Back to the Future and Forth to the Past

In the movie *Back to the Future*, Marty McFly accidentally travels back in time to 1955 to find his parents back in high school. Being stuck in the past, Marty needs to go back to the 1980s, in other words, the future. Hence, the movie's title.

If a cognitive engineer could travel back in time to, say, the early 1950s, what would they be able to discover? Today, most researchers would believe not much of interest was going on in the 1950s, as American academic psychology was still heavily dominated by behaviorism. Yet, the first seeds of a "cognitive revolution" (Baars, 1986) had already been sown, and for simplicity's sake, one might even date the cognitive revolution back to September 11, 1956, when Allen Newell, Herbert Simon, and Noam Chomsky presented their work at a Symposium on Information Theory at MIT. All of this history is well known and the reader is referred to Gardner (1985) for a historical overview.

What is less well known, however, is that one of the driving forces behind this cognitive revolution was the applied research carried out by RAND's Systems Research Laboratory in the area of air defense. The question posed to RAND early in 1950 was whether they could develop a training program that would markedly increase the ability of Air Defense Centers to prevent enemy aircraft from getting through. In August 1950, a senior social scientist at RAND Corporation, John L. Kennedy, proposed a study on how groups of Air Force personnel would respond to possible intrusions of Soviet bombers into U.S. air space. Kennedy was particularly interested in the effects of stress, learning, and organizational adaptation. His approach would very much resemble what we would call today "staged-world studies" (Woods, 2003); that is, the faithful design of scenarios that are meaningful to actual practitioners. It is remarkable that Kennedy and his coworkers, Robert Chapman, William Biel, and Allen Newell, did not resort to highly simplified stimuli that would be presented to college students under controlled laboratory conditions. Rather, they chose to recreate an actual Air Defense Direction Center in an old pool hall at 410 Broadway in Santa Monica, manned by actual Air Force personnel (Baum, 1981; Klein, 2016). In order to instill a realistic military culture, the experimenters communicated with the crew solely in the name, form, and style of the Air Force (Chapman, Kennedy, Newell, & Biel, 1959).

A gruesome schedule of experimentation, programming, recording, and data analysis followed: from February 1952 until June 1954, they conducted four large-scale experiments consisting of 595 hours of experimentation with approximately 40 Air Force officers per session, with more than 12,000 hours of recordings in total, including tape recordings of all verbal communications between team members (Chapman et al., 1959). Marks on IBM printouts simulated the blips of radar scopes. The programming of the stimuli on the large radar screens was accomplished by 3,570,000 punched cards.

Returning "back to the future" from the early 1950s, there are many lessons to be learned from the Systems Research Laboratory's air defense experiments. First, somewhat serendipitously, early in 1952, Simon, who was a mathematics consultant to RAND at the time, met Newell for the first time. Newell had figured out a way of using a computer to generate maps that could be used on a simulated radar screen. To Simon, this was his first introduction to the idea that one could use a computer for something other than producing numbers (Baars, 1986, p. 373). If only for historical reasons, this first meeting between Newell and Simon is of major significance in the history of cognitive psychology and AI. Many cognitive psychologists would be well advised to take note of these highly complex experiments carried out by two pioneers of AI who are generally only known for studying "toy

Journal of Cognitive Engineering and Decision Making
2019, Volume 13, Number 1, March 2019, pp. 3–9
DOI: 10.1177/1555343418819832
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problems" or "highly simplified problems." Of course, Simon, who was in his late thirties around this time, already had obtained a PhD in political science and had studied organizational decision making all his professional life, so the type of complexity presented by the air defense experiments was not foreign to him.

Second, methodologically, the air defense experiments are an almost prototypical instance of "staged-world studies" (Woods, 2003). They were highly authentic and lent themselves perfectly to process tracing studies. Yet, in Simon's own words, they "made little substantive contribution to basic science" because "we lacked the necessary language and technology to describe thinking people as information processors" (Simon, 1991, p. 168). However, the important general lesson to be learned from this may be a bit different than what Simon thought. It is remarkable that Chapman et al. (1959), in their "relatively innocuous paper" (Simon, 1991), did not present much in the way of generalizable insights from their large-scale experiments. Compare this with the related research by Patterson, Watts-Perotti, & Woods (1999) on voice loops as coordination aids in Space Shuttle Mission Control. Here, too, hundreds of hours of observations were carried out in a mission control center, albeit under less experimental control than the air defense experiments. Yet, the main difference is not so much one of validity of empirical data collection, but rather the concepts used to interpret the data collected.

In hindsight, it is easy to recognize all sorts of phenomena in the air defense experiments carried out in the early 1950s that would later be classified under such headings as "complex adaptive systems," "team learning by after action reviews," "team reflection," and "team strategizing." If "chance favors the prepared mind" (Louis Pasteur), then the minds of Kennedy and his colleagues were less well prepared than we are today. As Woods and Hollnagel (2006) have stated, new specific observations can only be understood by bringing general patterns to bear. Patterns "are empirical generalizations abstracted from and grounded on observations made through different studies" (p. 12). When Simon, in his autobiography, reflected on these studies and stated that he lacked the necessary language and technology at that time, what he meant was that he lacked knowledge of general patterns, primarily because the research base on complex team processes had not been established yet.

Third, even though the air defense experiments made little substantive contribution to basic science, their practical impact cannot be underestimated. Basically, these endeavors showed that Air Force personnel could be trained in a standardized manner, using objective performance measures to track their performance and guide their learning processes by self-guided team reflection in debriefing sessions (what would later be called the Event-Based Approach to Training, or EBAT, see Fowlkes, Dwyer, Oser, & Salas, 1998). To senior Air Force officers, it was clear the RAND System Training Program had to be implemented throughout the entire Air Defense System. This required the establishment of a spin-off of RAND to oversee the training of military personnel. First, the Systems Development Division of RAND was established. It grew so quickly it soon dwarfed the rest of RAND. Therefore, in November 1956, a separate corporation, the System Development Corporation (SDC), was established. It would employ more psychologists than any other organization or institution at that time. SDC was also responsible for developing the first truly automated command and control system, the Semi-Automatic Ground Environment (SAGE) system. It would expand its activities rapidly into many government and private organizations before finally going "public" in 1980 (see Baum, 1981, and Weiner, 1996, for historical overviews).

In conclusion, traveling back in time to these experiments carried out in the early 1950s, armed with knowledge of concepts and patterns of today, would be highly illuminating to many cognitive engineers, even after almost 70 years have passed. But this raises the question what we can contribute to the future. If someone in 2090 would go back in time to, say, 2019, would they still be surprised by the research we carried out today? In particular, what has the *Journal of Cognitive Engineering and Decision Making* (*JCEDM*) contributed over its past 12 years of existence (2007–2018) in terms of knowledge of patterns or concepts?

JCEDM (2007–2018): ANALYSIS OF ABSTRACTS

I carried out an analysis of the frequency of occurrence of words and phrases in all abstracts published in *JCEDM* in its history. The underlying assumption in this analysis is that an abstract is an appropriate reflection of the contents of an article; more specifically, the contents of an article are appropriately reflected in the use of words in its abstract. Assuming that authors actively try to write abstracts that reflect the contents of their articles, this assumption is at least partially tenable (the assumption breaks down insofar as single words are poor substitutes for complex patterns of behavior). Abstracts rather than key words were chosen in order to obtain a richer dataset. In order to pinpoint developments over the years, abstracts were clustered by certain (3-year, 6-year) periods, even though this meant that the total number of words per period could differ (for instance, the first 3 years yielded approximately 9,000 words in total, whereas the last 3 years yielded almost 12,000 words in total).

Word and phrase frequency counts were carried out using the program WriteWords (www.writewords.org.uk). Concepts that are germane to the scientific process were not taken into account. For instance, words such as “research,” “analysis,” “participants,” “data,” “study,” or “results” were all omitted from further analysis. In case both a singular and a plural form was used in the data set (e.g., “system” and “systems” or “team” and “teams”), the most frequently occurring form was noted and the other one was ignored. In order not to go into too much detail (many words were used fewer than 10 times), I used the *h*-index philosophy, this time applied to *word frequency* (*f*) rather than to citations: the *h(f)*-index for a particular period of time is defined as the *n* number of words that are each used at least *n* number of times in abstracts. For instance, for the period 2007–2009, the *h(f)*-index is 18, meaning that 18 words were each used at least 18 times in all abstracts from that period. In order to detect substantial and meaningful shifts across periods, individual abstracts were inspected for the multiple occurrence of a particular word. For instance, the word “uncertainty” occurred 22 times in the 2007–2009 period, but its use was mainly restricted to two abstracts, each using “uncertainty” eight times. Therefore, we cannot meaningfully attribute any developments over time on the basis of this word.

The results are first presented for two periods: 2007–2012 and 2013–2018. Both single words and two-word phrases are reported. Subsequently, periods of 3 years are compared with each other. Table 1 presents the *h(f)*-indices and the list of words for both periods.

As seen from Table 1, the *h(f)*-index is 27 for the period 2007–2012, and 29 for the period 2012–2018, probably reflecting the increase in total number of words in abstracts for the latter period as compared with the former. Many words, particularly the most frequently used ones, are used in both periods, though to slightly different extents. There are a number of notable exceptions: first, the word “automation” is used 34 times in the first period, whereas it is used 98 times in the second period. This is a substantial difference that required some further exploration. To that end, two smaller periods were examined in more detail: 2007–2009 versus 2016–2018. The reasoning behind this is that, if there is a trend, it would be more visible if we would restrict our analysis to the periods most far apart. Indeed, the word “automation” was used only twice in the 2007–2009 period, whereas it was used 67 times in the 2016–2018 period.

Second, the word “engineering,” as is visible in Table 1, was used 35 times in the 2007–2012 period, whereas it did not appear in the top 29 in the 2013–2018 period. This does not mean that the word “engineering” was never used in the latter period (in fact, it was used 16 times). When analysis was restricted to the two periods farthest apart, results showed that in the period 2007–2009, “engineering” was used 28 times, whereas in the 2016–2018 period, it was used 10 times, by far not the large difference as seen for “automation,” but a large decrease nevertheless. The same decrease can be seen for the use of the word “dynamic:” from 21 times in 2007–2009 to six times in 2016–2018.

In terms of application areas, it is interesting to note that the words “military” and “health” are used differently in the periods 2007–2012

TABLE 1: *h(f)*-index, Word From a Particular Period, and Frequency of Occurrence

h(f)-index	Word (2007–2012)	Frequency	Word (2013–2018)	Frequency
1	cognitive	114	decision	164
2	decision	113	design	113
3	information	91	cognitive	103
4	task	85	performance	98
5	human	75	human	98
6	performance	74	automation	98
7	control	71	system(s)	88
8	system	67	information	82
9	design	64	work	73
10	model	52	task	72
11	SA	51	training	66
12	process	44	model	66
13	teams	43	support	56
14	work	42	situation	56
15	tasks	39	complex	54
16	situation	38	control	53
17	engineering	35	SA	50
18	automation	34	models	45
19	uncertainty	34	health	44
20	support	34	care	44
21	training	32	awareness	43
22	awareness	32	process	40
23	display	31	team	35
24	dynamic	30	mental	33
25	interface	29	safety	31
26	workload	28	interaction	31
27	military	28	naturalistic	30
28			development	30
29			strategies	29

Note. SA = situation awareness.

(military: 28 times) and 2013–2018 (health: 44 times). Of course, this is undoubtedly due to special issues devoted to these respective topics, but this by itself may be a reflection of the changes that have occurred over the years. In more detail, the word "military" was used 12 times in the 2007–2009 period, whereas the word "health" was used only twice in that period. Conversely, in the 2016–2018 period, the word "military" was used only twice, whereas the word "health" was used 29 times. Therefore, there seems to be a shift in attention to the medical domain to the detriment of the military domain (this conclusion needs to be confirmed by detailed analysis of each article, as it assumes that the use of words in an abstract is an appropriate reflection of its contents).

In terms of two-word phrases, the results are shown in Table 2 below.

The results in Table 2 clearly show the predominance of two pairs of words: "decision making" and "situation awareness." The *Journal of Cognitive Engineering and Decision Making* should perhaps be renamed the *Journal*

TABLE 2: *h(f)*-index, Two-Word Phrases From a Particular Period, and Frequency of Occurrence

h(f)-index	Words (2007–2012)	Frequency	Words (2013–2018)	Frequency
1	decision making	68	decision making	77
2	situation awareness	23	situation awareness	36
3	systems engineering	17	human factors	20
4	cognitive readiness	15	decision support	18
5	human factors	14	task analysis	15
6	adaptive automation	12	mental models	12
7	task performance	11	human-automation interaction	12
8			cognitive work	12

of Situation Awareness and Decision Making (if the past is in any way predictive of the future)! The use of the words "cognitive readiness" reflects the special issues devoted to this topic in 2012, whereas the words "human-automation interaction" reflect the 2018 special issue devoted to this topic. The increase in the use of the concept of "situation awareness" partially reflects the 2015 special issue devoted to this topic, but it should be noted that the concept of "situation awareness" has from the start been a mainstay of the journal (see also the use of the abbreviation "SA" in Table 1).

In conclusion, *JCEDM* is a journal that, based on the words used in its abstracts, has predominantly been about situation awareness and decision making. It looks at cognitive task performance by humans processing information in complex situations involving highly automated systems. These two sentences cover the top 10 of most frequently used words in the abstracts of this journal. Over the years, there has been a tendency to focus less on systems engineering or cognitive engineering and more on automation, but of course this is not a strict dichotomy, as "cognitive engineering" incorporates "automation." Hence, this change may reflect a change in terminology rather than a substantial change in actual topics or fields studied.

"FORTH TO THE PAST"

The 12-year period covered by *JCEDM* so far is only a brief one considering we can go back at least 70 years to discover worthwhile research. Trying to extrapolate from the past to the future is an exercise best left to fools. However, shaping the future by making small, incremental decisions in the present, is a viable alternative. As the French philosopher Jean-Paul Sartre said, "man is nothing else but that which he makes of himself," and a journal such as *JCEDM* hence also shapes the future by what it makes of itself, in other words, by what it publishes. We are planning on a special issue on human-machine teaming, which may be viewed as belonging to the general topic of automation, but with the twist that the automation should not be viewed as a passive object, a black box that is inaccessible, but rather as an intelligent teammate in its own right. The view already espoused by Woods and Hollnagel (2006) that joint cognitive systems, the ensembles of humans and machines, should be the unit of analysis, rather than each taken separately, may finally become a mainstream point of view and research topic. Special issues on topics such as these will shape the future, just as articles on other topics suitable for this journal.

For instance, in a recent review by an ISO Working Group of Human-System Interaction Standards for Robotic, Intelligent, Autonomous Systems (RIAS), Earthy and Downs (2018) distinguished six categories of human-RIAS issues/problems: (1) RIAS designed characteristics effects on individual humans, (2) human-RIAS interaction issues (individuals/teams interacting directly with RIAS, (3) RIAS to RIAS issues, (4) RIAS organizational issues, (5) social/cultural/ethical issues, and (6) emergent societal issues. *JCEDM* has so far focused mainly on the first two categories of issues. I would very much welcome papers addressing organizational, social, cultural, ethical, and societal issues of RIAS.

However, the intelligence that we have so far attributed to machines as stand-alone objects, even when considering them as teammates, is already far more distributed and invisible than some of us realize. The dangers of AI do not so much lurk in robots that take over the world and eliminate humans, but rather in us copying and being determined by and yielding control to smart algorithms determining what information we will process. In 1980, Simon wrote that we often find we are studying sociology when we think we are studying physiology (Simon, 1980). This is because there are few regularities and invariants to be found when we study adaptive systems. We adapt to the smart algorithms we have created ourselves, and by doing so we create histories that further determine our future actions. There is little psychology, let alone physiology, in here, as we are moving away from self-determined rational behavior to network-determined mass behavior. The macrocognitive concepts we developed in the heydays of human-machine autonomy may perhaps have to be relegated to the historical dustbin once we adapt to smart algorithms (just as Sartre later in his life discovered that individual freedom is bounded by materialistic and historical circumstances). All of this is to say that we are moving into an era of "networked cognitive systems" rather than "joint cognitive systems," and that classical constructs such as "situation awareness" and "decision making" will in all likelihood also undergo a transformation.

TIPS FOR GETTING AN ARTICLE PUBLISHED IN *JCEDM*

I would like to end with some tips for prospective authors who are considering submitting a manuscript to this journal. These tips are roughly based on what previous editors in chief of various human factors or applied psychology journals have written as part of their outgoing editorials (Ackerman, 2007; Cooke, 2009; Salas, 2008), as well as what Endsley, Hoffman, Kaber, and Roth (2007) wrote in their inaugural issue of *JCEDM*. These may be considered "lessons learned" and are worth repeating here for prospective authors. They go beyond what is listed on the journal's website under "authors' instructions."

1. Be sure the manuscript is within scope of the journal, that is, fits the general topic of how people engage in cognitive work in real-world settings (if the research is carried out in the laboratory, explicitly include *target-test mapping* (Woods, 2003) by indicating how one transcends *limits to authenticity*).
2. Be clear about why the issue at hand matters and to whom it matters.
3. Start from a theory and clearly link the current research to existing theory and to critical phenomena in the real world (if the research is carried out in the laboratory).
4. Clearly state a research question and make clear how it contributes to theory or methods beyond what is already known.
5. Connect methodology and research question: Make clear that the research question is indeed answered with the methods used.
6. Provide enough information about methods to enable replication.
7. Be clear about the success or failure of an approach and provide explanations.
8. Show the linkages between the laboratory and the real world for the reader to evaluate (if the research is carried out in the laboratory).
9. Make clear what the findings mean for practitioners, designers, or managers.

Science is the process of convincing one's peers by cogent argumentation and rigorous research (Latour & Woolgar, 1979). *JCEDM* should be viewed as the forum where the argumentation takes place and where we build up a pattern database with which to interpret future instances of cognitive work. Each article published contributes to the overall argumentative process and pattern database in which we, as a community, engage. I am looking forward to working with you in developing constructive arguments and patterns on how people engage in cognitive work in real-world settings.

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