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Psychological Analysis of Rugby Players Based on Self-Organizing Map (SOM) and Ward's Method

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Abstract

This research aimed to analyze the mental level of different players. The targets of the questionnaire were administered to 32 male elite rugby players. Two different types of clustering analysis algorithms: SOM and Ward's method were used for analysis. Results of SOM and Ward's method were checked with each other. The two different types of clustering methods were a good match with each other. Furthermore, the results of SOM made clearer visualization than Ward's method and could help us find more information about the features and relationships of each player. Although SOM had not been seen a lot used for analyzing in sports, this study confirmed that SOM is a very effective analysis method for the sports area.

Keywords

Psychological Analysis, Rugby Players, Psychological Tests, Self-Organizing Map (SOM), Ward's Method

1. Introduction

Excellent athletes not only need superior physical skill, strong sports skill but also need to have the psychological ability to play these advantages. Athletes' sports activities are carried out through sports and psychological sports. Here, psychological activities play a regulating, controlling, and leading role. Especially in group sports competition, the individual's physiological and psychological characteristics have a great influence on the state of a team. In a higher level of

sports, athletes may experience more negative experiences or difficult situations. Therefore, their psychological tolerance abilities such as mental toughness, coping, and resilience might be high and related to their performance. Therefore, psychological factors play an increasingly important role in sports, especially in competitive sports. Coaches, athletes, and sports researchers are more and more interested in the field of sport psychology (Vealey, 1994; Culver et al., 2012; Smith & McGannon, 2018). An individual athlete or a team needs good physical and psychological characteristics. The psychological features of Japanese rugby players are analyzed by Saijo et al. (1993).

Japan's elite players have different environments. Although there are professional teams, there are still some teams that mix professional players with players who belong to the company and are working. This trend is particularly strong in the top challenge alliances in subordinate organizations. In the current environment of Japanese rugby, it is important for a works team to improve their physical fitness effectively in a short period of time and balance their work and training. We think that the key to improving the training effect is to improve the psychological competitive ability of athletes. In order to achieve the expected goal of psychological training, we should first understand the psychological characteristics of athletes engaged in the sport. Therefore, the purpose of this study is to classify the characteristics of psychological ability, and the classification methods are discussed in this paper.

In this study, the survey was given to 32 members of a rugby team. All the players belong to the company and work other than practice daily, and they belong to the Japan Top Challenge League, which is Division II in Japan. This is because, in group sports competition, the individual's physiological and psychological characteristics have a great influence on the state of a team. To cluster the athletes by psychological characteristics, two clustering algorithms, self-organizing map (SOM) (Kohonen, 1995) and Ward's method (Ward, 1963) are used. SOM also has been used for the analysis of the relationship between roles in team sports (Takemura et al., 2014, 2018). SOM is one of the artificial neural networks and Ward's method is one of the hierarchical clustering methods. Ward's method can create several groups for data. By using SOM, similar observation data can be collected without having to discuss the number of clusters in advance. Furthermore, the classification results of SOM are more intuitive and easier to visualize. We analyzed and compared the psychological tendencies of rugby players. The results of SOM and Ward's method are compared and discussed.

From the results of this study, we confirmed that the resulting map of SOM can make us more easily understood also in the field of sports. At the same time, the visual results of SOM can be used as a reference for the number of clusters in hierarchical clustering analysis.

2. Clustering Analysis Algorithms

Cluster analysis is multiple variable techniques for classifying groups (clusters)

based on their similar characteristics. In this study, we use two different types of clustering analysis algorithms for analysis, SOM and Ward's method. The details of the two algorithms are described in follows.

2.1. Self-Organizing Map (SOM)

SOM is one of the artificial neural networks and was proposed by Kohonen T. (1995). SOM has been used for customer profiling and behavior analysis (Lee et al., 2004; Holmbom et al., 2011), evaluation for metabolic syndrome medical checkup data (Tokutaka et al., 2013). SOM can create a low-dimensional map to visualize high-dimensional data and can more intuitively understand the classification results of data. SOM neural network is composed of only two layers, which are called the input layer and output layer as shown in **Figure 1**. The input layer consists of n neurons and each neuron corresponds to one input variable. The output layer consists of m neurons, which m is the number of categories depending on the problem. Input neurons are fully connected to the output neurons with weights w_{ij}.

The basic SOM training algorithm (Kohonen, 1995; Masuda et al., 2012) consists of five steps as follows:

1) Initialization: Initialize the weight vector w_{ij} randomly for each neuron.

2) Sampling: Choose a vector x_i from the set of training data and input the vector x_i into input layer.

3) Matching: Calculate the Euclidean distance $Dist_i$ between the input vector x_i and the weight vector of each neuron in the output layer, as shown in (1).

$$Dist_i = \sqrt{\sum_i \left(x_i - w_{ij}\right)} \tag{1}$$

Then find the minimum value of $Dist_i$ as the best matching unit (BMU) shown in (2).

$$\text{BMU} = \arg\min_i Dist_i \tag{2}$$

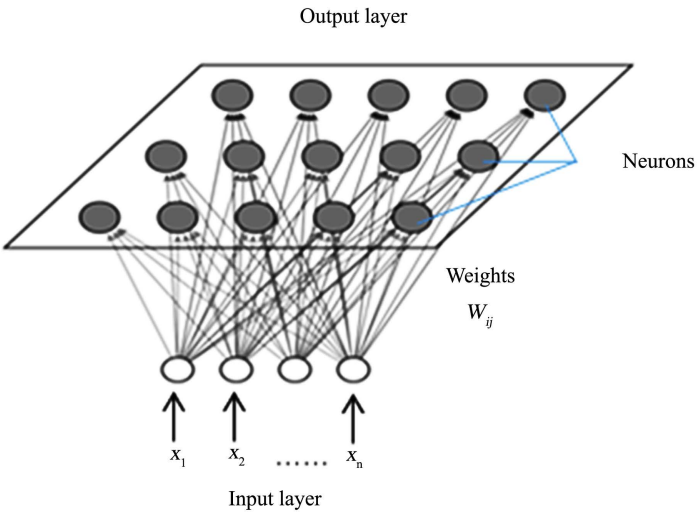

Figure 1. SOM neural network.

4) Updating: Update the weight of the wining unit as shown in (3) and (4),

$$\Delta w_i = h\left(l\left(\mathrm{BMU},(i)\right)\right)\left(x_i - w_i\right) \tag{3}$$

$$h(l) = \alpha \exp\left(-\frac{l^2}{2\sigma^2}\right) \tag{4}$$

where l represents the distance between the wining unit and the unit whose weight is updated. h and σ denote the neighborhood function and the range of the influence of the neighborhood function (neighborhood radius), respectively. α is the learning rate ranging from 0 to 1.

5) Continue: Repeat steps 2 to 5 sufficiently until the feature map becomes stable and stops changing.

2.2. Ward's Method

There are two main types of cluster analysis: hierarchical clustering analysis and non-hierarchical clustering analysis. Ward's method is a hierarchical clustering method, proposed by Ward (1963), and has been widely used to create groups. In Domokos and Bálint's (2017) research, for example, Ward's method was applied to define passenger groups. The computing processing of Ward's method is shown as follows:

First, calculate the initial distance between individual objects X_i and X_j defined by squared Euclidean distance d_{ij} as shown in (5).

$$d_{ij} = \left\| X_i - X_j \right\|^2 \tag{5}$$

Then find the closest pair of clusters and merge them into a new single cluster where d_{ij} is minimum until there is only one cluster.

When cluster p and q are joined to new cluster t, Ward's distance is used for updating the similarity between old cluster s and new cluster t as (6),

$$d_{st} = \frac{n_p + n_r}{n_p + n_q + n_r} d_{pr} + \frac{n_q + n_r}{n_p + n_q + n_r} d_{qr} - \frac{n_r}{n_p + n_q + n_r} d_{pq} \tag{6}$$

where n_p, n_q and n_r are the number of cluster p, q and r, respectively.

3. Clustering with SOM and Ward's Method

3.1. Preparation of Input Data

3.1.1. The Target of Questionnaires

The questionnaire was administered to 32 male elite rugby players, all of whom belonged to a team in Japan Top Challenge League which is Division II in Japan. The same 32 players were then divided for analysis between members, reserve members, and non-members. Players were classified into three groups. The first group is the group of players who played official games as "Members" (10 players, mean age: 26.6 ± 2.4), the second group is the group of players who played official games but not starting members as "Reserve members" (11 players, mean age: 26.6 ± 4.0), and the third group is the group of the players who did not play official games as "Non-members" (11 players, mean age: 24.7 ± 2.0). Surveys

were done right after the 2019 season (Sep 2019-Jan 2020). The team filled out the Ethical consent form before surveys were done. The participants of the questionnaire were voluntary and subject to team administration and coaches' cooperation. Also, the elite rugby team participated in this study as a private organization to get an outside evaluation of themselves, thus allowing their players the opportunity to freely express their views without considering coaches. Given these conditions, following Japanese rules on ethics, the material contained in the report can be used to compile an article.

3.1.2. Questionnaire Surveys

Four questionnaire surveys were conducted using the Diagnostic Inventory of Psychological-Competitive Ability for Athletes (DIPCA.3), the Athletic Coping Skills Inventory (ACSI), the Mental Toughness Index (MTI), and the Sukumune-Hiew Resilience Test (S-HRS). The four questionnaire surveys are explained as below, respectively.

1) Diagnostic Inventory of Psychological-Competitive Ability for Athletes (DIPCA.3)

The DIPCA.3 which was developed by Tokunaga (2001) was used. This research analyzed the 12 lower scales "Patience", "Aggressiveness", "Volition for self-realization", "Volition for winning", "Self-control", "Ability to relax", "Concentration", "Confidence", "Decision", "Predictive ability", "Judgment", "Cooperation" and 5 factors "Volition for competition", "Mental stability and concentration", "Confidence", and "Strategic ability" and total points. The highest total score is 240. Higher scores are indicative of the higher psychological competitive ability for sports. If they had less than 12 points in the Lie Scale, we planned to eliminate the data, but we could not find any data which was less than 12 points in the Lie Scale. In this study, the total points of the DIPCA.3 were used for analysis.

2) Athletic Coping Skills Inventory (ACSI)

The ACSI was created in 1988 and developed by Smith et al. (1995). It consists of seven sports-specific subscales such as coping with adversity, peaking under pressure, goal setting/mental preparation, concentration, freedom from worry, confidence and achievement motivation, and coachability. Participants answered 28 questions. Each question is measured using a 4 point Likert scale ranging from 0 to 3 with choices of "almost never", "sometimes", "often" and "almost always", whereby participants were asked to recall their experience in relation to the situation posed on the questionnaire. A score for each subscale can range from 0 to 12, while the summation of all the scores for each skill creates a value ranging from 0 to 84. Higher scores are indicative of the higher ability to cope with sports. In this study, the total points of the ACSI score were analyzed.

3) Mental Toughness Index (MTI)

The MTI is developed by Gucciardi et al. (2015) and it provided an eight-item scale for unidimensional assessment of mental toughness for athletes. Athletes answered items on a seven-point Likert Scale ranging from one to seven. Higher

scores are indicative of the higher mental toughness for sports. The total points of the MTI score were analyzed for this study.

4) Sukumune-Hiew Resilience Test (S-HRS)

The S-HRS is one of many tests that can be used for assessment of athletes' resilience ability. This test was created and developed by Sukemune (2007) and Hiew (1998). Hiew et al. (2000) showed individuals can tolerate difficult situations and develop their ability of resilience as long as the environments which facilitate health exist. The S-HRS posed 27 questions in part 1 and 8 questions in part 2. Part 1 has three factors such as "Social support", "Self-efficacy", and "Sociality", and measures their current resilience. Each question is measured using a 5 point scale ranging from 1 to 5 (1 = absolutely not; 5 = absolutely yes). The summation of all the scores for each factor creates 135. For men, 94 points or less is "Low", 95 to 107 is "normal", and 108 or more is "High" in resilience. In this study, only total points of three factors such as "Social support", "Self-efficacy", and "Sociality", in Part 1 was used for analysis.

3.2. Pre-Processing of Input Data

Total points for each questionnaire were used for analysis. Normalization is needed because the different gas concentrations differ considerably. In this study, all the data were normalized to fall in the range [0, 1] using (7)

$$x_{\text{new}} = \frac{x - x_{\min}}{x_{\max} - x_{\min}} \tag{7}$$

where x_{new} is the normalized value, x is the original value, $x_{\max}$ and $x_{\min}$ are the minimum and maximum values of the raw data, respectively.

3.3. Results of SOM

As the setting of learning of SOM, the map size was set at 10 × 10, the neighborhood radius was decreased from 10 to 1, and the learning coefficient was decreased from 0.3 to 0.01. This learning was repeated 100 times.

Figure 2 shows the results of SOM. In **Figure 2**, "A", "B", and "C" represent "Non-members", "Reserve members", and "Members", respectively. The number after "A", "B", and "C" represents the number of the subject in each group. For the SOM map shown in **Figure 2**, a grey scale is used for visualization. The data in the light area can be considered that they are close to each other. On the other hand, a dark color between the data means there is a large distance between neighborhoods. According to the red line, it can be roughly divided into three clusters. From **Figure 2**, we can see that the data are not classified according to groups of A, B, and C. This is because the groups' A, B, and C are grouped according to the player's competitive level. But the input data for SOM is collected from the scores of the psychological questionnaire survey. Therefore, it can be considered that the players are classified according to their psychological ability.

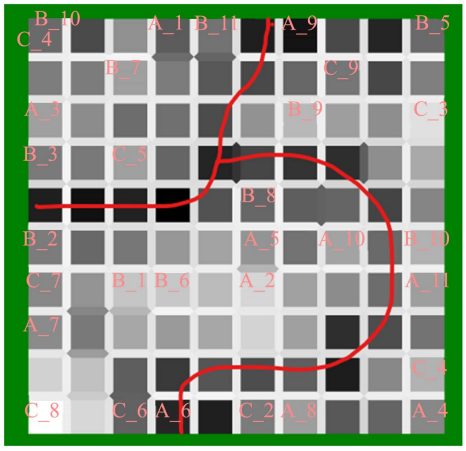

Figure 2. The results of SOM (map size = 10 × 10).

3.4. Results of Ward's Method

Figure 3 shows the dendrogram of Ward's method. In the dendrogram, groups A, B, and C are mixed in each cluster. This result also shows that the cluster is not classified by a player's competitive level. It is more than likely that clustered is classified by player's psychological ability.

4. Discussion

From Figure 2, according to the red line, dataset can be roughly divided into three clusters. Therefore, the number of cluster in dendrogram is decided as three. Figure 4 shows that the cluster in the dendrogram is classified into 3 clusters with color. Cluster 1, 2, and 3 are colored in green, yellow, and red, respectively.

According to the results of Ward's method, we analyzed the average of total scores in S-HRS, MTI, DIPCA.3, and ACSI in each cluster as shown in Table 1. The name of data (label) is the same used in the results of Ward's method. In Table 1, every average total score of cluster 3 tends to be lower than those scores of cluster 1. All of the psychological tolerance scores of cluster 3 tended to be lower than those of cluster1. Especially the total score of DIPCA.3 in cluster 3 is lower than the total score of the other two clusters. DIPCA.3 is not only looking at psychological tolerance but also looking at tactics, decision making, or others. Even a previous study (Tokunaga. 2001) showed that a higher level of players has higher total points of DIPCA.3. According to these results, cluster 3 has a lower psychological ability. Furthermore, cluster 3 has more non-member players compared to cluster 1. From these findings, these data need to be analyzed statistically for further discussion.

Next, the SOM map size was set to 25 × 25. We compared the results of SOM and Ward's method in Figure 5. The labels are colored according to the results of Ward's method. From Figure 5, the classified clusters are similar to Ward's method except the player A_6 is isolated from cluster 2 and mapped in the area of cluster 3. But the player A_6 has a big difference with cluster 3 because the

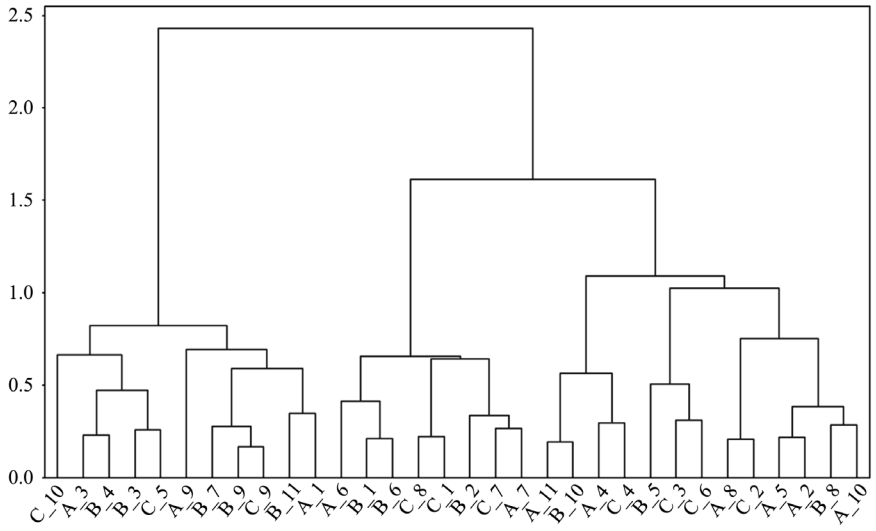

Figure 3. Dendrogram of Ward's method.

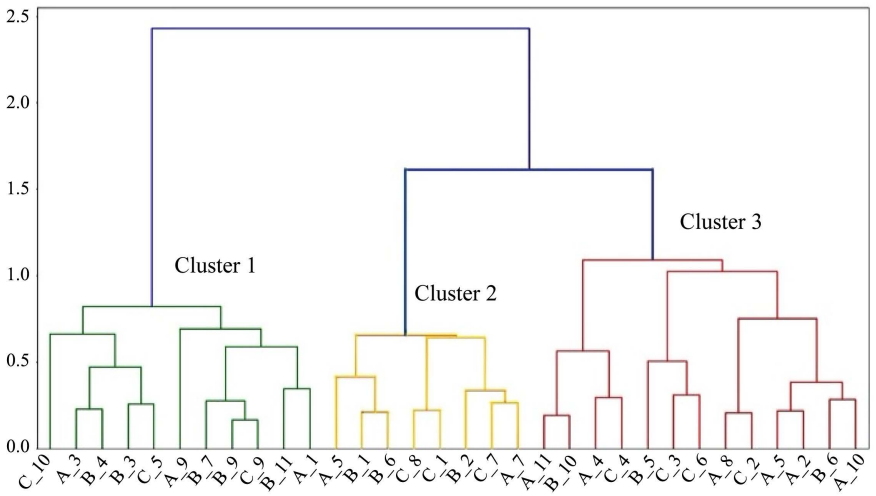

Figure 4. Three clusters in dendrogram of Ward's method.

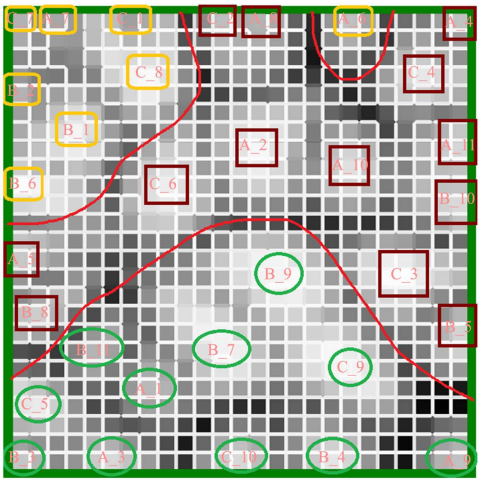

Figure 5. The results of SOM color according to the results of Ward's method (map size = 25 × 25).

Table 1. Average total scores of each questionnaire survey and player's competitive level in each cluster.

Label	S-HSR	MTI	DIPCA.3	ACSI	Competitive Level
Cluster 1	121.46	49.09	176.27	56.73	2.00
Cluster 2	102.88	39.63	186.13	50.25	2.13
Cluster 3	106.08	40.00	157.08	39.62	1.85

player A_6 is surrounded by dark color. In addition, although the player A_9 is mapped in cluster 3, we can clearly see that this player has a large distance between the other members (C_9 and B_4) in cluster 3. Like these, the SOM map can help us find more information about the features and relationships of each player. On the other hand, A_6 and A_9 players are also isolated from their own cluster in lower scale of Ward method too. These findings may help for coaching. Especially when coaches try to improve them, coaches may need to approach them differently from others in their clusters. Actually, according to coaches, these two players are players who were members for training match but non-member for official games. This kind of situation may influence their isolation. In addition to statistical analysis of Table 1, further research may need for these findings.

5. Conclusion

This study analyzed the mental level of different rugby players by using SOM and Ward's method. Results of SOM and Ward's method were checked with each other. SOM is a good reference to confirm Ward's method results in this study.

The two different types of clustering methods were a good match with each other in this study. Furthermore, the result of SOM makes clearer visualization than Ward's method and can help us find more information about the features and relationships of each player. Although SOM had not been seen a lot used for analyzing in sports, this study confirmed that SOM is a very effective analysis method for the sports area.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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