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Exploring the Use of Intelligent Agents for Team Training

Daniel N. Mountjoy[1], Janeria D. Russell[1], Bala Ram[1], and Xuefeng Yu[2]

[1]Department of Industrial and Systems Engineering
North Carolina Agricultural and Technical State University
Greensboro, NC 27320, USA

[2]Dassault Systemes Americas Corporation
10330 David Taylor Drive
Charlotte, NC 28262, USA

Corresponding author's Email: {DN Mountjoy, mountjoy@ncat.edu}

Teams within or across organizations are becoming more widely distributed in terms of their geographical location. This can result in expensive training sessions that are difficult to schedule. Therefore, tools used to train distributed team members should be designed so the knowledge, skills, and behavior of others can be learned through the assistance of remote training modules. The use of intelligent agents is becoming more popular because of its ability to simulate work related situations autonomously and flexibly. This work was performed to determine if an intelligent agent-based software tool can be used to effectively train geographically distributed teams. Five types of training were administered and compared to examine team performance, as well as individual knowledge and skills acquired during a simple manufacturing supply chain scenario. Results indicate the agent-based training has a positive training effect and can be used as an effective method of team training.

Significance: Training teams with geographically dispersed members can be expensive and logistically difficult. This paper explores the potential to use intelligent-agent based software as an alternative to more traditional training techniques.

Keywords: Intelligent agents, team training, agent-based software, distributed teams.

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1. INTRODUCTION

Brannick, Salas, and Prince (1997) define a team as two or more people with different tasks who work together adaptively to achieve specified and shared goals. Team members may have the same or different skills and/or responsibilities. Specific behaviors of the individuals, when conducted in concert, contribute toward meeting the team's desired objective. One typically considers a team to act in relative close spatial proximity. That is, team members are not generally very far from one another, and can witness first-hand the effect of other members' actions on meeting the desired end-state. Based on the outcomes of such actions, other team members may alter their subsequent actions/behaviors to ensure continued progress toward the goal.

In recent years, however, the previously described concept of "team," has become more obscure. Particularly within the U.S. military, with an increased emphasis on joint service operations, smaller force sizes and rapid deployment, the team paradigm is moving more and more toward distributed members. Team members are, in effect, often isolated from one another due to geographic or vehicular constraints. An undesirable outcome of this teaming arrangement is a possible reduction of team members' abilities to know and understand what others are doing around them; what decisions they are making, and what information they are using. Cannon-Bowers, Salas, and Converse (1993) contend that the creation of a shared mental model is an important aspect of effective team decision making. The formation of a shared mental model may be made more difficult when team members are not physically located together.

Beyond team performance, issues involved with training are made more complicated since members are geographically distributed, and bringing everyone together under the same roof at the same time is expensive in terms of time and travel, and is particularly difficult to schedule. At issue, then, is how to effectively train teams when certain team members are either absent, or perhaps dealing with incomplete information. In a non-distributed team situation, even if individual team members have different information sources available to them, the relative close proximity allows other members the ability to observe their behavior and possibly even the information source itself. One of the major difficulties in distributed teams is the ability of members to form a common mental model of the environment when expertise differs from member to member, and each member and their respective information sources are physically isolated from one another. In this type of situation, the use of intelligent agents may help bridge the information gap.

In reference to team training, an abundance of literature revolves around Crew Resource Management (CRM) methodologies. CRM was developed to study and improve human performance in cockpit environments (Weiner, Kanki, and Helmreich, 1993) with the intent that all information/resources available to cockpit crews was being properly utilized (Salas, Rhodenizer, and Bowers, 2000). While developed for cockpit teaming arrangements, data gathered and lessons learned can be applied to teams operating in other operational environments.

While much has been learned through CRM research over the last several years, Salas et al (2000) point out that not enough is known about the benefits of advanced technology such as various display types and computer simulations for team training. Furthermore, CRM focuses on teams where members are co-located. The evolving situation of interest is one where team members are either absent altogether, or are geographically separated from each other. This study was conducted to address some of these issues, in particular, to explore the potential effectiveness of agent-based training versus traditional instruction-based approaches.

2. METHOD

The goal of this study was to assess the effectiveness of agent-based team training versus a more traditional training approach. To address this issue, a simplistic manufacturing supply chain scenario was formulated that required teams to "produce" a personal computer through the correct identification of components to meet a production manager's performance and delivery date specifications. Team performance was evaluated prior to and following training.

2.1 Participants

Thirty individuals volunteered to participate in this study. Participants were a mixture of undergraduate and graduate industrial engineering students at North Carolina A&T State University, ranging from 20 to 41 years of age (average age = 24 years).

2.2 Experimental Design

The experiment was conducted as a between-groups, pre-training-post-training design. Each participant was randomly assigned to one three-member team, and each team received only one type of training. The independent variable in the study was Training Type, which had five levels: Control (C), Traditional (T), Traditional with Cross-Training (TX), Agent-Based (A), and Agent-Based with Cross Training (AX). Dependent variables were task completion time, number of correct selections made during the task, number of interactions with team members, proportion of correct interactions with team members, and the average score on the knowledge assessment prior-to and after training.

2.3 Training Materials

2.3.1 Agent-Based Training Platform

A multi-agent training system was developed using AgentBuilder™. Five collaborative agents were developed using Java, with each agent assigned to perform the following specific tasks:

- The Facilitator Agent initializes the training software and registers the trainees into the system.
- The Manager Agent creates the specifications and distributes any selection made to the remaining three agents.
- The Design Agent plans a list of components based on the specifications given by the Manager Agent.
- The Manufacturing Agent evaluates the list of components from the Design Agent and the list of vendors from the Purchasing Agent.
- The Purchasing Agent plans a list of vendors for the components.

This training software was designed such that it is capable of running with or without user intervention. Specifically, the Design Agent, Manufacturing Agent and Purchasing Agent can be replaced altogether, or in any combination, by human users if desired. During an agent-based training session, users acting in place of a software agent are able to witness interactions between the various agents, and have access to databases specific to their particular task within the team. A summary of each agents' functions is provided in Table 1.

2.3.2 Traditional Instruction Manuals

The instructional manual included an overview to provide an introduction and background of the decision-making process, and a job description to give each participant a description of what his/her responsibilities would be. The manual also consisted of a section for the terminology and definitions that the participant needed to be aware of. They were also provided a copy of the criteria and constraints that assisted in the decision-making process. A conscious effort was made to provide the same type of information that can be received through the agent-based system to reduce the possibilities that any training effects would be due to the training technique itself, not the quality of information presented in either method.

Table 1: Summary of Agent Functions

Agent Name	Agent Function
Manager Agent	Creates a pc specification for the new product request
Design Agent	Plans a list of pc components based on the new product request
Manufacturing Agent	Evaluates the part list from Design; Evaluates the vendor list from Purchasing
Purchasing Agent	Plans a list of vendors for the new product components
Facilitator Agent	Registers trainees into the system

2.4 Procedure

The experiment was conducted in three different phases: pre-training, training and post-training. These phases took place over the course of three days for all participants. During the pre-training phase participants signed a consent form, then completed demographics and pre-training knowledge assessment questionnaires. The pre-training knowledge assessment was designed to determine the subject's knowledge of each department's roles represented on the team prior to training. The team completed a task that required them to make decisions based on given criteria and constraints initially provided by the production manager (the experimenter).

Each personal computer the teams were to produce consisted of four major components: a motherboard, RAM, hard drive and CPU. The team’s goal was to produce a PC for the lowest price that would meet the production manager’s specified performance requirements and delivery date. An overview of the required information flow and decisions made by each team member is portrayed in Figure 1. The task was videotaped to assist in data collection. The post-training phase was identical to the pre-training phase, with the exception of the consent form and demographics questionnaire.

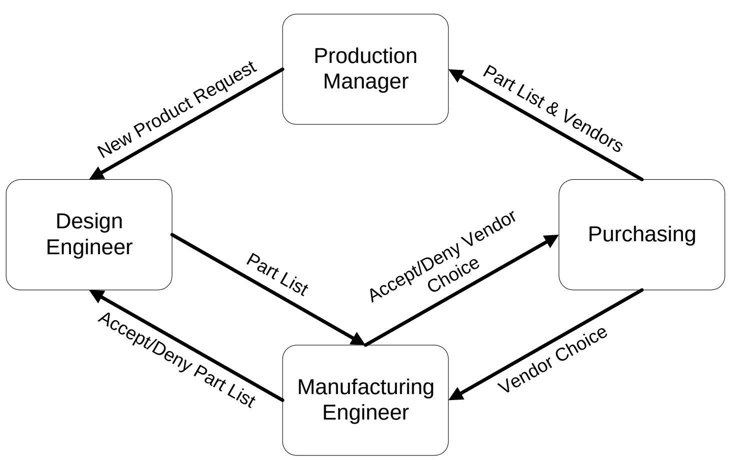

Figure 1: Flow of information required for the PC production task.

The training phase consisted of the team participating in the training method that corresponded to their assigned training type. The training simulated the process of the task that was completed in the pre-training phase. The process in each training type was similar in sequence, the only difference being the training approach. The control groups were the only teams that did not receive any training. The traditional trained (T) groups and the traditional cross-trained (TX) groups received the traditional instruction-based training. These teams were provided training manuals and used role-playing as a simulation method. The agent (A) and agent cross-trained (AX) groups received training by way of the intelligent agent-based software. In both training techniques, team members participated as their assigned role – the main difference was that traditional trainees participated with other people, while the agent-based trainees participated along with intelligent agent counterparts.

3. RESULTS

All data was analyzed via the Wilcoxon Signed Rank test. This analysis was run to determine if there was a statistically significant effect of training on subject matter knowledge (Figure 2), task completion time (Figure 3), and the number of correct interactions between team members (Figure 4). Statistically significant results were obtained for subject matter knowledge, $T(10) = 0$, $p < .05$, and task completion time, $T(10) = 8$, $p < .05$. Implications of these results are discussed in the next section.

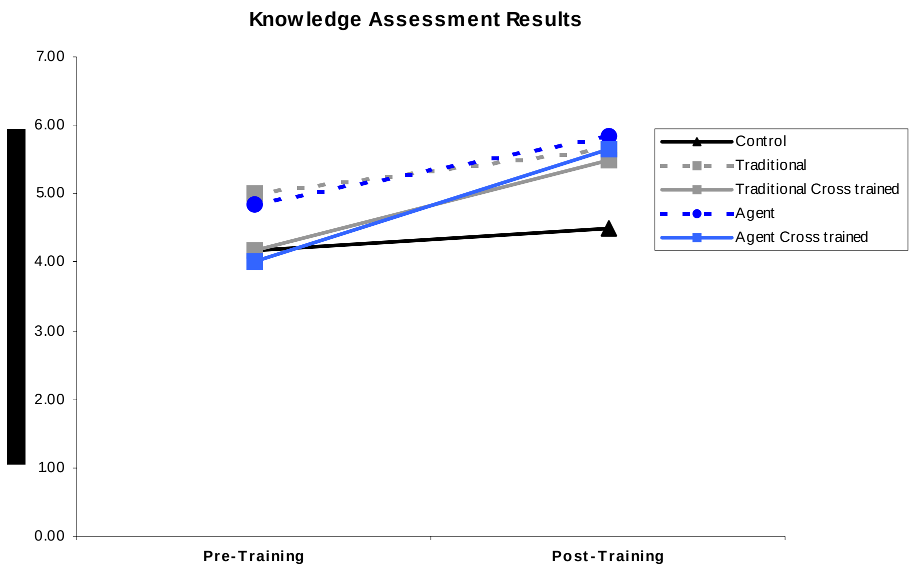

Figure 2: Results of the knowledge assessment questionnaire.

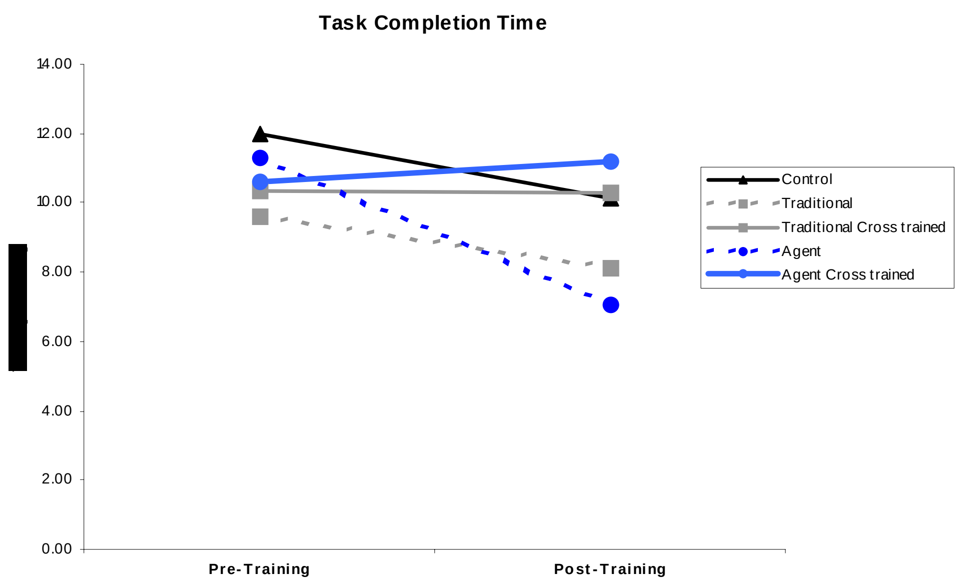

Figure 3: Task completion times recorded prior to- and after training.

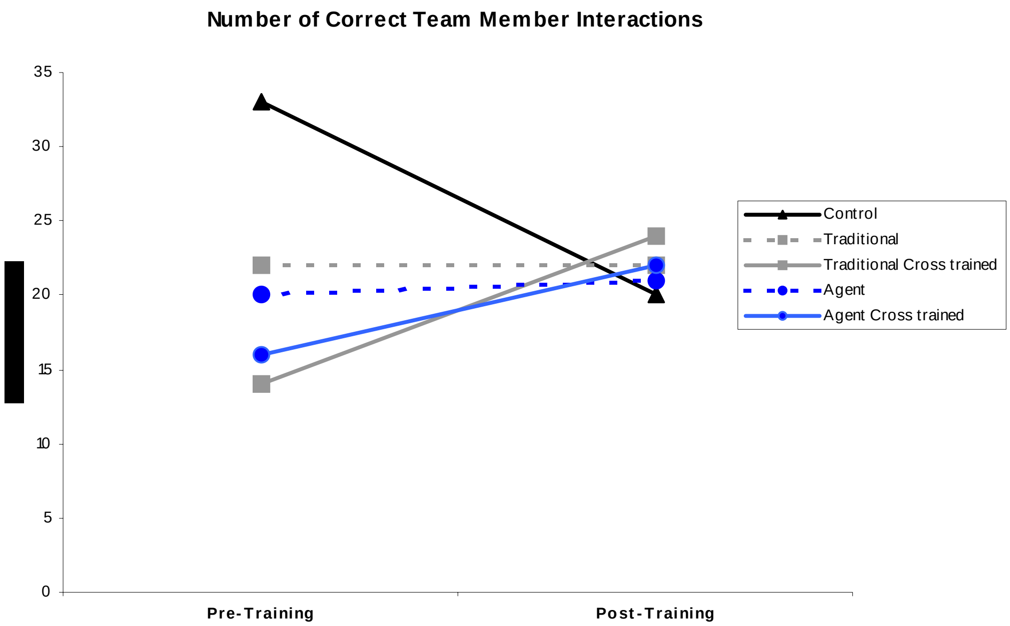

Figure 4. Number of correct interactions between team members during the PC production task recorded prior to- and after training.

4. DISCUSSION

It should be noted that the main point of interest in all results is the difference between the pre-training and post-training data. Participants were randomly assigned to training groups in an attempt to even out the knowledge and experience level between groups.

4.1 Subject Matter Knowledge Assessment

It is readily apparent from Figure 2 that all training types resulted in a positive effect on the participants' knowledge of supply chain management subject matter. The control group also shows a slight increase in knowledge level, although to a lesser degree than the experimental groups as would be expected. It is interesting to note that the results of the cross-trained teams (AX and TX) paralleled each other, as did those of the non-cross-trained teams (A and T), regardless if they participated in the traditional or agent-based training. Overall, the cross-trained teams showed a greater increase in their knowledge level than their non-cross-trained counterparts. This result is consistent with past research indicating the benefits of cross training.

4.2 Task Completion Time

While it was expected that task completion time would decrease following training, Figure 3 reveals mixed results, with training shown to benefit only some of the groups. The A and T training groups and the control group were able to decrease their respective task performance times, the TX group was virtually unchanged, while the AX group saw a slight increase in completion time. The AX group data was a bit skewed due to poor performance by one of the two AX groups in the post-training task. It is suggested that the cross-trained groups would have also seen a decrease in times (on average) had there been a larger subject pool. This issue deserves further attention in future studies.

4.3 Number of Correct Team Member Interactions

Since in the pre-training phase team members were not provided any sort of guidance on which other team members they should communicate with in order to complete the task, it was expected that the number of correct interactions would increase following the training phase. Indeed, as shown in Figure 4, the A, AX, and TX groups each increased the number of meaningful interactions following training, while the T group held steady. Curiously, the number of correct interactions in the control group decreased markedly during their second task performance. Again, it is noteworthy that the AX and TX groups exhibit the largest increase in correct interactions since cross training is often viewed as being particularly beneficial to team performance.

5. CONCLUSION

Since teams are increasingly more likely to include members from various geographic regions, it is wise to investigate team training methods that can help reduce travel costs and associated logistics problems. The research summarized here helps to support the idea that intelligent agents can be a beneficial piece of that solution. While no evidence was found to show that agent-based training is better than more traditional approaches such as instruction and role playing, this was not the goal of this work. The intent was to determine if intelligent agent-based software can be used to effectively train teams. In that sense, the results seem to indicate that agent-based training does indeed result in a positive training effect (often paralleling results from the traditional methods), and therefore has the potential to be used effectively as a tool for team training.

It can be concluded from our discussion that there is a need to develop disability specific work measurement data. This data needs to be developed in line with the requirements for standard data as defined by work measurement system. Such data would be useful not only to determine standard times for tasks but also help in determining wage compensations and design incentive schemes, determine the levels of productivity, determine insurance benefits, etc.

6. REFERENCES

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7. ACKNOWLEDGEMENTS

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