the movement of user is reflected and displayed in the avatar.

Time delay is known to affect the human psychology. Many research works have been undertaken regarding this mainly focusing on the interaction between humans and artifacts. It was pointed out that the delay of the computer response time adversely affects psychology [2][3][4]. The psychological influence in the utterance delay was studied well [5][6] and it was found that delay of one second or more has adverse impact, and voice of the conversation tends to increase. The effect of appearance of an artificial agent and utterance time on psychology was studied [7][8][9] and it was shown that higher is the delay, worse are the psychological changes. In the conversation between humans and robots, it was investigated the effect of starting time of utterance by Robot and timing of nodding on the psychology, and revealed that delay gives bad feelings [10][11][12][13][14].

In these studies, it is stated that in the interaction between humans and artifacts, delayed reaction of artifacts to a stimulus from the outside world has a negative impact on the psychology of humans. This impact pertains to usability when a human uses the artifacts, and it must be treated as an important problem. However, these studies consider the cases while verbal communication is taking place, and they do not discuss the effect of time delay in the body motion interaction between humans and artifacts on the psychology.

In this paper, we will analyze impression of the delayed motion of the avatar as an artifact that performs interaction where actions of human are simulated. Motion considered in this paper is swing movement often seen in exercising, where the human raises and lowers both arms. We will have this discussion about perception of the level of delay, impression of delay, and habituation to delay. Here, the level of delay means a quantitative expression of how much the delay a human feels.

We will explain the details of the experiment conducted in this paper for psychological evaluation to analyze impression. Recent software systems of artifacts can adjust the delayed degree of movement with digital filter functions. In other words, it is possible to adjust the delay time in the process of displaying avatar with human motion capture.

Using this, in our experiment, we measured the stage from when the human clearly recognizes it as delay when the delay time is changed in a stepwise manner. Measuring this delayed degree should be useful in offering guidance for improving the avatar system. Here, we assumed that the impression for the delayed motion may be similar to ones for precedent or synchronic motion. So, we set up the both motion to extract the inherent impression for the delayed movement.

Next, we administered a questionnaire survey about the impression the subject got when seeing the avatar that moves according to the movement of the subject. We studied the impression the subject got when the he saw that movement of the avatar is slower than him (hereinafter referred to as the delayed movement) while the subject does the swing movement.

In Section III, in order to obtain the characteristics of this impression, we use different movements than the delayed movement. These are two types of movements, namely, state where movements of the subject and the avatar seem to be

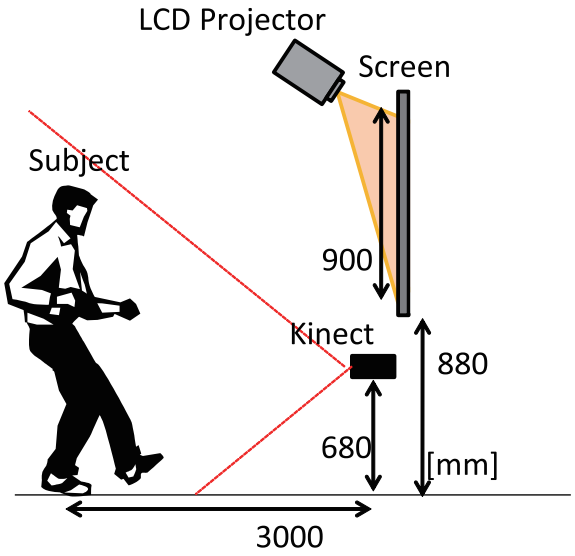


Figure 1. Outline drawing of the experiment setup

matching (hereinafter referred to as the synchronic movement) and the state where movement of the avatar seems to have progressed than that of the subject (hereinafter referred to as the precedent movement). The reason why these two movements are conducted is that the synchronic movement is used for the bench mark and the precedent movement is used to highlight the visual impression for the delay movement.

Then, we will compare impression evaluation and consider habituation to delay. In Section IV, we discuss the results of the comparison. In the last section, the paper is concluded.

## II. Experimental Environment and Method

Hardware used in the experiment is comprised of "Microsoft Kinect for Windows sensor" for measuring the movement of the subject, PC that creates movement of the avatar based on the movement of the subject, and projector and screen for displaying the avatar to the subject.

Figure 1 shows the hardware configuration for measurement of the human motion and the avatar display system. The subject stands in front of the screen and Kinect with 3000 mm distance so that Kinect can detect whole body of the subject. As software, we used Kinect for windows SDK [15] which is the library for obtaining the human motion from the depth data photographed with Kinect and Microsoft XNA Game studio 10 [16] for drawing the avatar. With Kinect for Windows SDK, we can obtain the subject's movement data, and by transferring this data to Microsoft XNA, avatar can display identical movement as the subject.

Figure 2 shows an image of the avatar displayed to the subject during the experiment. The avatar moves to imitates the movement of an user. There are some types of figures of avatar, and we chose a man type as shown in Figure 2 because it is not the most uncomfortable feeling in our preliminary experiments. The skeleton model as shown in Figure 2 is to help the user recognize the movement expressly.

Figure 3 shows the experiment in progress where the subject is moving his body while watching the avatar. Strictly speaking, movements of the avatar and the subject are not synchronized. Rather, after measuring the movement of the subject with Kinect, movement is created in the avatar and after that the avatar will act. Therefore, irrespective of whether the subject realizes or not, movement of the avatar starts with delay. In Kinect, with the filter process, by delaying and advancing the subsequent movement, it is possible to control the delay time from the actual movement.

In this experiment, in the first place, we will measure the level of delay where the subject feels that delay has occurred while gradually increasing the delayed degree of the movement of the avatar. For implementing the delayed movement in the avatar, in this paper, we adjust the parameters of digital filter included in Kinect for Windows SDK v1.8. The filter is based on the Holt Double Exponential Smoothing method for joint position jitter. It is equipped with the smoothing and correcting functions, and it is used for removing the errors in the measurement data where such errors have occurred due to disturbance of measurement conditions and the like in Kinect.

By changing the parameters of this filter, it is possible to have smoothing and estimating effects and cause delay and look ahead in the movement data of the subject obtained with Kinect. Then, by implementing this movement data with delay on the avatar, movement of the avatar will be delayed than the actual movement of the subject.

### A. Setting parameters

As the filter parameters, Prediction $[\geq 0.0]$ and Smoothing $[0.0, 1.0]$ are available. Although SDK provides "MaxDeviationRadius" and "JitterRadius", these two parameters are not adopted for changing avatar's motion, because these two parameters determine the region of compensation of jitter and these dimension is [m]. "Prediction" and "Smoothing" are adopted. The Value of Prediction is for estimating the movement, and its value is the number of frames that predicts the movement (Kinect's frame rate is 30 [fps]). Its default value is 0.0, and it tends to overshoot from around 0.5 (default value). So, we used the values in the range of 0.4 and below for delay movement. Value of Smoothing is the smoothing index. When it is 0.0, there is no delay, and when it is 1.0, delay is at the maximum. Default value is 0.5, and based on our experience, we selected values equal to or higher than this value.

Table I shows the perceived level of delay in five stages as the level of delay with respect to the delayed movement in this experiment.

TABLE I. Perceived level with respect to delay

| Parameter set # | Prediction, Smoothing |
|---|---|
| 1 (minimum delay) | Prediction=0.4, Smoothing=0.5 |
| 2 | Prediction=0.3, Smoothing=0.6 |
| 3 | Prediction=0.2, Smoothing=0.7 |
| 4 | Prediction=0.1, Smoothing=0.8 |
| 5 (maximum delay) | Prediction=0.0, Smoothing=0.9 |

We will now explain about the method of creating this perceived level. During the course when the subject moves his body while watching the avatar displayed on the screen, we gradually changed the parameter value using the Smoothing function of Kinect. When increasing the parameter of Smoothing, the movement of the avatar will not be able to keep up with the movement of the subject, and movement will become sluggish. This state where the avatar hardly move is considered

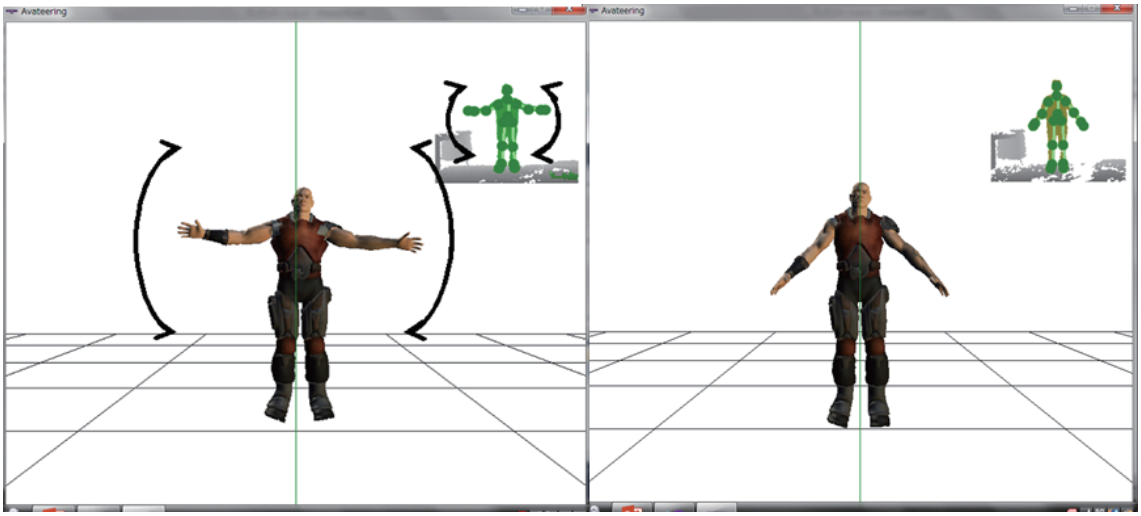

Figure 2. Avatar (a man type) doing the swing movement and skeleton model (green colored), arm up (left figure) and arm down (right figure)

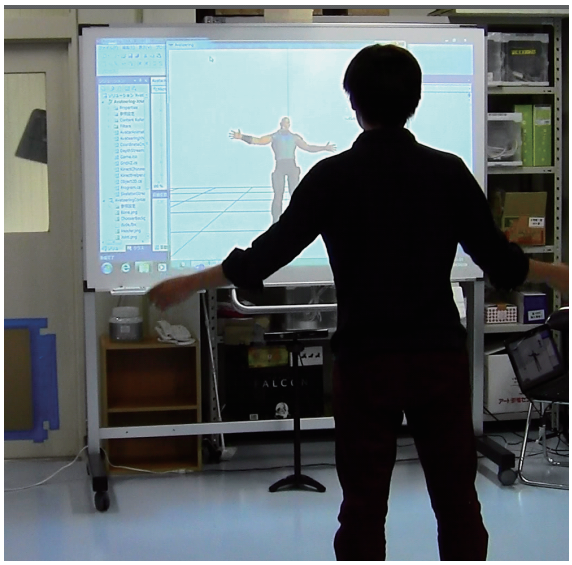

Figure 3. Experiment in progress

as maximum delay. Against this, the state where the movement of avatar appears to be synchronous with the subject himself is considered as minimum delay, and this interval was divided into 5 stages.

Subject's movement of raising and lowering arms while watching the avatar was aligned to the metronome of 100 BPM (Beat Per Minute) = 1.67 Hz, because the movement of subjects should be controlled in order to keep the frequency of the subject's movement, for the purpose of this paper. The sound of a metronome, therefore, was adopted as the standard sign for keeping the frequency of the movements.

Parameter set #1 through #5 shown in Table I was changed every 5 seconds. The subject would move his body for every parameter set. After that the subject was asked "Do you think that the avatar you just saw was delayed compared to your movement?" Subject's response was collected in Yes / No or Possibly as shown in Table II. This was repeated 5 times, and response data was collected and summarized.

TABLE II. Parameter set of percedence and synchronization

| | Parameter set |
|---|---|
| Precedent | Prediction=0.5, Smoothing=0.5 |
| Synchronization | Prediction=0.5, Smoothing=0.5 |

For verifying impression evaluation with respect to delayed movement, we thought that it is necessary to have another comparison target. Based on this, we designed "synchronic movement" and "precedent movement". The former one synchronizes with the movement of the subject, while the latter one advances the phase of movement using differential operation. This was also implemented by using the parameters of filter function of Kinect.

The parameters of "synchronic movement" adopted "Prediction = 0.5" (default value of the SDK). On the other hand, the parameters of "precedent movement" were determined by the preliminary experiment. "precedent movement" is the avatar's motion which is lead movement to the subject. The value of 1.0 is the highest prediction value and 0.5 is the default value of synchro motion. Here, there is a question: How step size of prediction parameter between maximum prediction and default prediction value should be determined and presented to subjects by being implemented to the avatar's motion? In this preliminary experiment, the value of 1.0 and 0.75 (the middle value between 1.0 and 0.5) were tentatively selected, and were implemented to avatar's motion to present their motions to subjects. If the subjects do not feel difference between two motions by two values, there is no need to select both values as the parameter for forming "precedent movement".

In order to verify this, we prepared two prediction values as 0.75 and 1.0, and verified the differences of the avatar's motions driven by two values. Here, 14 subjects participated in, and swung their arms with aligning to the metronome of 100 BPM while watching avatar's motion with above mentioned

two values. Then they were asked "Did you feel difference between two avatar's movement? ".

As the results, 10 subject could not distinguish 0.75 from 1.0, and 1 subject distinguished the difference. Therefore, there is no distinct difference between two values from the binomial test: $p = 0.012 < 0.05$, null hypothesis which is human impressions of two movements are different was rejected.

Thus we adopted 1.0 being the maximum value of prediction for "precedent movement". These parameters are shown in Table III.

TABLE III. Responses where the subjects felt that the movement is delayed with respect to the parameter set in Table I

| | | delay | possibly delay | not delay | total |
|---|---|---|---|---|---|
| Parameter set 1 Prediction=0.4, Smoothing=0.5 | number | 0 | 0 | 14 | 14 |
| | rate (%) | 0.0 | 0.0 | 100.0 | 100 |
| Parameter set 2 Prediction=0.3, Smoothing=0.6 | number | 0 | 8 | 6 | 14 |
| | rate (%) | 0.0 | 57.1 | 42.9 | 100 |
| Parameter set 3 Prediction=0.2, Smoothing=0.7 | number | 6 | 6 | 2 | 14 |
| | rate (%) | 42.9 | 42.9 | 14.3 | 100 |
| Parameter set 4 Prediction=0.1, Smoothing=0.8 | number | 6 | 6 | 2 | 14 |
| | rate (%) | 42.9 | 42.9 | 14.3 | 100 |
| Parameter set 5 Prediction=0.0, Smoothing=0.9 | number | 10 | 4 | 0 | 14 |
| | rate (%) | 71.4 | 28.6 | 0.0 | 100 |

### B. Experimental procedure

By using above mentioned parameters, we used three movements, namely, "delayed movement", "synchronic movement" and "precedent movement" in this experiment. The "synchronic movement" is placed as a bench mark to measure objectively, to compare, and to evaluate the difference of the impression. The following experiment was carried out for impression evaluation.

[Step 1] In the first place, in order to have the experience of the delayed movement of the avatar, while watching the avatar moving as per the settings of #3 in Table I, the subject moved his body for about 5 seconds along with the sounds of metronome and experienced the delayed movement of the avatar. Similarly, the subject moved his body for about 5 seconds for the precedent movement (Precedence in Table II) and the synchronic movement (Synchronization in Table II) and experienced these movements.

[Step 2] In order to find out perception of the level of delay, we changed the parameter set in Table I from #1 to #5 at every 5 seconds. Every time when changing the parameter, we asked the subject whether the movement is delayed or not.

[Step 3] Next, we find out how the impression regarding delayed differs from synchronic movement and precedent movement. For that, for each subject, we run the delay movement using the parameter sets in Table I for which the subjects felt the delay, and we changed the movements of avatar as per the following patterns.

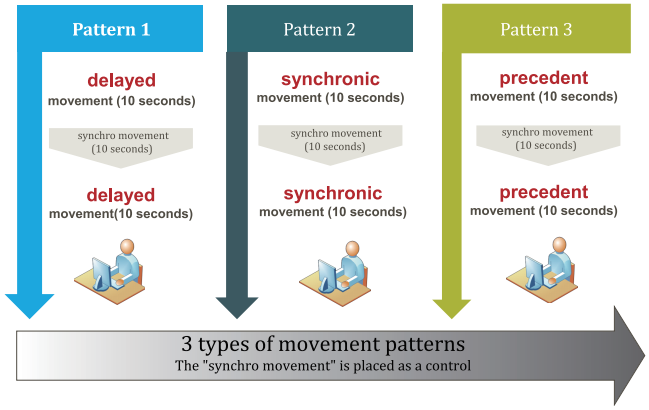


Figure 4. Outline drawing of the experiment setup

[Pattern 1] delayed movement (10 seconds) → synchronic movement (10 seconds) → delayed movement (10 seconds)

[Pattern 2] synchronic movement (10 seconds) → synchronic movement (10 seconds) → synchronic movement (10 seconds)

[Pattern 3] precedent movement (10 seconds) → synchronic movement (10 seconds) → precedent movement (10 seconds)

These patterns were created based on the concept of placing the synchronic movement at the middle position, and placing three types of movement patterns on both sides. Figure 4 shows an experiment flow.

In this experiment, there were 14 subjects, all males in their 20s. As for the sequence of the experiment, after completing [Step 1], subjects went to [Step 2], and after that they went to [Step 3]. [Step 1] is preparation for the experiment to be conducted here onwards.

## III. Analysis of Impression Evaluation

This section explains the analysis of the impression of the subjects. First, the evaluation items are explained.

### A. Evaluation items

Restating the explanation given in Section II, the following are the evaluation items in impression evaluation.

P1: From what stage does the subject sense "delay" in the movement of the avatar? This leads to perceptual evaluation of the level of delay.

P2: What kind of the impression the subject forms regarding delayed movement of the avatar?

P3: Look into impression of each movement of the avatar, and see if there are any differences in the evaluation of each pattern. This leads to finding out habituation to delay.

For investigating P1, we conducted the experiment mentioned in [Step 2] in the preceding section. For investigating

P2 and P3, we conducted the experiment mentioned in [Step 3].

### B. Analysis of P1

Response data for three perceptions, namely, the movement of the avatar is "delay", "possibly delay", and "not delay", was summarized for each parameter set. Table III shows the results of this.

From the results in Table III, for parameter set #3 and above, about 40% of the subjects responded that the movement of the avatar is "delayed". For parameter set #2 and above, about half of the subjects responded that the movement of the avatar is "possible delayed". Smoothing of parameter set #2 is set only slightly higher than the default value, and it resulted in somewhat ambiguous perception.

In the case of parameter set #4 and #5, the subjects are divided into two groups, namely, group that clearly recognized that the movement is "delayed" and the group that vaguely sensed the delay. However, this excludes a small number of subjects who responded that the movement is "not delayed". In the case of parameter set #5, about 70% of the subjects recognized that the movement of the avatar is clearly "delayed".

Based on these results, it came to light that the subjects sense the "delayed movement" of the avatar from parameter #3 onwards. At the stage of parameter set #2, the subjects may not sense that the movement is delayed.

### C. Analysis of P2

In P2, we administered a questionnaire survey to find out the kind of impression with respect to the "delayed movement" of the avatar. Simultaneously, apart from the "delayed movement", we also studied the "synchronic movement" and the "precedent movement".

The method of data collection which was taken up in our questionnaire survey of experiment is "Semantic Differential Method" (SD method) [17]. The SD method aims at the evaluation of the object in the test that investigates the impression of the panel. It is the method which uses the pair of adjectives of the opposite meaning. In the SD method, the pair of adjective often results in three factors such as good-bad for evaluation, powerful-powerless for potency and fast-slow for activity [18]. We referred to the previous studies [19][20] related to impression evaluation of the movement of robot, we made the pair of adjective which applied the three basic factors of impressions (activity, potency, evaluation) defined for the SD method. Then we prepared 13 pairs of adjectives shown in Table IV and we conducted evaluation in 7 stages.

The impression questionnaire for Table IV was applied for three movements; delayed, synchronic and precedent.

The answers of the questionnaire were collected from 14 subjects. Next, we transformed the answeres by following procedure.

1) The seven stages of collected data for Table IV is classified into three categories (1-3/4/5-7) which are assigned to values of 1 or 0. For examples, the item no.1 includes two adjectives "fast" and "slow", they are assigned to values of 1 and 0 when the stages is within 1-3, respectively. The both are assigned to values of 0 and 1 when the stages be within 5-7. The both are 0 when the stages be 4. Here, there are 26 adjectives in 13 items. An illustrative example of classified result by this operating is shown in Figure 5.
2) The total amount of counting up the values for each adjective for three movements are used for the correspondence analysis [21]

TABLE IV. Impression questionnaire items for P2

| No | factor | Evaluation Items | | |
|---|---|---|---|---|
| 1 | activity | fast | ⇔ | slow |
| 2 | activity | smooth | ⇔ | awkward |
| 3 | evaluation | like myself | ⇔ | like others |
| 4 | activity | anticipated | ⇔ | unanticipated |
| 5 | evaluation | comfortable | ⇔ | uncomfortable |
| 6 | potency | soft | ⇔ | rigid |
| 7 | potency | sudden | ⇔ | not sudden |
| 8 | evaluation | favorable | ⇔ | disagreeable |
| 9 | evaluation | interesting | ⇔ | boring |
| 10 | potency | rough | ⇔ | calm |
| 11 | activity | sensitive | ⇔ | insensitive |
| 12 | evaluation | friendly | ⇔ | unfriendly |
| 13 | potency | natural | ⇔ | unnatural |

| Subject No. | | | 1 | 2 | 3 | | 14 |
|---|---|---|---|---|---|---|---|
| questionnaire items | 1 | fast | 1 | 0 | 1 | | 0 |
| | | slow | 0 | 0 | 0 | | 1 |
| | 2 | smooth | 1 | 1 | 0 | | 0 |
| | | awkward | 0 | 0 | 0 | | 0 |
| | ≈ | ≈ | ≈ | ≈ | ≈ | ≈ | ≈ |
| | 13 | natural | 0 | 0 | 0 | | 0 |
| | | unnatural | 1 | 0 | 1 | | 1 |

Figure 5. Illustrative example of classified result by operating with 1) for Table IV , each cell takes a value of 1 or 0

Here, the correspondence analysis is one of the methodologies that statistically analyze the frequency data. It is a useful method for the analysis of the data in the questionnaire survey. One of the goals of correspondence analysis is to describe the relationships between two nominal variables in a correspondence table in a low-dimensional space, while simultaneously describing the relationships between the categories for each variable. For each variable, the distances between category points in a plot reflect the relationships between the categories with similar categories plotted close to each other.

Figure 6 shows the results of the correspondence analysis. The following can be concluded from the results shown in Figure 6.

- Our finding is that the impression formed for "delayed movement" is different from that for "synchronic movement" and " precedent movement".
- On the other hand, it cannot be said that the impression

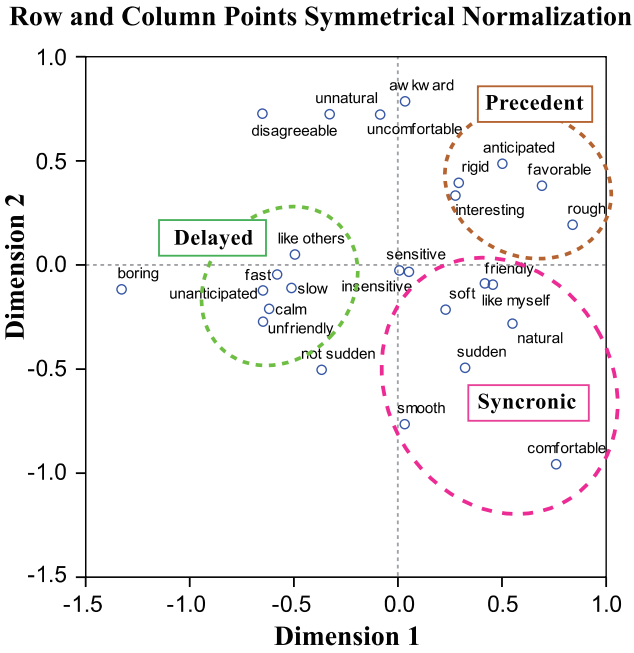


Figure 6. Results of correspondence analysis

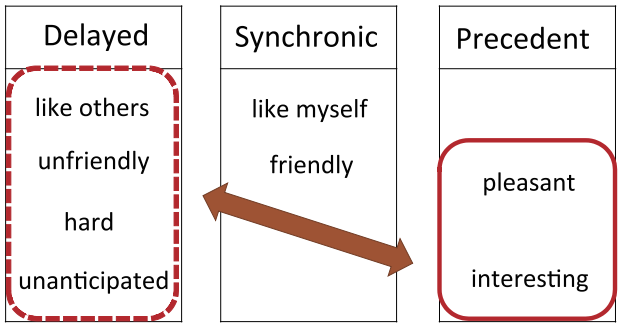


Figure 7. Typical impression of 3 types of movements

differs between ”synchronic movement” and” precedent movement”.

- For the ”delayed movement”, the subjects formed the impressions such as ”like other human”, ”unexpected”, and ”unfriendly”, and other impressions such as ”fast and slow” and ”moderate” based on the speed of movement.
- Figure 7 shows summary of findings by evaluation items. In precedent movement, even if movement was not synchronized, the result made a something good impression. Subjects felt it was pleasant and interesting. We found precedent movement made a better impression than delayed movement. This finding is in contrast with the impression of delayed movement.
- For ”synchronic movement”, the subjects formed the impressions such as ”smooth”, ”natural”, ”like oneself”, ”enjoyable”, ”soft”, and ”comfortable”.
- Subjects formed the impression that the ”precedent movement” was ”hard” and ”intense”. However, some of the subjects responded that they formed the impressions such as ”interesting”, ”as expected”, and ”pleasant”.
- As compared to the ”synchronic movement”, the subjects clearly realized the difference in the movement in the ”delayed movement”. The subjects felt uncomfortable that the movement of avatar did not match with their movement.
- There were some subjects who favorably treated the ”delayed movement” as smooth movement. However, in terms of the overall trend, subjects had a negative impression of the ”delayed movement”.
- Impression became positive in the case of the ”synchronic movement”.
- In the ”precedent movement”, while there was negative impression, simultaneously, the subjects also found it ”interesting” and ”pleasant”.
- In the settings of the ”precedent movement”, in the present Kinect, the avatar reacted acutely to the speed of exercising in the subjects, which formed the impression such as ”hard” and ”intense”. However, there were opposite responses to this impression such as ”interesting”, ”as expected” and ”pleasant”.
- We continuously examined whether there were any significant differences between the means of these three movement groups.

### D. Analysis of P3

In the subsection $C$, we mentioned that apart from ”hard” and ”intense” that was the impression evaluation with respect to the ”precedent movement”, subjects formed the impression of ”interesting”, ”as expected” and ”pleasant” as in the case of ”synchronic movement”. Because it was found that the subjects formed similar impression in these two movement patterns, we will verify whether there are any differences in impression between the ”synchronic movement” and the ”precedent movement”. From the point of view, P3 was designed.

The goal of this analysis was to compare means of the variable for the combinations of the three movements. We carried out impression evaluation for the experiment [Step 3] where three types of movements, namely, ”delayed movement”, ”synchronic movement”, and ”precedent movement” are combined. Here, data group for each of three types of movements of avatar were named as data group of movements.

We set the hypothesis that ”there is no difference between levels due to the data group of movement”, and we carried out corresponding one-way analysis of variance (Repeated measures ANOVA)[22],. ANOVA is a ”group comparison” that determines whether a statistically significant difference exists somewhere among the groups studied. If a significant difference is indicated, ANOVA is usually followed by a multiple comparison procedure that compares combinations of groups to examine further any differences among them.

Table V was made to be given to ANOVA in the next analysis and it shows the average value of response data obtained from 14 subjects for three movements.

TABLE V. Impression evaluation results using the SD method

| Evaluation Items | Average Value of Response Data | | |
|---|---|---|---|
| | Delayed | Synchronic | Precedent |
| 1 | 4.86 | 3.57 | 3.57 |
| 2 | 4.00 | 3.14 | 4.00 |
| 3 | 4.57 | 3.43 | 3.29 |
| 4 | 4.57 | 4.00 | 3.71 |
| 5 | 4.14 | 3.00 | 3.71 |
| 6 | 4.14 | 3.71 | 4.43 |
| 7 | 4.86 | 4.14 | 4.00 |
| 8 | 4.14 | 3.29 | 2.71 |
| 9 | 3.86 | 3.29 | 3.00 |
| 10 | 4.86 | 3.71 | 3.71 |
| 11 | 4.00 | 4.14 | 4.00 |
| 12 | 4.71 | 3.43 | 3.14 |
| 13 | 4.71 | 3.43 | 3.57 |

Table VI shows the results of the one-way analysis of variance (Repeated measures ANOVA) which is used to determine whether there are any significant differences between the means of two or more groups.

Results in Table VI showed statistical significant in the group of movement from the significance level ($p < 0.05$). Accordingly, the hypothesis "There is not difference between the groups" was accepted, and it can be said that the impression formed in the subjects for three movements of the avatar are different. The effect of Evaluation items, by contrast, did not reach conventional levels of statistical significance.

Furthermore, in order to shed light on the difference between movements of different phase, we used the Turky's method [23], and conducted multiple comparison. Table VII shows the results of this comparison.

Based on these results, it is evident that in the movements of the avatar, "delayed movement" and "synchronic movement", and "delayed movement" and "precedent movement" are statistically significant ($p < 0.05$). In other words, the impression formed for "delayed movement" is different from that for "synchronic movement" and "precedent movement". On the other hand, it cannot be said that impression differs for "synchronic movement" and "precedent movement". Figure IV shows a plots with observed means of Data group in Table VI.

The two-way interaction between the Data group and the Evaluation items in Table VI had a non-significant effect, it probably does not make sense to look at the results. However, this is for amount of all adjective pairs, not for each adjective pair. So we thought further investigation for each adjective is needed.

We investigated the results in Table VI for each adjectives and for three movements. Figure 9 shows the observed means of the Evaluation items in Table VI. In this figure, a line shows a mean data of a prepared Evaluation items, and 13 polygonal lines corresponding to the adjective pair shows parallel each other.

Investigating the results in Figure 9, the evaluation items in Table VI were divided into two groups as shown in Table VIII. Group 1 is an evaluation word directly connected with a movement of the appearance and Group 2 is a stable impression words because the experiment was repeated. The chart was made using a mean of the data collected from our experiment, we could see the change pattern of the evaluation words.

TABLE VI. Test Results of Effect between Subjects

Dependent Variable:

| Source | | Type III Sum of Squares | Degree of freedom | Mean square | F value | Significance level |
|---|---|---|---|---|---|---|
| Intercept | Hypothesis | 8138.579 | 1 | 8138.579 | 624.110 | .000 |
| | Error | 169.524 | 13 | 13.040[a] | | |
| Data group | Hypothesis | 84.806 | 2 | 42.403 | 17.757 | .000 |
| | Error | 1179.619 | 494 | 2.388[b] | | |
| Evaluation items | Hypothesis | 42.183 | 12 | 3.515 | 1.472 | .131 |
| | Error | 1179.619 | 494 | 2.388[b] | | |
| Subject No. | Hypothesis | 169.524 | 13 | 13.040 | 5.461 | .000 |
| | Error | 1179.619 | 494 | 2.388[b] | | |
| Data group * Evaluation items | Hypothesis | 41.289 | 24 | 1.720 | .720 | .832 |
| | Error | 1179.619 | 494 | 2.388[b] | | |

a. Mean square(id), b. Mean square (Error)

TABLE VII. Results of Multiple Comparison

Dependent Variable: Tukey HSD

| Movement | | Difference in average value (a)-(b) | Standard error | Significance level | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| (a) | (b) | | | | Lower limit | Upper limit |
| Deleyed | Syncronic | .86* | .162 | .000 | .48 | 1.24 |
| | Precedent | .81* | .162 | .000 | .43 | 1.19 |
| Syncronic | Deleyed | -.86* | .162 | .000 | -1.24 | -.48 |
| | Precedent | -.04 | .162 | 0.960 | -.42 | .34 |
| Precedent | Deleyed | -.81* | .162 | .000 | -1.19 | -.43 |
| | Syncronic | .04 | .162 | 0.960 | -.34 | .42 |

Based on observed average value.Error value is mean squqre(error)=2.388

The error term is Mean Square(Error) = 2.388.

* Difference is averae value is significant at 0.05 level.

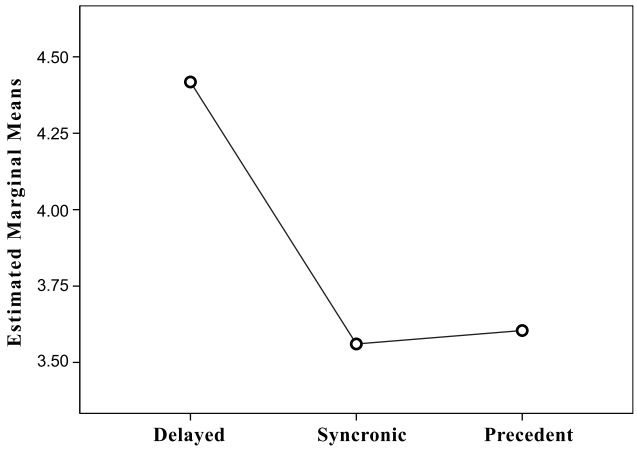


Figure 8. Estimated Marginal Means of score of Movement

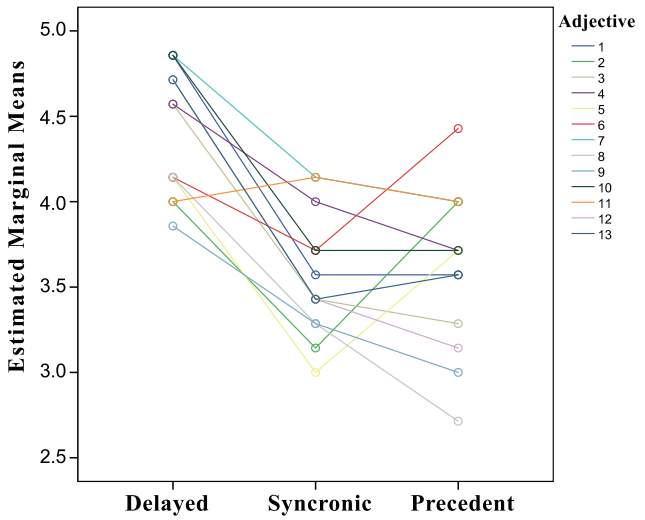


Figure 9. Estimated Marginal Means of score of Movement

TABLE VIII. Group of Evaluation Words

| Group 1 | Words of directly connected with movement Evaluation Items | | |
|---|---|---|---|
| 2 | smooth | ⇔ | awkward |
| 5 | comfortable | ⇔ | uncomfortable |
| 6 | soft | ⇔ | rigid |
| Group 2 | Words of stable impression Evaluation Items | | |
| 3 | like myself | ⇔ | like others |
| 4 | anticipated | ⇔ | unanticipated |
| 8 | favorable | ⇔ | disagreeable |
| 9 | interesting | ⇔ | boring |
| 12 | friendly | ⇔ | unfriendly |
| 13 | natural | ⇔ | unnatural |

Table VIII shows the group of evaluation words; ”soft - rigid”, ”smoothly - awkward” and ”comfortable - uncomfortable” and these are shown as the line in Figure 9. It is found that those shapes are forms as a V-shape and it is the same reaction at ”delayed movement” and ”precedent movement”. This group have the pair of adjectives of activity or potency factor defined by the SD method.

On the other hand, ”natural - unnatural ”,”anticipated - unanticipated ”, ”interesting - boring” and ”like myself - like other” these pair of adjectives it is the same reaction at ”synchronic movement” and ”precedent movement”. This group have almost the pair of adjectives of Evaluation factor; for example, good-bad for evaluation, defined by the SD method.

## IV. Discussion

In this section, we discuss the results obtained in the experiments described in the previous section.

For the results of P1, the response data for three perceptions, namely, the movement of the avatar is ”delayed”, ”possibly delayed”, and ”not delayed”, was summarized for each parameter set. Table III shows the results of this. We conducted experiment and quantitatively define the level of delay where the subjects recognize that the movement of the avatar is ”delayed” than their movement, and we ascertained the stage of this level. As a result, it became clear that at parameter set 3 and above, about 40% of subject sensed ”delayed movement” where the movement in the avatar was delayed compared to the subjects’ movement.

For the result for P2, some features are described by considering the results of the correspondence analysis in Figure 6. Figure 6 shows summary of findings by evaluation items. In precedent movement, even if movement was not synchronized, the result showed a something good impression. It is found that the precedent movement made a better impression than delayed movement. This finding is in contrast with the impression of delayed movement. Furthermore, it came to light that the subjects feel uncomfortable with the ”delayed movement”. In the ”synchronic movement” experienced by the subjects after the delayed movement, they formed the impressions such as ”natural”, ”like oneself”, and ”amiable”, and in the ”precedent movement”, the subjects formed the impressions such as ” hard” and ”intense”, as well as ”interesting”, ”as expected”, and ”pleasant”.

In the experiments for P3, we verified by using the repeated measures ANOVA whether there is any difference in the impression evaluation of each of three types of movements of the avatar confirmed in P2, namely, ”delayed movement”, ”synchronic movement”, and ”precedent movement”. From the results in Table VI and VII, it is evident that in the movements of the avatar, ” delayed movement ” and ” synchronic movement”, and ”delayed movement” and ”precedent movement” are statistically significant ($p < 0.05$). In other words, the impression formed for ”delayed movement” is different from that for ”synchronic movement” and ”precedent movement”.

Following these results and the results shown in Figure and Figure 9, we execute post hoc analysis. Here, we found that while the ”delayed movement” gave a different impression than the ”synchronic movement” and the ”precedent movement”, it cannot be said that impression differed in the ”synchronic movement” and the ”precedent movement”. From our experiments, it is found that there was an interaction partially, not a whole of interaction. It is significant to check the pattern of data to judge whether there is an interaction.

As for the impression of the ”precedent movement”, the impression evaluation was ”interesting”, ”as expected” and ”pleasant”, which was most likely because of habituation [24][25][26] in perception in terms of mitigation of the sense of discomfort to time delay and adverse psychological effect, becoming insensitive. From the interviews to subjects, some of them felt comfortable by watching the precedent movement of the avatar. They tried to follow the precedent movement at first, then as watching the repeated movement they had an illusion eventually as if the avatar would be a instructor and teach them an exercise to shaking up and down the arms. It is though that the reason why is some of peoples feel comfortable by following a certain instruction from the instructor.

This habituation differs from simple stimulation mentioned in the preceding studies [27][28][29][30] and reactive habituation [31][32][33][34] that occurs due to iterative presentation of irritation. Habituation showed by these results are similar to habituation explained by [35][36] in terms of order effect where after experiencing the ”synchronic movement”, the subjects become insensitive to the delay of the movement.

We think this effect based on the order is a new finding

that the order of movement patterns affects psychology. Now, we have not considered the mechanism of the effect precedent exactly, but we can say that the effect seems to be originated in the “Internal Clock”[37] of human beings. It is said that the Internal Clock sometimes varies caused by an extra disturbance such as the order effects and makes us misunderstand that two distances between the ”delayed movement” and the ”synchronic movement”, and between the ”synchronic movement” and the ”synchronic movement” are same.

However, we have used only three patterns of order in this experiment, and our next challenge is to study and discuss changes in impression and habituation for different order of movements. The aim of new experiment is to see whether the impression of three patterns of exercise with avatar change by another order under same conditions.

## V. Conclusion

This paper analyzed impression in an user exercise while watching an avatar delayed movement that imitates the user movements. In our experiments, the avatar moves to imitates the movement of the subjects and the speed of the avatar's movement is changed by varying the parameters of the SDK which conducts and controls the avatar movement. We conducted the movement of the avatar as the ”delayed movement”, the ”synchronic movement” and the ”precedent movement”

To define the speed, we shed light on the numerical value of the level of delay based on the experiment where the subject recognizes that the movement of the avatar is ”delayed” from his movement, and we verified its stage. Next, we conducted a survey about impression formed by the subject regarding the avatar that moves out of synchronization with the subject.

We set some novel assumptions to be tested by using the ordinary statistical methods, it is pointed out that the visual impression for the delayed movement of the avatar shows not only a usual situation but also varying situation under the conditions which is the context with the ”precedent” and ”synchronic” movement.

To test the importance of this factor, the new work need to be executed by some patterns with various orders. And in the future work, the authors will strive to increase the number of subject and the patterns with various movements to improve the accuracy of the analysis.

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