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The Relation between the Characteristics of Individual and Collaborative Concept Generation

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Abstract

The purpose of this study is to investigate the effect of the concept generation process on metacognition, and the relation between individual concept generation characteristics and the nature of collaboration. The results of the experiment revealed that the attitude affects individual concept generation characteristics, the metacognition developed and the quality of the concepts generated. In paired concept generation, the awareness and the attitude toward the partner and individual concept generation characteristics affect the nature of both the collaborative process and generated concepts.

Keywords: metacognition, intersubjectivity, collaborative design, design creativity, idea generation

1. Introduction

In the process of design, and especially during concept generation, designers often became aware of the self that is lurking in the background and, in doing so, gain a strong sense of expanding perspective. This phase is empirically observed as novice designers become more aware of the *self through designing*. They also notice that the nature of collaboration differs depending on who the collaborators are. This study aims to elucidate the influence of individual concept generation characteristics on collaborative concept generation, focusing on the cognition and attitudes of novice designers. The authors first examine the characteristics of each examinee during individual concept generation from the perspective of metacognition, and then analyse the nature of their collaborative concept generation.

2. Related Studies

Many previous studies have reported that suddenly appearing ideas called "creative leaps" (Cross, 2006) have led to excellent design solutions. These are mainly experienced as the inner sense-driven phase of concept generation at the very early stage of design (Taura and Nagai, 2013). Creative leaps are explained as phenomena enabled by an acquired metacognition, either *relaxation of constraints* or *release from fixation* metacognition (Marques *et al.*, 2014; Nagai and Taura, 2006; Santosh *et al.*, 2015; Taura and Nagai, 2010). Meanwhile, collaboration has also been regarded as a significant skill in design practice and design education (Détienne *et al.*, 2017; Matsumae and Nagai, 2017). The relationship between individual and social creativity has been studied more from management perspectives (Shin et al., 2012). Creativity in collaboration has been confirmed to imply an integrative approach according to which individual creative skills, team dynamics and organizational solutions interact (Taggar, 2002), and an appropriate organizational strategy is more effective, especially for novice designers (Bissola and Imperatori, 2011). This study has a stronger focus on cognitive perspective.

3. Research methods

To examine (1) the relationship between concept generation and metacognition and (2) the relationship between individual concept generation characteristics and collaboration, it is necessary to understand the concept generation process, metacognition, the nature of collaboration, and the attitude toward collaboration as individual concept generation characteristics.

The authors conducted an experiment consisting of individual concept generation to examine the relationship between an individual's concept generation process and concept generation characteristics, and examined paired concept generation to understand the relation between the individual's concept generation characteristics and the nature of collaboration (the subjectivity, process, and generated concepts of collaboration). The authors then quantitatively and qualitatively analysed the relationship between concept generation and metacognition by comparing individual concept generation processes and metacognition observed in the experiment. They also examined the relationship between individual concept generation characteristics and the nature of collaboration and attitude toward collaboration by comparing individual concept generation characteristics and attitudes toward collaboration.

4. Experiment

4.1. Examinees and environment

The examinees comprised 123 undergraduate students with a similar level of design education in an industrial design course at the School of Design, Kyushu University. This experiment was conducted remotely in October 2020. The worksheets used for the experimental tasks were shared online during the experiment among examiners so that they could monitor how the examinees participated in the experiment in real time.

4.2. Experiment procedure

First, the examinees practiced concept generation work to become familiar with the rules and manipulations of the process, and then they performed individual concept generation work for 15 minutes. To help the examiner understand the examinees' thinking processes during concept generation, the examinees provided their generated concepts in chronological order and wrote down their reflections on their thinking processes and a self-evaluation for each concept generated, ranking the generated concepts in order. They were then divided into pairs. Each pair performed paired concept generation for 15 minutes with the same word group that was used during individual concept generation. Finally, each examinee was asked for the same review process that was used with individual concept generation (Figure 1).

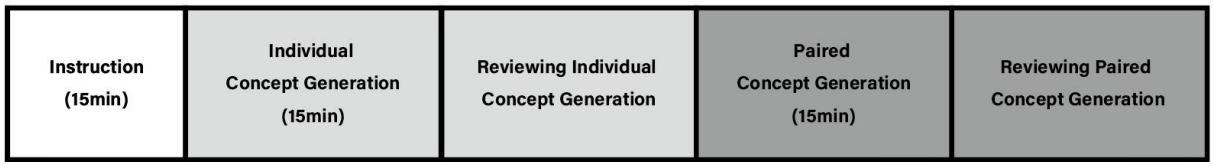

Figure 1. Experiment protocol

4.3. Experiment tasks

In previous studies, concept generation has been discussed within the framework of reasoning types of deduction, induction and abduction, with abduction being the most adequate representation of the characteristics of design (Taura and Nagai, 2013). Therefore, to correlate metacognition and concept generation, it was essential to visualize the concept generation process, that is, the process of *forming a mental image from collected materials*. In addition, the work should be able to evaluate (1) the breadth of the thinking materials accessed and (2) the ingenuity used in the combination of thinking materials. These two factors describe the evaluation indices of the *relaxation of constraints* and *release from fixation* that were focused on when examining metacognition in this study. To satisfy the above requirements, the authors designed concept generation work (referring to the KJ method) as an abductive

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idea generation method based on original data by *letting the chaos speak for itself* (Scupin, 1997). The KJ method was referred to not only because it visualizes the breadth of the thinking materials accessed but also because it requires ingenuity in the combination of thinking materials used during its abductive thinking process.

For both individual and paired experimental tasks, the authors directed the examinees to generate concepts using multiple words. The examinees were told that they should generate concepts by using two or more words from the eight words given in advance, and to create three or more concepts to allow evaluation of the ingenuity of the combination of thinking materials as *release from fixation*. In October 2020, when this experiment was conducted, Covid-19 was spreading and topics related to coronavirus were attracting attention. To evaluate the originality of the generated concepts, several words related to the novel coronavirus were included so that the originality would vary. The authors prepared eight words: post, mask, bus, PC, sticky note, travel, curtain, and library. In addition, the authors also instructed that new words other than the given words could be added. This was to evaluate the breadth of the accessed thinking materials as *relaxation of constraints*. Figure 2 shows an example of the concept generation worksheets; the words in red are words added by the examinees. The examinees first chose "trip" and "library" from the prepared words, added "straw hat," and then generated a concept of "summer vacation." Thus, examinees filled in their own work from top to bottom, listing each of their generated concepts with its chosen word group.

Generated Concept	Word Group				
Summer vacation	Trip	Library	Straw Hat		
Covid-19	Mask	PC	Alcohol Disinfection		
Quietness	Library	Curtain	Lakeside	Terrace	Forest
Study	Sticky Note	PC	Textbook	Pen	
Communication	Mailbox	PC	Smartphone		
Campus	Bus	Library	Restaurant		
Trip	Bus	Sticky Note	Guidebook	Hat	
Hobby	Trip	PC	Sewing	Running	

Figure 2. Example of concept generation work

5. Evaluation

5.1. Evaluation of metacognition

The concept of metacognition is regarded as being fuzzy with indistinct boundaries. In this study, the authors focus on metacognitive knowledge with dual cognitive processing characteristics, release and persistence, which are regarded as critical aspects of creativity (Jia *et al.*, 2019; Nijstad *et al.*, 2010). This metacognition was evaluated during the concept generation phase of this experiment with a focus on two perspectives: *relaxation of constraints* and *release from fixation* (Marques et al., 2014; Nagai and Taura, 2006). The relaxation of constraints expanded the idea space (Fauconnier and Turner, 1998) and allowed access to a wider range of thinking materials. At the same time, *release from fixation* enables the ingenious use of thinking materials obtained within the limited idea space. The authors evaluated metacognition by supplementarily analysing the inner thinking processes of the examinees through the examinees' written reflections.

5.1.1. Criteria for relaxation of constraints and release from fixation

The first evaluation criterion for relaxation of constraints in this experiment was *whether the examinee added a word that had not been added in a previous concept generation*. In addition, even if the added

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word was new, it could not be said that the constraint had been relaxed if the idea space was not expanded. Therefore, the second criterion was *whether the idea space from which the added word was extracted was different from the previous idea space*. As an example, it was not evaluated as relaxation of constraints when an examinee stuck to interpreting the word "mask" as a medical mask since the idea space was not broadened. The evaluation criteria for release from fixation were determined by *whether it was different from the way the words were combined before* or *whether there was any ingenuity used in how they combined words*. When an examinee listed "square" in the left column with the words "post," "sticky note," "bus" and "curtain", it was not counted as release from fixation since it did not generate any concepts but simply categorized the words.

5.1.2. Metacognitive transition process

The authors evaluated metacognition for each generated concept as described above and classified the results by four types, as shown in Figure 3 below: A–both relaxation of constraints and release from fixation occurred, B–relaxation of constraints occurred but release from fixation did not occur, C–relaxation of constraints did not occur but release from fixation occurred, and D–neither relaxation of constraints nor release from fixation occurred. However, the evaluation was basically only divided into two categories of A or C in the end, since release from fixation was considered to have occurred when the generated concept was counted in this experiment.

Each examinee's metacognitive transition process throughout the individual concept generation exercise was categorized by the following perspectives of basic metacognition state and stability, focusing on the relaxation of constraints. For instance, P1-2 means that relaxation of constraints occurred fundamentally, but not in a stable manner (Figure 3).

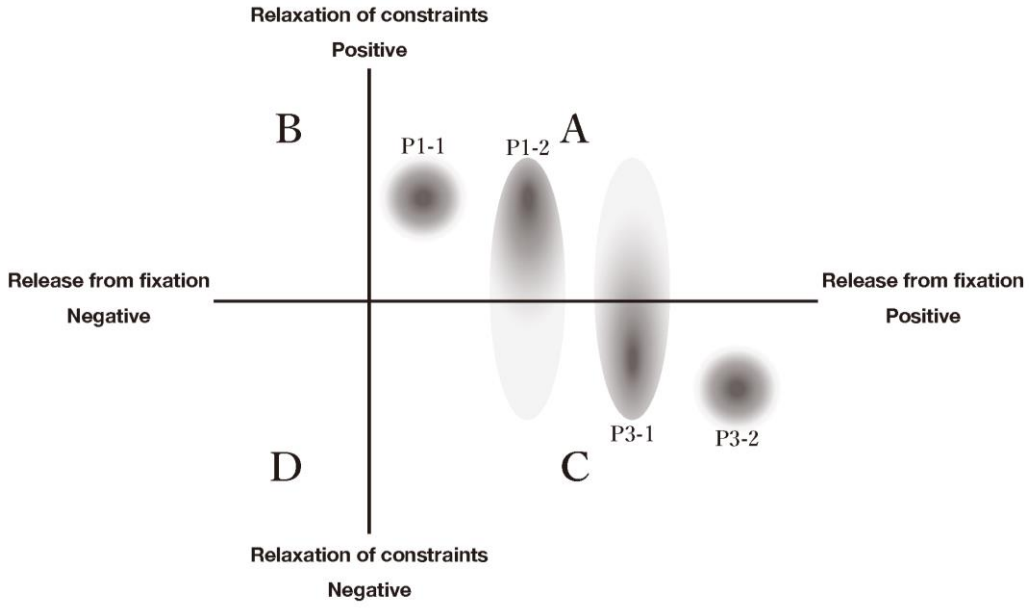

Figure 3. Metacognitive transition patterns

5.2. Evaluation of generated concepts

The presence of concept generation was evaluated by looking at a formed word group and free description during the experiment. Since the concept generation focused on in this study comprised *forming a mental image from collected materials*, and since it is not possible to form a mental image from collected materials unless one considers the explanatory hypothesis that exists in common at the root of the materials, the criterion was *whether the result of the concept generation was an abduction*, which is the formation of an explanatory hypothesis that explains why a certain concept is generated (Scupin, 1997). On the other hand, when the words are merely categorised, it cannot be called concept

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generation because the material is merely classified according to the existing framework and fails to form a mental image.

The quality of the generated concepts was evaluated for originality, both objectively (with the overlap rate) and subjectively (with the self-evaluation). Creativity is generally evaluated from two perspectives, originality and usefulness (Finke et al., 1992; Hennessey and Amabile, 2010), though usefulness was not required or evaluated in this study. As an objective evaluation of the generated concepts, originality was evaluated based on the overlap rate of the generated concepts among the examinees. The overlap rate was calculated by examining the number of examinees whose generated concepts were the same as those of other examinees. When an examinee generated a concept that no one else had generated, the inverted overlap rate was set to 100%. In addition, the quality of the generated concepts was evaluated by having the examinees provide a self-evaluation for each generated concept.

5.3. Evaluation of concept generation process

The authors analyzed the process of concept generation throughout from the viewpoint of the method used for concept generation and the transition of the quality of generated concepts. The concept generation method adopted was evaluated by using the free-form description written by the examinees reflecting on their thinking processes for each generated concept. Examiners evaluated them according to the representative methods of divergence and convergence techniques: free association method, forced association method, analogical conception method, spatial type method, and serial type method (Matsui, 2007). The transition of the quality of the generated concepts throughout concept generation was evaluated by applying the average overlap rate, the transition of the overlap rate of the generated concepts, and the transition of the self-evaluation.

5.4. Evaluation of collaboration

In this study, co-creative collaboration is defined as *a collaboration in which individuals share tacit knowledge and create something together*, while cooperative collaboration is explained as *a collaboration in which individuals do not share tacit knowledge and act together to achieve a given goal*. (Matsumae et al., 2020; Matsumae and Nagai, 2018). Therefore, co-creative collaboration was determined when both (1) the sharing of tacit knowledge and (2) the formation of tacit knowledge was observed, which distinguished it from cooperative collaboration. The two authors evaluated pair-work from the concept generation process, comparing the descriptions between each of their individual works and their following pair-work. The attitudes toward collaboration were also evaluated by using the examinees' descriptions of each thought process in paired concept generation, how they generated the concepts and how they felt about each other in the pair.

6. Results

After excluding examinees who ran into trouble during the experiment or had missing data, 79 examinees were included in the evaluation of individual concept generation, and a total of 12 pairs were included in that of paired concept generation.

6.1. Metacognition and individual concept generation characteristics

As a result of evaluating metacognition for each generated concept based on the evaluation criteria of metacognition in 5.1.1, a total of 373 concepts were evaluated as showing relaxation of constraint, and 115 concepts were evaluated as not. Based on the evaluation method of the metacognitive transition process in 5.1.2, the examinees were divided into four categories: P1-1 for 51 examinees, P1-2 for 21 examinees, P3-1 for 3 examinees, and P3-2 for 4 examinees.

Figure 4 shows the results of comparing the concept generation methods for each metacognitive transition pattern. Only P1-1 and P1-2, which are fundamentally constraint-relaxed, generated concepts not only by the free association method and the forced conception method but also by the spatial method and the serial method. In addition, in P1-1 and P1-2, efforts to interpret the words and attitudes recognizing the limitations of one's own vision and perspective were observed. Neither of these was seen in P3-1 or P3-2.

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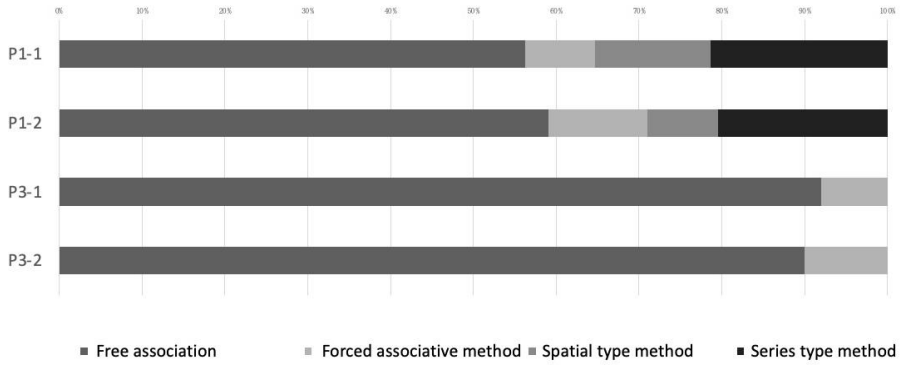

Figure 4. Concept generation methods for each metacognitive transition pattern

The originality of the generated concepts was evaluated for each metacognition each time a concept was generated. The average originality of the concepts (the inverse overlap rate among examinees) was shown to be significantly higher when constraint relaxation was observed.

The authors then compared changes in the quality of the generated concepts for each metacognitive transition pattern. When the authors focused on the high-originality average, it decreased in the order of P1-1, P1-2, and P3-1. Meanwhile, when the authors focused on the low-originality average, it increased in the order of P1-1, P1-2, and P3-1 (Figure 5). In other words, for P1-1, P1-2, and P3-1, the metacognitive transition pattern in which constraint relaxation occurred showed a wider range of high and low originality in the generated concepts.

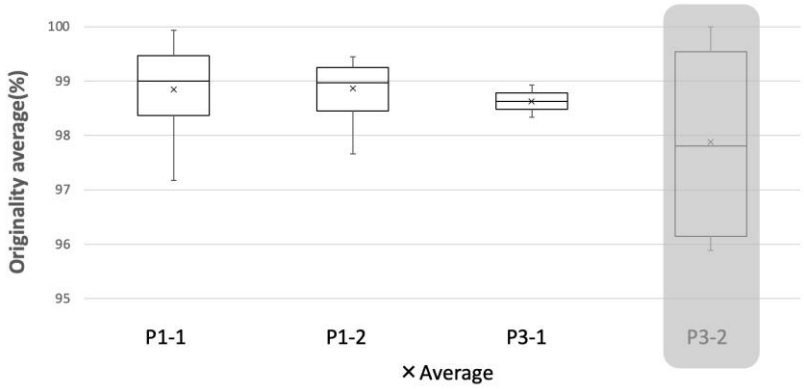

Figure 5. Originality average of concepts generated for each metacognitive transition pattern

When the authors compared the average number of generated concepts for each metacognitive transition pattern, they found that the average number of generated concepts for P3-2 was much lower (with 2.5 concepts generated) than for other metacognitive transition patterns (with 6.4 concepts generated). The descriptions given in the reflections on the thought processes of P3-2 were also much shorter than those given in the reflections on the thought processes with the other metacognitive transition patterns, indicating that examinees in P3-2, unlike those with other metacognitive transition patterns, were clearly unmotivated and completed the work with a minimum of effort. For this reason, P3-2 was excluded from the discussion to examine relationships between metacognitive transition patterns and the quality of generated concepts.

6.2. Collaboration and individual concept generation characteristics

When the concept generation characteristics of the individuals, which were gleaned from the concept generation work they did, were compared with each pair, three types were revealed: Type 1, those who basically use the associative method to generate ideas; Type 2, those who basically use the associative method to generate ideas and those who try every method and generate concepts with persistence; and Type 3, those who try every method and generate concepts with persistence. For each concept generation in the paired concept generations, the authors determined whether the collaboration was co-creative or

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cooperative, and calculated the ratio of co-creative collaboration to the total. The results showing the relationship between the pair type and the co-creative collaboration ratio are shown in Figure 6.

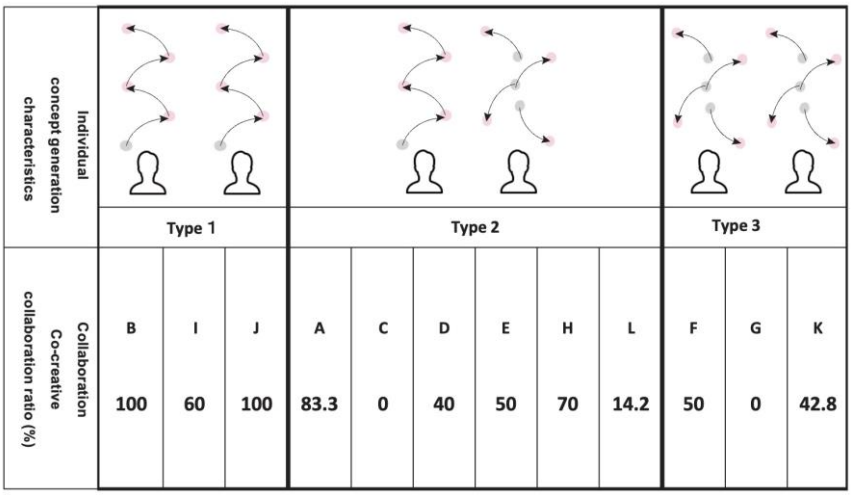

Figure 6. Co-creative collaboration ratio and individual concept generation characteristics

The authors ascertained whether the examinees were conscious of generating concepts as a pair. That is, they examined how they recognized the subject of the paired concept generation. Pairs A, B, D, F, H, and K were conscious that both they and their partners were paired for the concept generation work, while pairs C, G, and L were unconscious of it and ignored it. In pairs E, I, and J, examinees were unable to say in their reflections how much they were aware of their partners. Furthermore, it was observed from the reflections that the pairs who were not conscious of being a pair at first gradually became conscious of being a pair when one of them showed interest in and sympathy for the other.

7. Discussions

7.1. Metacognitive transition process and concept generation

Only in P1-1 and P1-2, where constraint relaxation occurred fundamentally, were the spatial and serial methods adopted as a concept generation method. There were descriptions such as "noticing my narrow view," "wondering if there is any other meaning," "wondering if there is any other way to look at the already existing combination," and "wondering if there is any other way to use the concept that is not common." On the other hand, in P3-1 and P3-2, without constraint relaxation, there were no such expressions as those observed in P1-1 and P1-2. Moreover, in P1-1 and P1-2, "mask" was transformed into "mask for wearing," "mask for masking," and "mask for face-pack," while P3-1 and P3-2 showed no transformation in the way the word was perceived.

These results suggest that examinees who have the attitude that their own viewpoints and perspectives are limited are more likely to notice that there are limitations in each concept generation method, and thus will actively adopt various concept generation methods. They start to generate concepts not only by the free association method but also by the spatial method and the serial method. Both methods are thought to evoke the relaxation of constraints because they try to see the essence of the words that are used as the materials for concept generation, a pattern of metacognition.

On the other hand, examinees who do not have the attitude that there are limitations in their own viewpoints tend to stay within the free association method and are unlikely to notice the limitations of the method until they run out of material, which may prevent the idea space from expanding.

The fact that the average range of originality of the generated concepts was wider in the metacognitive transition pattern with constraint relaxation suggests that constraint relaxation occurs when highly original concepts are generated. In other words, when constraints are relaxed, the range of originality of the generated concepts widens and, as a result, examinees who can generate highly original concepts emerge.

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7.2. Collaboration and individual concept generation characteristics

The importance of undefined features, e.g. the obscure features hypothesis (OFH), has been increasingly evaluated recently, and an attempt has been made to apply the idea to the design field to avoid design fixation (McCaffrey and Krishnamurty, 2015). In this study, it has been observed that the direction of the individual context vectors (Matsumae and Nagai, 2018) of the concept generation process, the generation of tacit knowledge, the degree of freedom, and the degree of formation of intersubjectivity are fundamental factors that determine the nature of a collaboration (Figure 7).

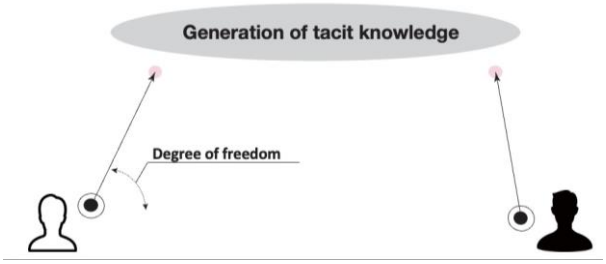

Figure 7. Concept generation characteristics of individuals

The degree of freedom of the context vector and formation of intersubjectivity lead to the ease of co-creative collaboration in pairs. The closer to each other the tips of the context vectors are, the more likely tacit knowledge is to have been shared.

This degree of freedom was related to the power of persistence in the concept generation method and the awareness of being a pair during paired concept generation. It was observed that the degree of freedom was low for those who showed strong persistence in a concept generation method and for those who had only a weak awareness that they were generating concepts in pairs. In addition, examinees with a concept generation characteristic that was generally based on association showed a high degree of freedom. The degree of freedom of the context vector was affected by the degree of awareness that the pair was generating concepts together, as well as by empathic attitudes and behaviours that expressed interest in the other person. Individuals with a concept generation characteristic fundamentally based on the associative method can easily incorporate others' ideas as one of the associations, and their thinking process is flexible. If one of a pair behaves in a way that brings the tip of his/her own context vector closer to the tip of the other's context vector, the sharing and generation of tacit knowledge will happen more easily, and the other's context vector will also gradually come closer to his/her partner's context vector. Furthermore, the self-awareness of the pair, intersubjectivity, is gradually formed, and co-creative collaboration becomes easier (Figure 8).

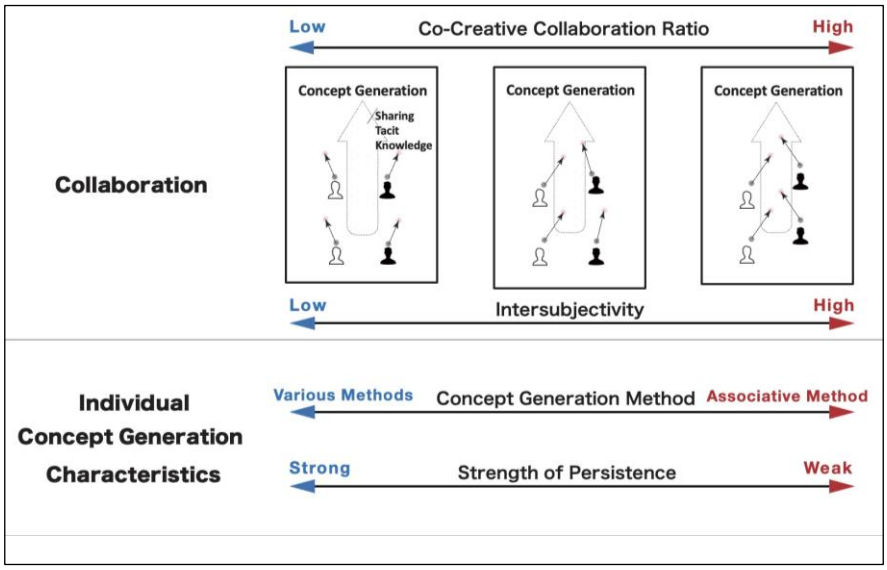

Figure 8. Collaboration and individual concept generation characteristics

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Comparing self-evaluations and the co-creative collaboration ratios for each generated concept, the authors found that discrepancies in self-evaluations within a pair decreased for concepts generated with a higher co-creative collaboration ratio. The self-evaluations in this study, expressing how much they liked the concept, can be considered to represent co-creativity. In other words, it was suggested that when the ratio of co-creative collaboration increases, co-creativity also increases.
These results are consistent with and provide a clearer view of the findings of the previous study that (1) intersubjectivity among individuals can be formed through co-creative collaboration; (2) co-creative collaboration is directed by individual context vectors, and individual context vectors are also affected by co-creative collaboration; and (3) co-creativity, a shared drive in individuals to develop and realize their concepts for the better, is formed through co-creative collaboration.

8. Conclusion

8.1. Summary

Those who have an attitude that there are limitations to their own viewpoints and perspectives give themselves the opportunity to notice and overcome these limitations by actively adopting various concept generation methods, and thus acquire metacognition in the process of concept generation that results in a metacognitive transition pattern with a relaxation of constraints. As a result, the range of originality of the concepts generated widens and highly original concepts can be generated. On the other hand, those who do not have the attitude that there are limitations to their perspectives and views remain in the free-association method, staying in their own thinking space, and are therefore less likely to be aware of constraints to expanding, resulting in a failure to acquire metacognition. Their metacognitive transition pattern is fundamentally without relaxation of constraints, which narrows the range of originality generated and makes it difficult to generate highly original concepts.
The direction and the degree of freedom of the individual context vectors in the concept generation process and the degree of formation of intersubjectivity are factors that determine the nature of the collaboration. If one brings the tip of their own context vector closer to the tip of the other's context vector, the other's context vector will gradually come closer as well, making it easier to share and generate tacit knowledge.
The knowledge obtained in this study contributes to the optimization of creative team formation. It implies that a combination of different individual concept generation characteristics, both flexible and persistent, could enhance collaborative concept generation.

8.2. Limitations and future research

The concept generation work in this experiment was based on words, and therefore there is an effect brought by the characteristics of words. The individual differences among examinees in sensitivity toward words may need to be considered in another context. Since this study focused more on the relaxation of constraints, as mentioned, further study in relation to the release from fixation, the other aspect of metacognition, is expected.

Ethical Statement

This study was approved by the Institutional Review Board of Kyushu University

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