# Training for Emergencies

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**Background:** Disaster triage embodies all key features of dynamic decision making. Multiple decisions have to be made under time pressure and workload. Situations are often unpredictable requiring trainees to apply learned routines to novel conditions. Up to this point, psychologic theories of learning can provide only little support on how to train disaster responders for these challenging situations.

**Methods:** We summarize and illustrate several examples of dynamic decision-making research using simulations and microworlds as a starting point for a new theory of learning and skill acquisition in disaster triage. We describe MEDIC, a microworld in the context of medical diagnosis, and other simple tasks designed to gather people's understanding of accumulation, a basic component of dynamic tasks.

**Results:** Using a microworld called MEDIC, we demonstrate the difficulties of learning to be effective at medical decision making and present a set of theoretical constructs that help to explain those difficulties. Implications for how to overcome them are also discussed. On the basis of this kind of research and our instance-based learning theory, we develop principles for the design of effective disaster training and for building a theoretical framework that can systematically predict how to best train for successful performance in disaster situations. Finally, we also demonstrate the difficulty of understanding dynamic systems; educated adults with medical expertise have trouble understanding even simple dynamic medical problems.

**Conclusions:** Dynamic decision-making research can be used as a theoretical and empirical reference for advancing pediatric triage training to prepare trainees for disaster triage. Recommendations for effective learning derived from dynamic decision-making research are presented.

Key Words: Dynamic decision making, Triage, Emergency training, Disaster training, Instance-based learning theory, microworlds.

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Disaster situations are characterized by a casualty load exceeding the available resources. These situations are becoming more relevant and often negatively impact human physical and psychologic well being. Often disaster responders must make multiple decisions while the situation is rapidly changing or evolving. Furthermore, decisions in disaster situations are frequently made under extreme uncertainty and in real time, meaning that the timing of the decisions determines their value.

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Triage is a critical element of emergency care, and a great deal of work has been done on developing triage techniques and on training medical personnel to do triage.<sup>1-6</sup> Nevertheless, little is known about the reasoning skills required and the difficulties of acquiring those skills—a critical element if training is to be effective. This research is a first look at some of those issues based on the instance-based learning theory (IBLT), a theory of decision making in dynamic and complex situations.<sup>7</sup> We will demonstrate how difficult it can be to acquire the necessary skills for disaster triage, and we will suggest several important principles that promise to improve training based on the IBLT and previous research described below.

The characteristics of emergency and disaster situations are the key features of dynamic decision making (DDM), a field of research that has been described and studied by psychologists and decisions scientists since the 1960s.<sup>7–9</sup> Examples of DDM research contexts include the following: firefighting resource allocation and management in real time; triage decisions in a medical emergency room; 911 operators determining relative urgency and deploying resources; and supply chain management, among others. In general, DDM often involves a dynamic allocation of limited resources in real time.<sup>10</sup>

Up to this point, there are few theories of DDM, and psychologic theories have little to say about how to prepare and train individuals for disaster triage.<sup>11</sup> Typical emergency training procedures involve rigorous classroom instruction where students receive information about the general emergency response planning. Training performance is often evaluated through the administration of written or oral exams and sometimes by hands on performance during drills and practical exercises. An initial step toward the development of a new theory of learning and skill acquisition in triage and disaster situations is the instance-based learning theory (IBLT).<sup>7</sup>

IBLT is a theory based on cognitive science and memorybased decision-making ideas, developed to explain performance and learning in dynamic decision-making situations. This theory proposes that decisions in DDM situations are made from experience, retrieving the best decision from memory made in a situation that is similar enough to the situation being confronted. IBLT is a psychologic theory that basis its predictions on the characteristics of human memory and cognition. A basic element from this theory is an instance. IBLT proposes that in each decision-making situation, we save an instance in our memory, structured in the form of situationaction-outcome triplet.

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The situation in an instance consists of a set of cues. For example, in triage decision making, an instance can be a case of a patient in the emergency room, the classification decision made regarding this patient and the resulting outcome from that decision. The patient is defined by a set of cues such as walking conditions, respiratory rate, pulse, mental status; and the healthcare worker needs to make a decision (action) about the urgency for care of the patient (e.g., immediate priority, minor priority, delayed, and deceased). If provided, feedback (often delayed) helps to determine the accuracy of the decision made. In IBLT, an outcome is associated with the decision-situation relationship; in a way that, in future triage experiences the healthcare worker would retrieve similar cases that produced best outcomes.

Figure 1 shows the detail of an instance representation in IBLT. Instances are discrete units of knowledge, which are constructed, upgraded, and reused through experiential learning. According to IBLT, decision instances progressively accumulate in memory with experience. Therefore, when the conditions of the disaster situation are stable (similar across practice) and paired with feedback, decision making will gradually improve. In general, the applicability of past decisions to a situation will be determined by the similarity between a situation confronted in the environment and the situations stored in memory; the accuracy of past decisions will be determined by the feedback received from the environment; and the appropriate application of the feedback to the right instances. Although IBLT can make some suggestions that would improve triage training, the theory needs to



**Figure 1.** Instance-based learning. Instances are composed of three parts: situation, decision, and outcome. The instances accumulate over time. At each time point, a situation is compared with past instances and based on similarity past instances are reused for future decisions.

be molded and extended to make more complete and precise predictions of the effects that different training programs would have on the transfer to triage disaster situations.

Triage in disaster situations and other emergency medical procedures are DDM tasks that present several challenges to the current theories of human learning and to existing training programs.<sup>11</sup> First, mass casualty incidents are unique, infrequent events that present the trainees with rare opportunities to put into practice what they have trained for. Thus, a challenge is to help the trainee maintain and activate the knowledge and skills learned. Second, despite the great efforts to prepare trainees, accidents and disaster situations are by their nature unpredictable. Thus, the training will commonly be incomplete and trainees will often confront unexpected and unforeseen demands.

Current research in learning in DDM situations and IBLT<sup>7</sup> helps define a number of initial steps to improve training for disaster conditions and triage decision making. These are summarized below.

## FACTORS THAT IMPEDE LEARNING ABOUT DYNAMIC SYSTEMS

Learning in dynamic systems is difficult.<sup>6</sup> Although humans can learn to perform dynamic, complex tasks, learning in dynamic systems occurs gradually and slowly.<sup>12,13</sup> In the Dynamic Decision Making Laboratory (www.cmu.edu/ddmlab), we have empirically investigated how a number of factors suggested by IBLT<sup>7</sup> influence learning in dynamic systems. These are some examples that are of special relevance to triage disaster situations:

1. Learning under time constraints. IBLT recommends that slow is fast when it comes to learning to perform under time constraints. In a dynamic resource allocation task like triage, Gonzalez<sup>14</sup> has demonstrated that individuals who trained a task at a slow pace were able to perform more accurately at transfer and under high time constraints than did those who only trained under high time constraints. These results come from a study using a dynamic resource allocation task similar to triage. Thirty-three graduate and undergraduate college students recruited from local universities were randomly assigned to either the fast or slow condition group. The Water Purification Plant simulation was used for this study. The goal in this task is to distribute all the water in the system on time and under time constraints by activating and deactivating pumps. The environment is opaque, so the user is uncertain about some key variable values. For example, water appears in the system according to a scenario defined by the experimenter and unknown to the user. The environment changes autonomously and in response to the user's decisions. Because a maximum of five pumps can be activated at any one time, the decision maker's actions are interrelated. This task translates directly to disaster triage situations because it involves time pressure, limited resources, incomplete knowledge about the situation, unexpected events, and the need to coordinating efforts to meet the demands. All participants ran the model on 3 consecutive days. Under the fast condition, each simulation trial lasted

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8 minutes. Participants under this condition completed 18 trials during the 3-day period (6 trials/d). Under the slow condition, each simulation trial on the first 2 days lasted 24 minutes (2 trials/d), whereas each trial on the last day lasted 8 minutes (6 trials). For all the participants, the first 2 days were training days, and the last day was the test day. The results show that slow training led to better performance than fast training on day 3 with fast performance for both the groups. Studies like this do not only generate fundamental understanding of triage training but also to formulate training recommendations. In this case, Training for high time pressure tasks is more effective if performed at a slow pace before releasing learners to realistic time-constrained conditions.

- 2. Learning under workload. Similar to the results on time constraints, Gonzalez<sup>15</sup> found that individuals who trained a task under low workload were able to perform more accurately at transfer and under high workload than did those who trained under high workload conditions all along. Thus, these two studies demonstrated the fact it is not a good idea to train individuals in conditions "close to the real conditions" when it comes to workload and time constraints. Slow and low workload is best during training for fast and high workload tasks.
- 3. The similarity and diversity of experiences. In other studies, Gonzalez and and coworkers16,17 found that the similarity between situations people confront influences how fast and how well they learn. Gonzalez and Quesada<sup>16</sup> demonstrated the influence of the similarity of past decisions on future decisions. In another study, Gonzalez and Madhavan<sup>17</sup> used a luggage screening task for investigating effects of similarity of experience on learning. In such a task, each piece of luggage can have distractors and targets. Targets could be of different kinds: knives, guns, glass objects, liquids, etc. This task resembles disaster triage situations in their key features: disaster responders have to discriminate between patients who would profit most by treatment based on their symptoms and available resources (targets) and patients who would not (distractors). As a dynamic decision-making task, the condition of a patient might change over time resulting in a different category membership. Gonzalez and Madhavan demonstrated that a condition where target change (targets can be targets in some trials and distractors in others) results in better learning and transfer compared with more consistent conditions (in which targets are always targets). In addition, Gonzalez and Madhavan demonstrated that a larger diversity of instances during training helped individuals detect unknown and novel targets more accurately at transfer than did those trained with a consistent set of targets. According to IBLT,7 heterogeneity of practice implies a larger diversity of instances in a multidimensional space of the cues that define the instances. The more diverse those instances are, the better the chances will be of finding similarity to past decisions when a novel instance is confronted.
- 4. The type of feedback. This study<sup>15</sup> suggests that simple knowledge of results is not enough for learning. In addi-

tion, reflecting on our own performance during training might not be good enough for learning in dynamic and complex tasks. What improved learning best in this study was to reflect on an expert's performance, which helped improved the own person's performance.

All the factors described above were studied using simulations of complex, dynamic tasks, called microworlds.18 The design of simulations and games for training is common and microworlds are becoming more prevalent in the classroom, for research, and for practitioners. Many disciplines are now adopting simulations and games in the classroom, such as Engineering<sup>19</sup>; Business and Management<sup>20</sup>; Medicine<sup>21,22</sup>; and Political Science.<sup>23,24</sup> The usage of microworlds for research goes back several decades and was introduced by Turkle.25 Recently, we developed a microworld in the context of medical diagnosis, MEDIC, to study probability learning and perceptions of probabilities for hypothesis generation and testing. The design of MEDIC is discussed in a recent publication.<sup>26</sup> In correspondence with Kleinmuntz,<sup>27</sup> MEDIC represents decision making in medical diagnosis and treatment. MEDIC has some key features of complex decision-making scenarios: the task is complex with numerous diseases and symptoms; there are base rates for symptoms associated with diseases, making associations probabilistic; and decisions need to be made in real time (i.e., the status of the patient deteriorates unless an action is taken). The system allows investigation of the effects of different degrees of test diagnosticity, treatment effectiveness, and treatment risks on participants' performance and learning. In addition to Kleinmuntz's criteria, MEDIC has feedback delays implemented (e.g., for receiving test results) and it can be potentially used for dynamic diagnostic cues or dynamic symptoms. A learning study with MEDIC and other aspects of learning in the medical context are presented next.

### LEARNING AND PERFORMANCE IN THE MEDICAL CONTEXT

In a recent study, college students learned to diagnose four possible diseases among simulated patients, with varying degrees of associations between symptoms and diseases (see Table 1).

As shown in Table 1, associations between symptoms and diseases varied between 0.1 and 0.9. After deciding on a diagnosis, deterministic treatment for that disease had to be provided by participants. A laboratory study was conducted similar to that reported in Gonzalez and Vrbin.<sup>26</sup> In this study, 12 college students from a local university participated in this

TABLE 1.	Disease Symptom Associations for Four Diseases
of Simulate	d Patients in MEDIC

	Disease 1	Disease 2	Disease 3	Disease 4
Paga ratas	0.25	0.25	0.25	0.25
Symptom 1	0.23	0.25	0.25	0.25
Symptom 2	0.9	0.1	0.5	0.5
Symptom 2 Symptom 3	0.9	0.9	0.1	0.1
Symptom 4	0.5	0.5	0.9	0.1

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study for a flat payment rate. Each participant solved cases, where each case represented one patient. Participants were presented with a simulated patient and were asked to give a diagnosis by testing for the presence or absence of as many symptoms as needed according to the symptom-disease matrix (available to them). Thereafter, they had to prescribe a treatment, once again according to a probability table indicating the effectiveness of a treatment for each possible disease. Each case ended once a treatment was prescribed. The treatment could be either effective or not effective, and participants received feedback about the effectiveness of the treatment and the accuracy of their diagnosis before seeing the next simulated patient. Performance was measured by the final health of simulated patients, after the treatment had been prescribed.

Participants improved their performance with repeated trials (patients) as shown in Figure 2. That means they learned to come up with the appropriate diagnosis and the appropriate treatment for that diagnosis faster, resulting in the better final health of their patients. Nevertheless, the performance of participants remained suboptimal even after 56 cases. In Table 1, there are three diagnostic symptoms (2, 3, and 4) where the presence of the symptom is strongly associated with just one disease. In contrast, symptom 1 was associated at chance level with all four diseases. Therefore, this symptom was not diagnostic. While students learned with practice to favor testing for diagnostic symptoms, they did not stop testing symptom 1 despite associated costs in time and patients' health and the lack of information that this symptom resulted in. In 32% of the patients, participants tested symptom 1; in 69%, they tested symptom 2; in 97%, symptom 3; and in 64%, symptom 4.

These results illustrate an effect that is well known in dynamic decision-making tasks: humans have great difficulties learning these tasks; learning is slow and suboptimal; and humans are not maximizers or optimizers, but rather they are satisficers in the way that they often adopt "good enough" solutions, a concept known as bounded rationality.

Recently, Gonzalez and coworkers have found that learning can be difficult even in situations defined as "simple" by traditional means: few variables and components in-



**Figure 2.** Average final health for 56 patients diagnosed and treated in the MEDIC simulation.

volved, no time constraints and workload, no uncertainty, complete feedback, and no need for real-time decisions. Highly educated adults were tested for their understanding of the basic building blocks of dynamic systems that can scale up to disaster situations and triage: accumulations and flows.<sup>7,28,29</sup> The regulation of a stock or a system state is one of the most common DDM tasks.<sup>30</sup> In a disaster, the number of patients to be treated can be understood as a stock that accumulates with patients coming in and leaving the ER after treatment. Another example of the relevance of understanding accumulation and flows concerns the amount of fluids in a patient's body. This is often an important indicator of health and thus important to monitor. The amount of fluids in the body increases when the intakes exceed the outflows and decreases when the outflows exceed the inflows. Thus, in medicine as well as in many other contexts, the regulation of a system state, the perception of the system state, and the effect of the flows on the system are essential skills for dealing with dynamic tasks13 and an essential skill for allocating resources in real time.

The regulation of stocks can be understood as a closedloop learning process in which the status of the situation is influenced by our goals, external events, and previous decisions (see Fig. 3). For example, for regulating a stock or a system, decisions are made to correct for the discrepancy between the goals and the current status of the system, and thus learning depends on feedback or the associations between the results and our actions.<sup>30</sup> This feedback is often spaced out and separated in time from the actual decisions, making it difficult to understand the cause-effect relationships over time.<sup>15</sup> This lack of understanding is a serious obstacle for disaster response that hinders learning from experience.

It is known from several studies<sup>13,28,29</sup> that welleducated adults have difficulties understanding even simple dynamic systems like a bathtub with just one inflow, the faucet, and one outflow, the drainage. In a current study, we investigated whether medical students would perform better when estimating stock dynamics than other college students for medical domains.

A group of medical students and a group of college students were asked to answer four questions for one of six scenarios like the one illustrated in Figure 4. That scenario involved the judgment of the amount of fluids in a human







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**Figure 4.** Diagram from a recent stocks and flows study with medical and nonmedical students that shows the amount of intravenous fluid and urination for a patient and a 30-hour period of time.

body according to the rate of intravenous fluids administered and urination over a 30-hour period of time.

For this scenario, participants had to estimate when the most IV fluid was administered, when the most urination occurred, when the amount of fluid in the body was highest, and when it was lowest (correct answers: 4, 21, 14, 30).

Medical students and college students did quite well answering the first two questions: the majority of medical students answered these questions correctly (95.5% and 95.5% for questions 1 and 2, respectively). The same holds for college students (96.7% and 96.7% for questions 1 and 2, respectively). This essentially indicates that both groups, medical students and generic students, were able to read the graphs. However, only a small minority could correctly answer the last two questions (27.3% and 18.2% of medical students as well as 3.3% and 13.3% of college students for questions 3 and 4, respectively). Comparisons of these numbers show a significant difference only in the question regarding when the amount of fluid in the body was highest (Exact Fisher test Chi-square (1) = 6.24, p = 0.033), but no difference in the other questions. In any case, the fact that the percent correct in questions 3 and 4 was lower than 30% for medical students is worrisome. Therefore, medical students did not profit from their medical knowledge and experience when answering these questions. These results suggest that medical students have to cope with the same cognitive limitations as lay students when interpreting and judging flows. We are currently working on designing learning and training routines to help people acquire a deep understanding of these dynamic relationships.

#### SUMMARY AND CONCLUSIONS

Despite triage's critical role for emergency care, little is known about the decision-making skills required and the conditions for acquiring those skills. This research is a first look at some of those issues. We have demonstrated with MEDIC that acquiring the necessary skills is much more difficult than one might first think. We suggest a number of important principles that promise to improve training. These include diversity of training practice cases and a careful mix of slow training under thoughtful conditions with more rapid training under realistic conditions.

We have argued that responding to disaster situations can be understood as dynamic decision making with demands exceeding available resources and with multiple decisions that have to be made under time pressure and uncertainty. We have illustrated how research on dynamic decision making using microworlds and instance-based learning theory can be applied to generating principles for disaster training. The factors of DDM that are of special relevance for emergency training are time constraints, workload, similarity or diversity of experiences, and types of feedback. For these factors, we found that what best prepares people for novel situations is not to train under maximal realistic conditions but under conditions that foster skill acquisition and a deeper understanding of the situations confronted.

Some examples of principles for emergency training derived from DDM research are the diversity of practice and the slow is fast principles. Larger diversity of instances during training helped individuals detect unknown and novel targets more accurately at transfer than did those trained with a consistent set of targets.<sup>17</sup> In addition, slow training led to better performance than fast training.<sup>15</sup> Thus, training for high time pressure tasks is more effective if performed in a slow path before releasing learners to realistic conditions. We also illustrated that training routines have to take into consideration the cognitive abilities and constraints that trainees cannot overcome with domain experience.

IBLT<sup>7</sup> and DDM research can be used as an initial step toward a new theory of learning and skill acquisition in triage and emergency situations as a theoretical and empirical framework to account for and make accurate predictions about the effectiveness of different training methods for pediatric emergency triage activities.

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