Simulation Training Effectiveness Evaluation Based on Fuzzy Comprehensive Evaluation

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Abstract. Based on the comprehensive analysis of the components of simulation training, the whole process and systematic evaluation and analysis of the effect of simulation training are carried out in three aspects: the group training ability of the group trainer, the expected degree that the simulation training system meets the simulation training and the training effect of the trainee, and the corresponding evaluation index system is established.

Keywords: Simulation training; Effectiveness evaluation; Fuzzy comprehensive evaluation.

1. Introduction
Simulation training refers to the practice activity of simulating realistic battlefield environment, conditions and actions, and drilling operation strategy and action methods with the aid of simulation training system. Simulation training evaluation is to use the method of system analysis to analyze the factors that affect simulation training, reveal the relationship between these factors and training effect, and then evaluate and estimate all the components of simulation training to find the best training efficiency. Simulation training system is a complex system, including many factors, the relationship between the factors, and some factors are difficult to be described quantitatively. How to make a comprehensive analysis and scientific measurement of simulation training effectiveness has become an urgent problem in simulation training.

2. Analysis of Simulation Training Elements
2.1. Elements of Simulation Training
The constituent elements of a system refer to the constituent elements, factors and units connected into a system in a certain way. Therefore, the elements of the system are the basis and actual carrier of the system. As a form of military training, simulation training has common elements with military training. At present, there are many theories about the elements of military training, some of which are shown in Table 1.

| Name             | Contains elements                                                                 |
|------------------|----------------------------------------------------------------------------------|
| Two factor theory| Substantive, Functional elements                                                 |
| Three factor theory | Group trainer, Trainee, Training intermediary                                   |
| Four factor theory | Group trainer, Trainee, Training content and Training method                  |
| Five factor theory | Group trainer, Trainee, Training content, Method and Training environment      |
In the theory of five elements, the group trainer is the general name of the training organization executor. It includes training leaders and training institutions at all levels who are responsible for the organization, leadership, planning and implementation of simulation training, as well as all kinds of personnel who undertake the work of professors, coaches and leaders. Trainees refer to the individuals or units receiving simulation training, which is the ultimate target of simulation training. The training content refers to the relevant theories and skills that the trainees need to master. Training method is the general name of organization form, implementation procedure, teaching coach method and means of simulation training. Training environment refers to the time, space, facilities, equipment, equipment and other physical environment of training. For simulation training, training environment includes two aspects: one is the place provided by simulation training, including virtual command post and corresponding seats. The second is the high fidelity synthetic battlefield environment provided by the simulation training system.

2.2. System Structure of Simulation Training
The structure of the system refers to the relatively stable interrelation, the sum of the interaction and the change mode among all levels and elements of the system. For simulation training, the structure of the system is the basic part to ensure the function of the system. Through certain training methods, the training environment, simulation system and equipment are used as the media by the group trainers of simulation training, and the training contents are applied to the trainees. The relationship between the components of simulation training is very complex, and the interaction between the components is the fundamental driving force for the smooth progress of simulation training.

2.3. Content of Simulation Training Evaluation
Based on the principle of effectiveness evaluation, the evaluation of simulation training is divided into three parts: the evaluation of group training ability, the evaluation of effectiveness of simulation training system and the evaluation of training effect.

3. Evaluation and Analysis of Simulation Training Effectiveness

3.1. Establishment of Simulation Training Efficiency Index System
According to the above analysis of the elements of simulation training, the overall effectiveness of simulation training is divided into three abilities that are group training ability $U_1$, system ability $U_2$ and training effect $U_3$.

The constituent elements of group training ability refer to the essential elements of group training ability. For the group training ability of simulation training, because of the different standards and angles of cognition and understanding, there will be different perspectives when dividing the components. If it is divided according to the responsibilities of the group trainers, the group training functions of simulation training can be divided into decision-making, planning, control, adjudication and assessment, and the corresponding group training ability can also be divided into the ability to reasonably determine the training content, the ability to formulate training plans, the ability to control the training process, the ability to make adjudication, evaluation and assessment, and the ability of comprehensive support, etc.

The ability of simulation training system refers to the degree of meeting the expected training objectives, which is demonstrated by organizing trainees to use this system for campaign simulation training. Here, it refers to the degree of the final system meeting the expected degree of simulation training or various functional requirements of training. According to the functional structure of the simulation training system, the ability of the system can be measured from four aspects: the ability to set up the combat background, the ability to simulate combat operations, the ability to simulate weapons and equipment, and the ability to simulate the battlefield environment.

Training effect is the direct embodiment of the realization degree of simulation training goal and the direct measure of training level. The evaluation of simulation training effect can measure the change of the trainees' command ability before and after training. It can be considered from two aspects: one is the improvement of trainees' mastery of battle command theory; the other is the improvement of
trainees’ mastery of battle command practice. The practice of battle command mainly includes: the ability to master the situation, the ability to determine the battle decision, the ability to make the battle plan, the ability to organize the cooperation, the ability to organize the support and the ability to control and coordinate the operation of the troops.

According to the above analysis, the evaluation system as shown in Figure 1 is established.

3.2. Establishing a Three-level Fuzzy Comprehensive Evaluation Model

3.2.1. Build Fuzzy Comprehensive Evaluation Factor Set. According to the evaluation index system established in Figure 1, it can be considered that the effectiveness of simulation training to be evaluated is a fuzzy set \( U \). It consists of three subsets \( U_1, U_2, U_3 \), i.e. \( U = \{ U_1, U_2, U_3 \} \). Each subset \( U_i \) has its own factor set \( U_{ik} \), that is \( U_1 = \{ u_{11}, u_{12}, u_{13}, u_{14}, u_{15} \} \), \( U_2 = \{ u_{21}, u_{22}, u_{23} \} \), \( U_3 = \{ u_{31}, u_{32} \} \).

Similarly, \( U_3 = \{ u_{311}, u_{312}, u_{313}, u_{314}, u_{315} \} \), \( U_3 = \{ u_{321}, u_{322} \} \).  

3.2.2. Determine the Judgment Set. The effectiveness of simulation training is divided into the following five levels.

\[
V = \{ v_1, v_2, v_3, v_4, v_5 \} = \{ \text{good, better, medium, worse, bad} \}
\]

3.2.3. Single Factor Comprehensive Evaluation. The expert scoring method was used to determine the membership degree \( \mu_{31k,w} \), \( \mu_{32k,w} \), \( \mu_{jkw} \), \( \mu_{2lw} \) of each factor \( u_{31i}(i=1,2,3,4,5,6) \), \( u_{32j}(j=1,2) \), \( u_{1k}(k=1,2,3,4,5) \) and \( u_{2l}(l=1,2,3,4) \). That is to say, if twenty experts are invited to grade \( u_{ijk} \) independently, and eight of them give “good”, the membership degree is \( \mu_{31i,j,k}=8/20=0.4 \). According to this method, the membership degree of all factors is calculated, and the fuzzy evaluation matrix \( R_{31} \) from \( U_3 \) to \( V \) can be obtained.

\[
R_{31} = (\mu_{31k,w})_{6 \times 5}(i=1,2,3,4,5,6; w=1,2,3,4,5); \quad R_{32} = (\mu_{32k,w})_{2 \times 5}(i=1,2; w=1,2,3,4,5);
\]

The fuzzy evaluation matrix \( R_1 \) and \( R_2 \) of \( U_1, U_2 \) to \( V \):

\[
R_1 = (\mu_{jkw})_{5 \times 5}(k=1,2,3,4,5; w=1,2,3,4,5); \quad R_2 = (\mu_{2lw})_{4 \times 5}(i=1,2,3,4; w=1,2,3,4,5);
\]

If the weight of \( u_{3ik} \) relative to \( u_{3i} \) is given, that is, \( \omega_{3j} = \{ \omega_{31}, \omega_{32}, ..., \omega_{3f} \} \), \( \sum_{k=1}^{f} \omega_{3ik} = 1 \). Among them, \( f \) is the number of factors of \( u_{3i} \), there is the first level comprehensive evaluation vector, \( B_{31} = \omega_{31} \cdot R_{31}, B_{32} = \omega_{32} \cdot R_{32} \).
3.2.4. Secondary Comprehensive Evaluation. If $B_{3i}$ is regarded as the single factor comprehensive judgment vector of $U_3$, then the fuzzy comprehensive judgment matrix of $U_3$ to $V$ is $R_3=(B_{31}, B_{32})^T$.

The weight of $u_{ij}$ in $U_i$ is $\omega_{ij}$, $\omega_i=\{\omega_{i1}, \omega_{i2}, \ldots, \omega_{ig}\}$, $\sum_{j=1}^{g} \omega_{ij} = 1$, Where $g$ is the number of factors of $U_i$, the third level comprehensive evaluation vector is $B_i=\omega_i \cdot R_i$.

3.2.5. Three Level Comprehensive Evaluation. Considering $B_i$ as the single factor comprehensive judgment vector of $U$, the fuzzy comprehensive judgment matrix from $U$ to $V$ is: $R=(B_1, B_2, B_3)^T$. The weight of $U_i$ in $U$ is $\omega_i$, $\omega=\{\omega_1, \omega_2, \omega_3\}$, $\sum_{i=1}^{3} \omega_i = 1$, then the third level comprehensive evaluation vector is:

$B=\omega \cdot R=(b_1, b_2, b_3, b_4, b_5)$, $b_i$ indicates that the effectiveness of simulation training is rated as the membership of $V_i$.

3.2.6. Algorithm. The effectiveness of simulation training is a comprehensive reflection of many factors, so the weighted average operator is selected to calculate the evaluation vector.

3.2.7. Determination of Efficiency. For a simulation training, the evaluation grade $V_i$ corresponding to the value of the maximum membership degree in the evaluation vector $B$ can be taken as the final evaluation result.

4. Conclusion
Simulation training is a complex system, which contains not only a large number of random uncertainties, but also many fuzzy factors that are difficult to quantify, so the evaluation of it will inevitably involve many theories and methods. In this paper, starting from the theory of five elements, the components and system structure of simulation training are analyzed, and the corresponding evaluation index system is established, and its effectiveness is evaluated by the method of fuzzy comprehensive evaluation. The evaluation results can provide reference for improving training design and training level.

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