Evaluation of Visual Impression of Delayed Movement of Avatar while Exercising

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***Abstract*— This paper considers psychological evaluation of the visual impression of the delayed movement of an avatar 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. From the results of the questionnaire for subjects who experience the delayed movement of the avator, those visual impression are analyzed and the novel habituation based on a certain level in the experience is discussed.**

Keywords-delayed movement;avator;visual impression; habituation.

I. INTRODUCTION

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 seeing 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 [1],. The psychological influence in the utterance delay was studied well [2],[3], 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 [4],[5], 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 [6],[7],.

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 discuss about psychological evaluation of the visual 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. 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.

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 3, 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 matching (hereinafter referred to as the synchro movement) and the state where movement of the avatar seems to have progressed than that of the subject (hereinafter referred to as the lead movement). The reason why these two movements are conducted is that the synchro movement is used for the bench mark and the lead motion is used to highlight the visual impression for the delay movement. Then, we will compare impression evaluation and consider habituation to delay.

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II. EXPERIMENTAL ENVIRONMENT AND METHOD

Hardware used in the experiment is comprised of Microsoft Kinect 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. As software, we used Kinect for windows SDK [8], which is the library for obtaining the human motion from the depth data photographed with Kinect and Microsoft XNA [9] ,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. 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.

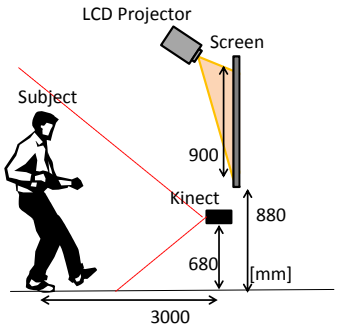

Figure. 1. Outline drawing of the experiment setup.

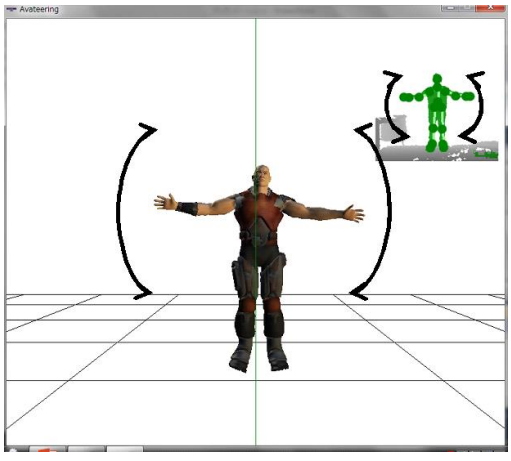

Figure. 2. Avatar (in the middle of the Figure) doing the swing movement

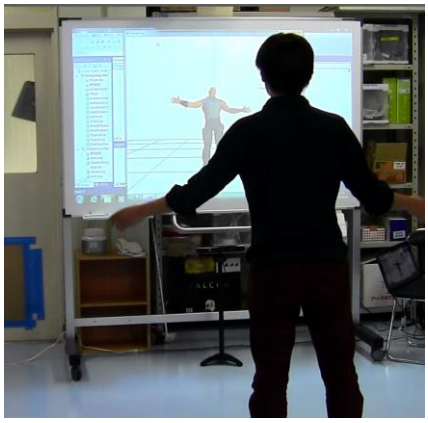

Figure. 3. Experiment in progress.

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. This filter is equipped with the smoothing function, and it is used for removing the errors in the measurement data where such errors have occurred due to disturbance of shooting conditions and the like in Kinect. By changing the parameters of this filter, it is possible to have smoothing effect and cause delay 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.

As the filter parameters, Prediction [>=0.0] and Smoothing [0.0 , 1.0] are available. Value of Prediction is the number of frames that predicts the movement. Its default value is 0.0, and it tends to overshoot from around 0.5. So, we used the values in the range of 0.4 and below. 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.

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 as maximum delay. Against this, the state where the movement of avatar appears to be

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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

TABLE II. PARAMETER SET OF LEAD AND SYNCHRONIZATION

Parameter set	Prediction, Smoothing
Lead	Prediction=1.0, Smoothing=0.5
Synchronization	Prediction=0.5, Smoothing=0.5

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 too to the metronome of 100BPM (Beat Per Minute). 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 III. This was repeated 5 times, and response data was collected and summarized.

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 "synchro movement" and "lead 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 implemented using the parameters shown in Table II.

In this experiment, we used three movements, namely, "delayed movement", "synchro movement", and "lead movement". The "synchro 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 lead movement (Lead in Table2) and the synchro movement (Synchronization in Table 2) 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 synchro movement and lead 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.

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

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

[Pattern 3] lead movement (10 seconds) → synchro movement (10 seconds) → lead movement (10 seconds)

These patterns were created based on the concept of placing the synchro movement at the middle position, and placing three types of movement patterns on both sides.

In this experiment, there was 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

A. *Evaluation Items*

Restating the explanation given in Chapter 2, 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 "delayed", "possibly delayed", and "not delayed", 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

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

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 "synchro movement" and the "lead movement". With regard to the pair of adjectives used in this method, we referred to the previous studies [10], [11] ,related to impression evaluation of the movement of robot, and we prepared 13 pairs of adjectives shown in Table IV and we conducted evaluation in 7 stages.

Table V shows the average value of response data obtained from 14 subjects for three movements. Next, from the data group of each movement, in order to find out relationship with the respective impression evaluation, we conducted correspondence analysis [12], on the results shown in Table V. Figure. 4 shows the outcome of this analysis.

The following can be concluded from the results shown in Figure. 4.

- 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
- For “synchro movement”, the subjects formed the impressions such as “smooth”, “natural”, “like oneself”, “enjoyable”, “soft”, and “comfortable”.
- Subjects formed the impression that the “lead 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 “synchro movement”, the subjects clearly realized the difference in the movement in the “delayed movement”. The subjects felt uncomfortable that the movement of avatar didn’t match with their movement.
- There were some subjects who favorably treated the “delayed movement” as smooth movement. However,

TABLE IV. IMPRESSION QUESTIONNAIRE ITEMS FOR P2

Evaluation Items			
1	Fast	⇔	Slow
2	Smooth	⇔	Awkward
3	Like oneself	⇔	Like other human
4	As expected	⇔	Unexpected
5	Comfortable	⇔	Uncomfortable
6	Soft	⇔	Hard
7	Sudden	⇔	Not sudden
8	Pleasant	⇔	Unpleasant
9	Interesting	⇔	Boring
10	Intense	⇔	Moderate
11	Susceptible	⇔	Insusceptible
12	Amiable	⇔	Unfriendly
13	Natural	⇔	Unnatural

TABLE V. IMPRESSION EVALUATION RESULTS USING THE SD METHOD

Evaluation items	Average Value of Response Data		
	delay	synchro	lead
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

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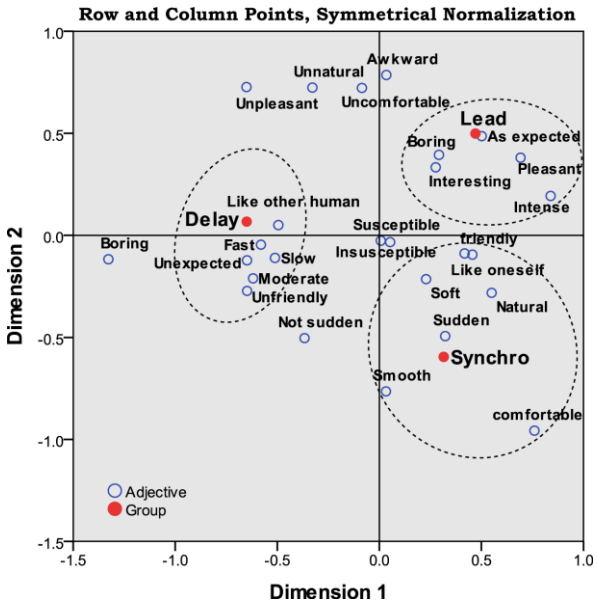

Figure. 4 Results of correspondence analysis.

in terms of the overall trend, subjects had a negative impression of the “delayed movement”.

- Impression became positive in the case of the “synchro movement”.
- In the “lead movement”, while there was negative impression, simultaneously, the subjects also found it “interesting” and “pleasant”.
- In the settings of the "lead 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".

D. *Analysis of P3*

In the preceding paragraph, we mentioned that apart from "hard" and "intense" that was the impression evaluation with respect to the "lead movement", subjects formed the impression of "interesting", "as expected" and "pleasant" as in the case of "synchro 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 "synchro movement" and the "lead movement". From the point of view, P3 was designed.

We carried out impression evaluation for the experiment [Step 3] where three types of movements, namely, "delayed movement", "synchro movement", and "lead 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)[13],.

TABLE VI. TEST RESULTS OF EFFECT BETWEEN SUBJECTS

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]		
Subject No.	Hypothesis	84.806	2	42.403	17.757	.000
	Error	1179.619	494	2.388[b]		
Data group	Hypothesis	42.183	12	3.515	1.472	.131
	Error	1179.619	494	2.388[b]		
Evaluation items	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: Bonferroni

Movement (a)	Movement (b)	Difference in average value (a) - (b)	Standard error	Significance level	95% Confidence Interval Lower limit	95% Confidence Interval Upper limit
Delay	Synchro	.86*	.162	.000	.47	1.25
	Lead	.81*	.162	.000	.42	1.20
Synchro	Delay	-.86*	.162	.000	-1.25	-.47
	Lead	-.04	.162	1.000	-.43	.35
Lead	Delay	-.81*	.162	.000	-1.20	-.42
	Synchro	.04	.162	1.000	-.35	.43

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

* Difference in average value is significant at 0.05 level.

Table VI shows the results of this analysis. The one-way analysis of variance (Repeated measures ANOVA) 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 class of movement from the significance level ($p < 0.01$). Accordingly, the hypothesis "There is not difference between the levels" was rejected, and it can be said that the impression formed in the subjects for three movements of the avatar are different.

Furthermore, in order to shed light on the difference between movements of different phase, we used the Bonferroni's method [14], 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 "synchro movement", and "delayed movement" and "lead movement" are statistically significant ($p<0.05$). In other words, the impression formed for "delayed movement" is different from that for "synchro movement" and "lead movement". On the other hand, it cannot be said that impression differs for "synchro movement" and "lead movement".

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IV. DISCUSSION AND CONCLUSION

In the present paper, 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.

To start with, as the results of P1 stated in this paper, 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 3 and above, about 40% of subject sensed "delayed movement" where the movement in the avatar was delayed compared to the subjects' movement.

Next, as the result for P2, it came to light that the subjects feel uncomfortable with the "delayed movement". In the "synchro movement" experienced by the subjects after the delayed movement, they formed the impressions such as "natural", "like oneself", and "amiable", and in the "lead movement", the subjects formed the impressions such as " hard" and "intense", as well as "interesting", "as expected", and "pleasant".

In P3, we verified 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", "synchro movement", and "lead movement". Here, we found that while the "delayed movement" gave a different impression than the "synchro movement" and the "lead movement", it cannot be said that impression differed in the "synchro movement" and the "lead movement". As for the impression of the "lead movement", the impression evaluation was "interesting", "as expected" and "pleasant", which was most likely because of habituation [15], in perception in terms of mitigation of the sense of discomfort to time delay and adverse psychological effect (becoming insensitive). This habituation differs from simple stimulation [16], mentioned in the preceding studies and reactive habituation [17], that occurs due to iterative presentation of irritation. Habituation showed by these results are similar to habituation explained by [18], [19], in terms of order effect where after experiencing the "synchro movement", the subjects become insensitive to the delay of the movement. However, we think it is a new finding that the order of movement patterns affects psychology. Nonetheless, 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.

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