Process in Establishing Communication in Collaborative Creation

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Abstract. We try to quantify the communication in collaborative activities in terms of verbal and non-verbal processes, using collaborators of a creative activity as the study subjects. This study set up a production task using LEGO® blocks. Our study subjects consisted of 5 groups of 3 males. They were asked to use their imagination freely to build a “castle” using the LEGO blocks. We recorded their activities with video cameras, while measuring their bodily movements three dimensionally using a motion capture system. Our experiment showed that the works created by groups with many illustrators (gestures for spatially expressing inner ideas and images) rated high both in perfection level and favorability rating. In a collaborative creation, it was shown that direct visual expressions of mental representations through nonverbal, rather than verbal, communication among the collaborators increased perfection level of the end product.

Keywords: Collaborative Creation, Nonverbal Behavior, Bodily Movements.

1 Introduction

When a plural number of people engage in a collaborative creation, what kind of communication will occur in its process and how will it affect the end results, i.e., the works?

Suzuki et al (2007) revealed that verbal and nonverbal behavior such as eye contact, and finger-pointing were critical in the success and/or failure of a task of building a box-like structure. Matsuda et al (2007) showed that nonverbal behavior exchanged among highly intimate workers contributed to promote task achievement. These studies prove the importance of nonverbal behavior among workers in a collaborative work. Each study, however, used a “task-fulfilling type” collaboration in which the conditions for achieving the task were clearly shown to the collaborators.

Some collaborative activities such as music composition, developing stage settings, etc. lack an overall finished product vision or image that all the collaborators share. It is each collaborator’s creative talent that will form the final product. In a non-task-oriented joint activity, collaborators must present their thoughts and images accurately and understand what are presented by other collaborators. In doing so, how do they

collaborate to create their final product, the end product of their constantly changing images and ideas?

With these questions in mind, we try to quantify the communication in collaborative activities in terms of verbal and non-verbal processes, using collaborators of a creative activity as the study subjects.

2 Experimentation

2.1 Experiment Outline

This study set up a production task using LEGO® blocks in order to analyze how communication is established in a collaborative creation.

2.2 Procedure

Our study subjects consisted of 5 groups of 3 males without prior acquaintance. They were seated at a round table and asked to use their imagination freely to build a “castle” using the LEGO blocks. The time allowed for this task was 30 minutes.

We recorded their activities with a video camera, while measuring their bodily movements three dimensionally using a motion capture system. Each collaborator was asked to take the Big Five Character Trait Test and then answer a questionnaire before and after the experiment about the impressions of their collaborators and about the experiment itself.

2.3 Emotional Evaluation of Final Product

Pictorial images of each work(see Fig.1) were used for emotional evaluation using a pair comparison method (Thurstone method), using 68 evaluators who were all university students (29 males and 39 females, aged 19.53 ± 1.04). All the finished works were paired up and the paired were shown to the evaluators, who were asked to select which work showed “greater creativity”, “greater perfection” and “higher favorability rating”.

2.4 Analytical Indicators

Using the results of the questionnaire, the researchers calculated the character trait of each group, evaluation of the experiment, and the changes in the collaborators’ impressions before and after the experiment.

Using the recorded data, the researchers extracted “speech” (5 types - making suggestions, approvals, confirmations, other, and general chats, Table 1), “illustrators” (gestures for spatially expressing inner ideas and images, Fig.2), and the “eye contacts” “nodding” the collaborators made to one another. ELAN application software was used for data tagging (<http://www.lat-mpi.eu/tools/elan>). ELAN supports event extraction in visual observations, allowing unlimited annotations to be added to visual and audial data. It enables the researcher to record, in a time-series manner, the frequency and duration of each event occurring in visual data.

Fig. 1. Final Product

Table 1. Speech Category

Speech Category	Classification Criteria
Suggestion	Presentation of ideas about castle structure to the collaborators.
Approval	Responses implying consent to the suggestions and/or confirmations.
Confirmation	Reconfirming the preceding suggestions or the images shared by the collaborators.
Other	All other speech concerning experiment but not included in the above three categories.
General Chat	All speeches without any relevance to the purpose of the project.

Fig. 2. Sample of Illustrator

Using the motion capture data, we calculated the movements of the upper body and the distance between the table and each collaborator’s forehead during upper body movements. We used the obtained results as analytical indicators. The movement of the upper body was defined to be the time-series distance of travel of the marker attached to the 7th cervical bone, using its relative coordinates, while keeping the marker attached to the sacral bone as the origin(Fig. 3). Okubo et al (2009) showed the relationship between the level of concentration and the forward lean posture. In

Fig. 3. The movements of the upper body

Fig. 4. The distance between the table and each collaborator's forehead

this study, we defined an index to show the worker's level of concentration by calculating the distance between the table's center and the worker's forehead (Fig.4).

In order to observe the time-series changes in the communication generating process in a series of collaborative works, this study divided the experiment into three 10-minute phases, from the start signal to the finish signal. These three stages are called Phase 1, Phase 2 and Phase 3 herein.

3 Results and Discussion

3.1 Work Score

As a result of the pair comparison method, Group 3 received the highest evaluation in creativity, while Group 5 was evaluated highest in terms of perfection and favorability rating. Fig.5 shows a plot chart of the creativity and perfection scale score obtained by the pair comparison method.

Fig. 5. Plot Chart of the Creativity and Perfection

A result of correlation analysis showed a negative correlation between perfection and creativity(-0.546), but a positive correlation between favorability and perfection(0.846). In other words, greater perfection increased favorability but reduced creativity. It was also found that work’s creativity was not related to its becoming favorable.

3.2 Subjective Evaluation by the Participants

We asked the participants to answer ten questions about their subjective evaluation, by allocating a maximum of 10 points to each question. By conducting principal component analysis using the score-based correlation matrix, we extracted two principal components with eigenvalue of 1 or greater(Table2). From the component matrix, we can call the first principal component as “Communication Component” and the second principal component, “Sense of Achievement Component”. In other words, the 10 subjective evaluation questions listed in the table can be summarized into two viewpoints: “smooth communication with the others” and “sense of achievement doing the task.”

By plotting the first component on the x-axis and the second component on the y-axis, we obtained the result shown in the Fig.6. Except for the three collaborators in Group 4, the participant’s evaluation was different in no small way even among those belonging to the same group.

Table 2. Result of PCA

	Communication	Achievement
Did you enjoy doing this task?	0.739	0.491
How do you like the finished work?	0.840	-0.019
Did you feel a sense of achievement doing this task?	0.454	0.818
Did your group divide the work load among the collaborators?	0.385	-0.484
Did your group achieve a good communication?	0.842	-0.165
Did your group enjoy conversations?	0.887	0.025
Did you willingly bring forth your ideas?	0.803	0.176
Did you willingly consent to other collaborator’s ideas?	0.696	-0.523
Were your ideas adopted?	0.736	-0.104
Do you think you had a good team work overall?	0.881	-0.133
eigenvalue	5.549	1.505
cumulative contribution ratio(%)	55.486	70.534

3.3 Speech

The total time of different speech categories for each group are shown in the Fig.7. From this figure, one can see that the total speech time varied greatly from group to group and that Group 3 showed the exceptionally long total General Chat time.

We then conducted the Ward’s cluster analysis of the total speech time for the different phases and obtained the results which are graphed below(Fig. 8). From this, we learned that Phase 1 (opening phase) contained suggestions and confirmation about the castle design, Phase 2 (mid-point phase) contained design approvals and general chats, and Phase 3 contained all other categories of speech.

Fig. 6. Plot of the PCA score

Fig. 7. The total time of different speech categories for each group

As a result of correlation analysis, the length of general chats are closely tied to creativity, while the frequency of confirmation and approval contributed to favorability and perfection($r > 10.71$).

In order to “build a castle with LEGO blocks”, each collaborator must first visualize the final product and communicate this to others, in an encoding process. Speech is, needless to mention, one of the most important modes of communication to relay a message. It is also important to accurately understand the message given by the others, in a decoding process. In this report, the message initiated by the collaborator is classified into the “Suggestion” category. It is also important to

accurately understand the message given by the others, in a decoding process. These processes are included in the “Approval” and “Confirmation” categories.

This experiment confirmed the changes in speech in the series of collaborative activities. Also there was a strong relationship between the collaborator’s personality and the content of his speech, so verbal communication developed in a natural manner, in accordance with the character trait of each collaborator. As a result, the speech exchanged during collaborative activity was shown to affect the creativity element of the finished product.

Fig. 8. Tree Diagram : Result of cluster analysis of the total speech time

3.4 Nonverbal Behavior

The Fig.9 shows the frequency of the occurrence of illustrators. Illustrators occurred more frequently in the order of Group 5, 2, 3, 4, and 1. This order is the same as the order of work’s perfection shown in Section 3.1. The illustrator frequency is assumed to be related to the work’s perfection.

The Fig.10 shows the timing of illustrator’s occurrence plotted in a time-series manner of group2 and 3. From this figure, illustrators occurred between a plural number of collaborators.

In order to find out how nonverbal behavior affects the work score, we conducted a correlation analysis. From this table 3, it was clear that the frequency of the occurrence of nonverbal behavior by the collaborators contributed to the work’s creativity, perfection and favorability. In sum, the group with the frequent use of illustrators during collaborative work achieved high creativity, perfection and favorability of their work.

As described earlier, each collaborator must visualize “what kind of castle he wants to build” and relay this message to the others (by encoding) in order to “build a castle with LEGO blocks”. So far, language is described to be an important medium to achieve this. However, it is by no means the only way.

McNeill (1987), the foremost researcher in gestures, describes that mental representations in humans first exist as undifferentiated imaginary thoughts and syntactic thoughts in the deep layer, which become differentiated into two when they appear on the surface. When these thoughts appear as an audio channel, it become speech, and when it appears as a bodily movement channel, it is represented as gesture. Our “illustrator” was a gesture that appeared accompanying speech. The original mental representative formed deep inside each collaborator appeared on the surface partly as speech (language) and partly as illustrator. An illustrator, therefore, was an outward expression of a mental representation showing itself through the collaborator’s bodily movement channel.

Our experiment showed that the works created by groups with many illustrators rated high both in perfection level and favorability rating. In a “collaborative creation” as in our study, as opposed to task-oriented study, it was shown that direct visual expressions of mental representations through nonverbal, rather than verbal, communication among the collaborators increased perfection level of the end product.

Fig. 9. Frequency of the occurrence of illustrators

Fig. 10. The timing of illustrator’s occurrence

Table 3. The Correlations of Work Score and Nonverbal Behavior and Work Score

		Creativity	Perfection	Favorability
Illustrator	Phase1	0.629	0.095	0.522
	Phase2	-0.425	0.986	0.903
	Phase3	-0.188	0.846	0.907
	Sum	0.080	0.749	0.952
Nodding	Phase1	0.832	-0.531	-0.086
	Phase2	0.872	-0.529	-0.059
	Phase3	0.834	-0.524	-0.075
	Sum	0.852	-0.530	-0.072
Eye Contact	Phase1	0.615	-0.183	0.184
	Phase2	0.778	-0.442	-0.010
	Phase3	-0.167	-0.722	-0.961
	Sum	0.795	-0.562	-0.142

3.5 Bodily Movements

After eliminated noise from the motion data obtained by three-dimensional motion measurements, we outputted the coordinates of the x, y and z axes of each marker in a time-series manner. As bodily movements were recorded using 120FPS, we extracted one frame from every 12 frames and used them for analysis after standardizing them into the same data volume as behavior analysis.

In order to quantify how much the collaborator's upper body movements were synchronized, we calculated a cross-correlation coefficient for the upper body movements. For each group, the obtained data between two collaborators were divided into 60-second portions, and they were phased out by 30 seconds until the cross-correlation coefficient was obtained at the maximum lag order 300 (30 seconds). The Fig.11 shows the time-series change in the cross-correlation coefficient of Group 1. From this graph, it was learned that the upper body movements of different collaborators were synchronized to no small measure.

The sum of the correlation coefficient for each group whose absolute value was 0.3 or greater is shown in the Table 4. As the correlation coefficient overlapped by 30 seconds, we used values by dividing the sum by two.

Fig. 11. The upper body movements of different collaborators

Table 4. The sum of the correlation coefficient for each group

	Group 1	Group2	Group3	Group4	Group5
Phase1	6	1.5	5	1	9.5
Phase2	4.5	3	1.5	2.5	3.5
Phase3	5	4.5	7	3.5	3
Sum	15.5	9	13.5	7	16

It has been known that “entrainment” occurs in physical communication, which is time-oriented mutual synchronization of biological rhythms (Condon, 1974). Our study also showed in a quantitative manner that the collaborators’ bodily movements synchronized and entrained one another. Entrainment is known to play an important role in smooth conversion of information in communication (Watanabe, 1998). Our study showed that entrainment among the collaborators helped sharing of each other’s thoughts and images in their search for the goal.

4 Conclusion

In a collaborative activity of “building a castle”, we were able to confirm multilaterally the process of creating a final product through a verbal and non-verbal fusion of one another’s mental representations. Overall data analysis showed that “no one rule existed that was common to all collaborators and groups.” That is why the final products showed different creativity levels. The different mental representations fusing within the work space created new representations, which then converged into the work’s creativity. So it seemed only natural that creativity was widely varied. However, the design of the final product clearly embodied the various elements such as each collaborator’s personality, group’s structure, and communication process. Being able to prove this using experimental data was a large achievement.

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