Errors in Randomness and Understanding of Stochastic Risk Assessments

A Presentation for the

Health Physics Society Annual Meeting

Spokane, WA

Professional Enrichment Program
PEP 3-C
Sunday, 2:00 – 4:00 pm, July 17, 2016

by

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While health physicists usually understand that radiation is of main concern for stochastic effects (future random chance of cancer), most of the world does not understand stochastic effects, randomness, or probabilities. Most people just want to know if they will be “Safe or Not Safe.” They do not want to hear about radiation risk estimates as probabilities. When confronted with a risk probability, they are inclined to substitute an easier question, such as, “How do I feel about getting cancer?” They can easily answer this question without any technical knowledge or understanding of randomness or probabilities. Research has shown that when chance or randomness is involved, people’s thought processes for safety decisions are often seriously flawed. Not many people understand the principles that govern chance and how these processes play out in decisions for radiation safety. The normal processes for safety decisions can lead to mistaken judgments and technically inappropriate reactions for radiation safety (consider reactions following Fukushima Dai-ichi). Health physicists have long been puzzled and often frustrated about how people can make instant decisions regarding radiation with little or no actual data. Studies in psychology show that our ability to make instant decisions for safety is a part of how our brains are wired for our protection. We are programmed to fear first and think second. We have survived by this innate ability to foresee dangers and take protective actions accordingly. Instant prediction of danger is not something we do consciously by evaluation of facts or circumstances. This is done by our subconscious mind which functions as a superfast computer processing all incoming signals by associations with images and experiences in our memories. Thus we are programmed for instant response without any conscious thought.

While this instinct for safety is important for our survival, it is also prone to substantial errors for some dangers, such as radiation. There are at least 15 or more ways that our subconscious is prone to errors relative to the actual circumstances. My studies are showing that even professionals with technical understanding are also prone to errors. This can be demonstrated by the question, “Are your sources of radiation safe?” An instant answer to this question can only come from the subconscious because a conscious evaluation of data takes time to process. Also, when asked, “How do you know?” the answers invariably come down to beliefs in what we have heard or read about radiation safety. Out subconscious mind is prone to running ahead of the facts to draw coherent conclusions from a few scraps of evidence. Subconscious impressions then become the basis for instant decisions and long term beliefs about radiation.
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- BS - Civil Engineering, University of Vermont (1961)
- MS - Sanitary Engineering, Massachusetts Institute of Technology (MIT) (1963)
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- CHP – Certified Health Physicist, American Board of Health Physics (1983–present)
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- FHPS - Fellow of the Health Physics Society and Past President (2000)
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Experience

2010 – pres. Director, Radiation Safety Counseling Institute. Workshops, training, and counseling for individuals, companies, universities, or government agencies with concerns or questions about radiation and x-ray safety. Specialist in helping people understand radiation, what is safe, risk communication, worker counseling, psychology of radiation safety, and dealing with fears of radiation and nuclear terrorism for homeland security.

2007 – pres. VP, Training Programs and consultant to Dade Moeller Radiation Safety Academy, training and consulting in x-ray and radiation safety, safety program audits, radiation instruments, NORM, and regulatory requirements.

1984 - 2007 Director, Radiation Safety Academy. Providing x-ray and radiation safety training, audits, and consulting to industry (nuclear gauges and x-ray), universities, research facilities, and professional organizations.

1988 - 2006 Manager and Contractor to National Institutes of Health (NIH) for radiation safety audits of 3,500 research laboratories and 2,500 instrument calibrations a year, along with environmental monitoring, hot lab and analytic lab operations, and inspections of three accelerators and over 100 x-ray machines.

1990 - 2005 President of Key Technology, Inc. a manufacturer and primary laboratory for radon analyses with over 1,500,000 measurements since 1985. Primary instructor at Rutgers University for radon, radon measurements, radiation risks, radiation instruments, and radon risk communication courses (1990-1998).

1986 - 1988 Laboratory Director, RSO, Inc. Directed analytical programs and Quality Assurance for samples from NIH, Aberdeen Proving Ground, radiopharmaceutical companies, and the nuclear industry.


Health Physics and Professional Activities

Publications
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An Introduction and Brief History of My Counseling Career

Ray Johnson, CHP

Introduction
This new monthly column will address issues regarding general perceptions about radiation risks that have puzzled specialists in radiation safety for decades. While many such specialists have ideas about why the public seems so fearful of radiation, they generally are not prepared to deal with the psychology of risk perceptions. Likewise psychologists, who understand how to provide help with fears, generally do not understand the principles or practice of radiation safety. Although I am not the ultimate authority on matters either of psychology or radiation safety, I have attempted to provide a bridge for transfer of understanding between these two professions for more than 30 years.

How I Got Started
In the middle 1970s, at about 13 years into my career in radiation safety, I found myself attempting to provide helpful responses to public inquiries of concerns for fallout from Chinese atmospheric nuclear weapons tests. While I had the data and understood the technology of radiation safety, I was totally unprepared for questions such as, “It’s raining, should I keep my children home from school?” Or, “When fallout arrives over the US, should I stop nursing my baby?” The underlying aspect of such questions was about fears of radiation. Even with more than eight years of college, I had not learned how to hear and respond to fears in a helpful way. I did not know how to identify feelings or have any vocabulary for describing or discussing fears.

No Understanding of Feelings
Although my wife could have told me this, I discovered my deficiency in a men’s group at church. I was about 35 when at a Saturday meeting one of the men described an issue at home. The leader of the group (Rev. Dr. James Morgan) asked me for my feelings on the issue. So I told him what I thought. He again asked for my feelings and again I told him what I thought. Finally after he patiently asked me a third time for my feelings, I suddenly realized that I had no idea what he was asking about. I had given him my thoughts twice, what more could he want. When he at last said, “I wanted to know your feelings, not your thoughts,” I understood that an awareness of feelings was totally lacking in my education up to that time.

TA Training
When I asked Dr. Morgan how I could learn about feelings, he said that he taught a nine-month class on Transactional Analysis (TA) which was mainly about training counselors to hear and respond to feelings. I enrolled and quickly found that I was the only engineer in a large group of people learning to become psychological counselors and therapists. Needless to say, I felt like a
fish out of water and was overwhelmed for most of the class. However, I began to see possibilities and enrolled a second time. After considerable progress, I enrolled a third time as an assistant to Dr. Morgan.

First Presentations
I was just nearing the end of my third enrollment in TA when the Three Mile Island (TMI) nuclear plant accident occurred in March 1979. Using my newly gained insights in psychology, I presented a paper at the annual meeting of the Health Physics Society in Philadelphia in July 1979 on “Communication – the Health Physicists Dilemma.” Within a few months I was invited to be the dinner speaker at a program by The Oak Ridge Institute for Science and Education (ORISE) and later at a joint meeting of three HPS Chapters at Cherry Hill, NJ to discuss TMI.

I had an interesting experience while driving to Cherry Hill. I had with me another invited speaker, a Ph.D. Social Psychologist from the Nuclear Regulatory Commission. We had been collaborating to study psychological issues at TMI. All the way to NJ he kept asking for my counsel on how to deal with girlfriend issues. Although he was a psychologist, he knew nothing about interpersonal relations or how to deal with feelings. Although I had no degree, I was a trained and experienced counselor.

Early 1980’s
I continued to take training, workshops, and seminars on listening skills, journaling, death and dying, EST, etc. while practicing counseling informally in my church. I also presented numerous seminars, classes, and retreats for the church on listening to God, each other, and ourselves. In early 1983, Dr. Allen Brodsky called a meeting at his house to discuss communication needs of health physicists. More than 30 attended. At this meeting, I volunteered to lead a committee on communications for the Baltimore Washington Chapter of the Health Physics Society. Larry Petcovic was part of this committee. Together we put on a Myers-Briggs Type Indicator (MBTI) workshop with help from staff of Johns Hopkins. Larry and I then presented a morning Continuing Education Lecture on communications at the annual meeting of the HPS in Baltimore in 1983.

1984
This year I attended a year-long Johns Hopkins program on Organizational Systems and Communications. Larry and I began writing a monthly column for the HPS Newsletter on Insights in Communication. We continued this column until 1989. At the 1985 midyear HPS meeting in Colorado Springs, I presented the first MBTI workshop for HPs. Larry and I continued to present these workshops to over 3,500 HPs at HPS meetings until about 1989.

1990s to the Current Day
I once again wrote a monthly column, Communication Insights, for the HPS Newsletter from 1994 until 2001. I also wrote and presented several hundred papers, articles, workshops, and seminars on radiation risk communication to the HPS, ANS, AAHP, AARST, and AIHA. I have continued training in counseling and have served as a Commissioned Stephen Minister and counselor in my church since 2003.
Topics for this New Column
Possible topics could include (in no particular order):

- The basis of radiation fears
- Hearing and responding to fears
- How people make decisions for radiation safety
- The role of the subconscious mind and radiation fears
- Counseling fearful or angry workers or others
- Facing the terror of nuclear terrorism
- Practical tools for radiation risk communication
- How to talk with people who are fearful of radiation
- The gift of fear
- Brain based learning for HPs
- Emotional intelligence
- Communication with the subconscious mind
- Neuroscience marketing
- What to say, when you do not know what to say
- Communication with the media
- Active listening skills
- Becoming a radiation myth buster
- Effective presentations
- How to stay non-defensive
- How to position for win-win
- Non-advocate communication
- Techniques for persuasion
- How to achieve credibility with any audience
- Leadership and motivation

Other ideas for this column are welcomed. Contact webed@hps.org
No. 2 – Radiation Safety Psychology

Health Physics Society Newsletter – June 2012

The Power of the Subconscious Mind

Ray Johnson, CHP

For decades we (radiation safety specialists) have been puzzled by the widespread fears of radiation which seem irrational and unwarranted by the circumstances. We keep asking ourselves, “Why do so many people view radiation with such great alarm?” We have also wondered, “Why are our best efforts to provide truthful, factual, information about radiation risks not always helpful for alleviating fears?” In my counseling training from many years ago, I learned that fears are driven by images in people’s minds. From this insight I proposed that the reason people are fearful of radiation is because of an image in the back of their minds of unacceptable consequences that may result from radiation exposure. While I still believe this is true, I am now learning there are more than images that drive people’s fears and reactions to radiation. After reading several books on the workings of the subconscious mind, I now realize that people’s fears are about automatic or instinctive functions of the subconscious mind for their protection.

Our Conscious Mind

To help understand the workings of the subconscious mind, we need to distinguish the functions of the conscious and subconscious. Our conscious mind functions rationally in a relatively slow deliberate manner to think, reason, and make decisions and choices based on sensory input. This function, which is the source of our awareness, occupies less than one percent of our brain. Our conscious mind serves as the captain of our ship and the giver of orders. However, our conscious minds can basically only deal with one thing at a time (have you noticed when looking for a street address on a dark night, that you automatically reach over and shut off the car radio).

Our Subconscious Mind

This is the seat of our emotions and creativity. More than 99.999% of stimuli to the brain are processed subconsciously. Our subconscious mind functions exceedingly fast like an enormous super computer which operates the machine we call our body. Without our awareness, our subconscious mind functions 24/7 regulating our heart, our breathing, the digestion of food, the healing of cells, etc. Better than any computer, our subconscious is a multi-tasker which handles hundreds of thousands of inputs simultaneously for our health and protection. Our subconscious mind takes orders from the conscious mind without judgments. Our subconscious mind is also programmed from infancy to react instantly to signs of danger. Do we want to allow the slow acting conscious mind to take time to think about whether a snake is going to strike?
Fears of Radiation May Now be Involuntary

Fear is a natural response of our subconscious to protect us from danger. We have survived by paying attention to our fears and reacting accordingly. For most of us, our subconscious mind is already programmed with instinctive fears of heights, snakes, spiders, closed spaces, being submerged, etc. After hearing repeatedly the message “radiation is deadly” for our entire lives, the conscious mind of many people has transferred this message to their subconscious for their protection. Thus, radiation has now become programmed into their subconscious mind as another instinctive or involuntary source of fear. This means adverse reaction to radiation is often now automatic and leads people to quickly conclude, “Radiation, I don’t want anything to do with that.”

Our subconscious mind hears that radiation is very dangerous and to assure our safety our subconscious attaches terrible feelings (fears) to radiation. By linking radiation with emotional trauma, a powerful negative association is formed to avoid this source of danger and a radiation phobia is born. Thus, fear of radiation is no longer a rational conscious choice based on logical analysis, but a gut instinct (feeling). Our subconscious does not consult with our conscious mind before raising the alarm of fear. For protection our subconscious has to react before we can even consciously think about it. Avoidance of radiation is now an automatic response.

Can we Talk a Person Out of Their Fears?

Since radiation may now be the source of automatic instinctive fear, the question is whether we can talk someone out of their fear of radiation. Like other instinctive fears, such as fear of snakes, can we talk someone out of their fear by saying, “It’s only a harmless garter snake.” Can we change a person’s fear of radiation by saying, “You do not have to be afraid, it’s only like a chest x-ray.”

Since fears of radiation come from our subconscious, efforts to speak to the rational thinking mind may not help. Giving out facts about radiation safety does not change the feelings. Fears of radiation are based on images of unacceptable consequences. All fears are the result of imagination of what will happen next. A person afraid of heights imagines getting near the edge and falling. Appeals to the conscious mind with explanations about reality and safety may not change these images and the basis of fear. The least helpful response is to say, “You do not have to be afraid.” Trying to tell people that they do not need to fear radiation does not connect with their gut feelings and images of danger. The imagination of the subconscious mind will win over the rational conscious mind every time.

It may also not be helpful to ask a person fearful of radiation, “Why are you afraid?” Since their fear comes from their subconscious, they do not know the answer. If forced, they may rationalize an answer that may not make any logical sense to a technical person. At this point, if a technical person attempts to correct errors of technology, the fearful person may become distrustful and even angry because their fears are not about facts, but feelings. Experts are wrong to think they can ease fears of radiation by simply “getting the facts out.” While facts are
evaluated by the rational conscious mind, fears come from subconscious gut feelings, not logical analysis. The gut feeling of a fearful person will tell them that even though radiation injuries are very unlikely to occur, that is not an adequate justification for ignoring risks of possible future effects.

**Fears May be the Greatest Danger from Radiation**

Fear, anxiety, stress, and worry can cause drastic psychological and physical effects such as

- high blood pressure
- addictions to alcohol and drugs
- heart disease
- weight loss or gain
- depression, insomnia
- suicides, abortions
- post traumatic stress syndrome

Since our subconscious mind reacts automatically to messages forwarded from our conscious mind without judgment, all of the effects above could be controlled by our subconscious. We all know of the “placebo effect” where our subconscious mind produces a beneficial outcome for some type of medication because our conscious mind believes the medication will work. Since our subconscious does not judge messages from our conscious mind, it will carry out the expectations of the conscious mind. For example, a person retires and says to themselves that their useful lifetime is now over. How long do they live after retirement? A person dies and their spouse concludes they no longer have a reason for living. How long before the spouse also dies?

Studies of the subconscious mind show that it will attempt to carry out whatever the conscious mind believes. Henry Ford is reported to have said, “If you believe you can or believe you cannot, you are right.” Your subconscious mind takes the orders you give it based upon what your conscious mind believes and accepts as true. When you repeatedly say to people, "I can't afford it," your subconscious mind takes you at your word and sees to it that you will not be in a position to purchase what you want.

Because our conscious beliefs so strongly affect the reactions of our subconscious mind, I am now asking questions about how beliefs may affect our physical reaction to radiation. Is it possible if people believe that they will be harmed by radiation, that their subconscious will cause that to happen? To put this question into a current context, I would wonder, “*How many persons evacuated from the Fukushima province in Japan will suffer harmful effects because they have been told that they should expect effects from radiation?*” Will their belief in harmful radiation effects cause them to happen? I hope someone more knowledgeable than myself will explore such questions.
References


How Do We Make Decisions for Radiation Safety – Part I?

Ray Johnson, CHP

The answers to this question are very complex. Despite my studies for 25 years with the Myers-Briggs Type Indicator (MBTI) trying to understand how people acquire information and make decisions, I still have much to learn. While the MBTI provides helpful insights on dominant data gathering preferences using our five senses or intuition and dominant decision making preferences using either logical thinking or feeling, decisions for safety involve all of these preferences at the same time. Our brains are programmed to protect us in many different ways. In this article I would like to share some observations drawn from a recent book by David Ropeik, “How Risky is it, Really? Why Our Fears Don’t Always Match the Facts.”

Two Systems for Safety Decisions
People make decisions for radiation safety based on how much they fear radiation. There is nothing wrong with fear which is a natural response of our minds for our safety. We have survived as a species by paying attention to our fears and reacting as needed for protection. While we may take time to think about dangers, most of our fears originate at a subconscious or instinctive level which reacts very rapidly as appropriate for protecting us from imminent danger, such as a striking snake. Psychologists have commonly believed that there are two separate systems involved in safety decisions: 1) reason and rational analysis of facts and 2) emotion, instinct, and gut reactions. Ropeik says these are not separate systems. We are not perfectly rational or completely emotional and instinctive.

System 1 seems to be favored by technical specialists and may lead to more intelligent judgments, however, this approach is very slow and takes more effort. Also, we often do not have all the facts for making a good decision, the time for gathering the facts, or the knowledge to understand what the facts mean. On the other hand, System 2 is often favored by non-technical people based on gut instincts and feelings which are much faster and do not need all the facts before sounding an alarm for safety. Ropeik says we actually use both systems all the time and he says we are Affective. This means we make decisions using both our minds and heart. We decide based on facts and how we feel about the facts, as well as instincts, values, cultural views, personal experience, and life circumstances.

We are Programmed to Fear First and Think Second
Our first reactions to danger happen subconsciously in the part of our brain close to the top of the spinal cord called the amygdala. Sensory information speeds from our five senses through our spinal cord to a group of cells in the center of our brain called the thalamus. These cells act as a relay station between the midbrain which sits directly on top of the spinal cord (sensory pathway) and the larger cerebral cortex (where thinking occurs). The thalamus also shares a signal with the amygdala which resides closer to the cerebral cortex, so it responds quicker. The
amygdala recognizes signals of danger and immediately mobilizes automatic responses for protection. Ropeik calls these Fight, Flight, and Freeze responses. Before you are even consciously aware of danger, your body has already reacted without benefit of a slow rational analysis. If a snake is about to strike you, you do not want to take time to process the degree of danger. Somewhat later processing of information by the cerebral cortex may modify the fear response.

While the amygdala responds immediately to external indications of danger, it may also respond to memories of previous signs of danger. These memories of danger are implicit, meaning that you cannot consciously recall them, but the amygdala, whose goal is to protect us, will always remember. As the amygdala responds it also enhances our ability to consciously recall explicit memories of danger. Thus, recall and reaction are speeded up when the same danger is encountered again.

Programmed Fears and Flaws for Dealing with Radiation
Some fears seem natural or common to most everyone, such as fear of the dark, snakes, spiders, heights, closed spaces, and being underwater. Other fears include public speaking, fear of intimacy, and fear of failure or social rejection. These fears are also about survival because we have learned to rely on others to protect us. Our sensory system and amygdala are constantly scanning for signs of danger and quickly leap to action at the first hint. The amygdala takes control immediately with a fear response which overrides conscious processes. While this may be appropriate for response to a striking snake, this process does not do well when considering issues such as safety of radiation. Our programmed fear response does not know what to do with radiation which is not programmed into our alert system. However, other parts of our subconscious brain have evolved to allow us to process information and make quick judgments for our protection.

Bounded Rationality
Ropeik describes Bounded Rationality as our approach to making decisions when we do not have all the data, time to acquire more data, or the intellectual ability to process the data. Ropeik shows that we are constantly making judgments without perfect knowledge, but doing the best that we can at the time. We process, sort, compare, categorize, and analyze information in relation to our immediate circumstances, experiences, and life factors, such as health, wealth, traditions, and lifestyles. With all these inputs we can come up with instant judgments. Such quick judgments are crucial to our survival. However, because they are based on limited information, these decisions may not always be best for us in the long run.

Mental Shortcuts
Some of the tools described by Ropeik for mental shortcuts to quick decision making include: the framing effect, categorization, loss aversion, anchoring and adjustment, awareness and recall, and optimism bias. Much of how we see a certain risk has to do with how it is framed or presented (in DC, this is called spin). We also tend to categorize perceived risks that seem similar and this could lead us to jump to conclusions based on small samples. This shortcut may also lead to problems with probabilities where we see patterns that seem suspicious (perceived
cancer clusters lead to questions of causation when the clusters may be purely random chance). Because we are inclined to avert losses, we tend to hold onto stocks longer than we should when the value is going down.

For our survival we are also very sensitive to factors which may cause a loss of health. The media is especially vocal on losses (dangers) that may affect our health or that of our children. Anchoring is a process which influences the starting point or anchor for a decision. People tend to be more influenced by the first data presented. Recall has to do with whether the danger comes readily to mind. The greater our recall and awareness of a certain risk, the more concerned we become. Vivid, dramatic, or frightening events are recalled more quickly (where were you on 9/11/01?). The media plays a big part on our recall abilities according to how they report stories. For example, many people fear nuclear power plants because they believe the plants might blow up like an atomic bomb. Even after learning that this can’t happen, images of Hiroshima, Nagasaki, Chernobyl, and Fukushima come so readily to mind that these images may override any rational judgment about risks from nuclear power.

Numeracy may also be an issue when people try to comprehend risks from radiation. Because many people have trouble with numbers, difficulties with trying to understand the data may lead people to rely on their affective mental shortcuts. People are also often optimistically biased that certain risks will not happen to them (such as health risks of being overweight, heart disease, stroke, diabetes, etc.). Certain ways of dying get more attention, such as cancer (the predominant fear for radiation). As people associate radiation with cancer, fears of radiation risks escalate far beyond the fears of much greater health risks listed above. The fact that “we are actually very resistant to harmful effects of radiation” gets lost.

Ropeik says that risks have personality traits that help us instinctively judge their character, even before we consciously process the facts. The media have done a great job conditioning people’s minds with the words “deadly radiation.” Thus, today the word “radiation” alone takes on the personality trait of great risk independent of any actual facts.

**The Role of Trust**

Another factor in decisions for radiation safety is trust. Our survival may depend on knowing who to trust for our safety. Promises of absolute safety may lead to mistrust if something happens. Lack of trust increases fears. Organizations perceived as creating risks are not likely to be seen as trustworthy. The appearance of withholding information is a cause for mistrust and increased fears. Failing to take fears seriously, failing to be open, and failing to share the decision making process with affected people all lead to mistrust.

If any of the above discussion attracts your interest, you are encouraged to get the book by Ropeik who provides much more elegant perspectives than I could offer in this article.

**Reference**

No. 4 – Radiation Safety Psychology

Health Physics Society Newsletter – August 2012

How Do We Make Decisions for Radiation Safety – Part II?

Ray Johnson, CHP


Beliefs about Decision Making

Kahneman’s book is intended to raise questions about our common beliefs in the ways we make judgments and choices. He notes that most of the thoughts and impressions which come to our conscious mind arise without our knowing where they came from. For example, can we trace the process of detecting irritation in our spouse’s voice or how we avoided an obstacle in the road before becoming consciously aware of it? The mental work that produces impressions and decisions is based on intuition which goes on in the silence of our minds. This book is about biases in intuition that affect our decisions.

Intuitive Biases

Kahneman notes that even after teaching and using statistics for years, he had not developed an intuitive sense of the reliability of statistical results. He found that he was too willing to believe research findings based on inadequate evidence and prone to collect too few observations in his own research. A survey showed that other expert colleagues also exaggerated the likelihood that experimental results would be confirmed, even with a small sample. One study conducted with a colleague showed that participants ignored relevant statistics and relied on “resemblance” as a simplifying rule of thumb (heuristic) for making a judgment. In other words, they ignored data in favor of information that resembled something they already knew about.

In another study they found that participants made judgments based on how easy they could “recall” certain events as a basis for generalizing a conclusion. People tend to assess the relative importance of issues based on how easily they can recall events, which may be largely determined by media coverage. This is an interesting paradox, because the media tends to report what seems to be currently in the public’s mind. Kahnman’s studies were to demonstrate possible flaws in our thinking which occur outside of our awareness. Our minds are susceptible to systematic errors of intuition.

Emotion as a Basis for Judgments

Studies are showing that emotion is a large factor in intuitive judgments and choices. Decisions are often guided by feelings of liking or disliking, with little deliberation or reasoning. When a question is difficult and a knowledgeable solution is not readily available, an answer may still
come quickly to mind. But, the answer may not specifically respond to the original question. Rather, in place of the difficult question we “substitute” an answer to an easier and related question (having to do with what we like or dislike). Since this substitution is outside of our conscious awareness, it will usually go unnoticed.

Two Systems of Thinking
Kahneman refers to earlier researchers who describe two systems for judgments characterized by fast thinking and slow thinking.

- **System 1**, commonly called the subconscious mind, operates automatically and **very fast** with little or no effort and no sense of voluntary control.
- **System 2**, commonly called the conscious mind, **slowly** and deliberately devotes attention to demanding mental activities that require effort. This system has beliefs, makes choices, and decides what to think about and what to do.

While we generally identify ourselves with System 2, the automatic System 1 is the basis for effortless origination of impressions and feelings that are the main source of explicit beliefs and deliberate choices of System 2. We are born with innate System 1 skills for perceiving our world, recognizing objects, orienting our attention, and avoiding danger. As we mature we also learn new skills, such as reading and interpreting nuances of social situations. All processes that become automatic, such as athletic or game skills, playing a musical instrument, driving a car, or knowing that $2 + 2 = 4$ are System 1 functions. “**System 1 is the secret author of most of our judgments and choices**.”

System 1
We are born with innate skills to perceive the world around us, recognize objects and people, and orient out attention to predict and avoid losses. As we mature we build on this innate resource through learning, impressions, and experience. Subsequently this knowledge is drawn upon by System 1 automatically without conscious intention or effort. Mental activities associated with skills derived from prolonged practice also become fast and automatic. Basically all of the actions, decisions, and functions which we perform without thinking about them are System 1 functions. System 1 or our subconscious mind is an enormous super computer which operates the machine which we call our body. This system is able to handle thousands of inputs simultaneously to regulate our hearts, breathing, digestion, healing of cells, etc, without any conscious or thinking effort.

System 2
Functions of this system have one feature in common. They require attention and these functions are disrupted when attention is diverted. In other words, System 2 can basically only do one thing at a time. The admonition to “pay attention” is appropriate for this system. We have a limited budget of attention and will fail if we try to go beyond our budget. A current example is what happens to a driver’s attention when he/she is talking on the cell phone or even worse if they are texting. We have all observed a car weaving over the lines in the road and then saw the driver engrossed in a cell phone conversation. The same inattention to surroundings applies to
persons walking and talking on their cell phones. Intense focusing on one task can essentially make us blind to other stimuli that would normally attract our attention. Thus, we can become blind to the obvious and blind to our blindness. People on cell phones do not realize that their attention has drifted away from driving or walking.

**Conflict of Systems for Radiation Risk Decisions**

Both systems function continuously while we are awake. System 1 runs automatically and System 2 is comfortable in a low-effort mode in which only a fraction of our thinking capacity is engaged. System 1 generates suggestions for System 2 such as impressions, intuitions, intentions, and feelings. If accepted by System 2, these impressions and intuitions turn into beliefs and impulses turn into voluntary actions. Thus, we normally believe our impressions and act accordingly. System 1 is usually very good at what it does, its models of situations and short term predictions are accurate, and its initial reactions are swift and generally appropriate. Such automatic assessments of radiation risks, however, may be far from appropriate for the circumstances. Since System 2 relies on sensory input to warn of dangers, and radiation provides no information for our senses, then System 2 has to rely on impressions from System 1. System 1 impressions may come from mythology perpetuated by the media and images of unacceptable consequences that could result from radiation exposures. Such impressions may have no relevance to technical reality as understood by specialists in radiation safety.

Since System 1 operates automatically and cannot be turned off, errors of intuition and impressions may be difficult to prevent. Biases cannot be avoided because System 1 has no clue to errors in radiation risk decisions. Even if cues to errors in response to radiation risks are evident, such errors can only be prevented by concentrated monitoring and significant effort by System 2. Thus, when a responder instinctively decides to run in response to a screaming Geiger counter, reversing that decision requires considerable effort on the part of System 2. Our conscious minds (System 2) are not intended to constantly monitor the decisions of System 1. System 2 is much too slow and inefficient for most routine decisions. Do we want to slowly analyze the potential of a striking snake before instinctively jumping back? In the mind of a first responder, running will seem like an appropriate response to a radiation signal.

This discussion of Systems 1 and 2 (subconscious vs conscious mind) will continue in a series of forthcoming articles, including more notes from Kahneman’s book.
No. 5 – Radiation Safety Psychology

Health Physics Society Newsletter – September 2012

How Do We Make Decisions for Radiation Safety – Part III?

Ray Johnson, CHP

This month we will continue to draw upon observations from a recent book by Daniel Kahneman (Nobel prize in economics) “Thinking, Fast and Slow.” Farrar, Straus, and Giroux, New York, 2011. He defines two systems for making judgments characterized by fast thinking and slow thinking.

- **System 1**, *commonly called our subconscious mind*, operates automatically and **very fast** with little or no effort and no sense of voluntary control. We are born with innate System 1 skills for perceiving our world, recognizing objects, orienting our attention, and predicting and avoiding danger. System 1 can process thousands of inputs simultaneously like a super computer that runs the machine called our body. “**System 1 is the secret author of most of our decisions for safety.**”

- **System 2**, *commonly called our conscious mind*, **slowly** and deliberately devotes attention to demanding mental activities for logical rational analysis that require effort. This system has beliefs, makes choices, and decides what to think about and what to do. However, System 2 can basically only do one thing at a time. We have a limited budget of attention and will fail if we try to go beyond our budget.

To illustrate the workings of these two systems in PEP and CEL classes at the HPS meeting in Sacramento, I raised the following questions.

**Are Your Radiation Sources Safe?**

Are your radioactive materials or x-ray machines safe? Before you answer this question you have to decide, “What does safe mean?” If you are inclined to answer, “Yes, my radiation sources are safe,” then you must have some basis for that answer. How do you know that your radiation sources are safe? What information did you rely upon? What data or understanding did you bring to your decision? What observations? What experience? What have others told you? Do you have any knowledge of radiation risks beyond what others have reported? How did you evaluate this information? How long did you take to answer the question? Was your decision on radiation safety logical, analytical, and rational? Did you carefully analyze any data before arriving at your conclusion?

If you answered the question about radiation safety instantly, and most people do, then your decision was not based on logical rational analysis (conscious mind). Carefully analyzing information to draw conclusions takes time and this slow deliberate process does not lend itself to instant decisions for safety. Quick decisions by the subconscious mind have to draw upon previous knowledge, experience, or beliefs stored in memory. Some of the factors leading to your decision may include:

- the results of safety inspections,
- annual audits,
• radiation surveys,
• the results of your personnel monitoring program,
• your radiation safety program,
• meeting regulatory requirements,
• meeting license or registration requirements
• response of radiation meters,
• trust in co-workers,
• trust in manufacturer’s design and safety testing,
• training for radiation safety, and
• technical understanding of radiation.

Do you have all the facts for a fully informed, rational, analytical decision for the safety of your radiation sources? How much do you rely on information provided by others? Do you actually have any knowledge of radiation risks other than scientific reports? How do you judge trustworthy data? Who do you respect as a resource? How would you defend your decision on safety?

Many of you were able to answer the question about radiation safety because you already have knowledge or experience to draw upon. If you have worked with radiation for a long time, then you have made the decision about safety dozens or hundreds of times over the years, such that now your decision is automatic. But, how would you answer the question without direct knowledge or experience? How would workers or the public decide on the safety of your sources without special safety training or knowledge? What information would they rely upon? What source of information would they trust? What would they likely conclude about radiation safety? We know that much of the public would conclude that any source of radiation is unsafe. How would they arrive at that conclusion and how long would it take?

Basis for Instant Decisions
Our subconscious mind is programmed to constantly monitor all inputs and impressions to predict and avoid imminent danger for our survival. Anything unusual, such as radiation, instantly triggers a search of all knowledge or memories related to radiation to decide if protective action is needed. Even specialists in radiation safety will use their subconscious mind to decide on safety and then consciously rationalize their decision after the fact (see the above listing). People without technical knowledge of radiation will use the same subconscious process to decide most commonly that radiation is dangerous. However, without technical knowledge they may not be able to defend their decision very well, but deep in their gut they know radiation is bad. Once the subconscious mind has made a decision, it is very difficult for the conscious mind to override that decision. Imagination of unacceptable consequences from radiation exposure will win out every time.

While the functioning of the subconscious mind is crucial for protecting us from imminent danger, such as a striking snake, it does not do well for dangers that are not imminent, such as radiation. Kahneman describes many ways in which the subconscious mind is prone to errors. These errors will be explored in further monthly articles.
No. 6 – Radiation Safety Psychology

Health Physics Society Newsletter – October 2012

How Do We Make Decisions for Radiation Safety – Part IV?

Ray Johnson, CHP

This month we will continue to draw upon observations from a recent book by Daniel Kahneman (Nobel Prize in economics) “Thinking, Fast and Slow.” Farrar, Straus, and Giroux, New York, 2011. Last month we looked at the function of our conscious and subconscious minds for making safety decisions. We learned that while we, as radiation safety professionals, may believe our decisions for radiation safety are logical, deliberate, and rational, that may not be the case. Any quick, spontaneous, decision about the safety of our radiation sources most likely comes from the subconscious mind, which Kahneman says is the secret author of most of our decisions for safety. Kahneman also describes many ways in which the subconscious mind is prone to errors when making decisions for safety, especially where the danger is not imminent, such as radiation.

The Functioning of Our Subconscious Mind and Cognitive Ease

Our subconscious mind is constantly scanning all information and sensory inputs to detect and predict dangers to be avoided. This process functions by quickly associating inputs with all previous experience and memories to predict what may be coming next. Since this process is automatic and outside of our awareness, it requires no conscious effort. Our subconscious is continuously updating answers to key questions. Is anything new happening now? Is there a threat? Are things going well? Should my attention be redirected? Is more conscious effort needed for some task at hand?

Kahneman says we experience cognitive ease when things are going well with no threats, nothing new is apparent, and no need to redirect attention or mobilize conscious effort. We experience cognitive strain when a problem or something new is detected which requires mobilization of conscious effort. The extent of the strain is related to the level of effort required and the presence of unmet demands. Cognitive ease is related to whether the experience is repeated and familiar, whether the input feels good and true, how we are primed for the input, and whether the information is clear. When we are in a state of cognitive ease we probably like what we see, believe what we hear, trust our intuitions, and feel the current situation is familiar. In this state we are likely to be relatively casual and superficial in our thinking. Under cognitive strain, however, we are likely to be more vigilant and suspicious and invest more effort in what we are doing.

Familiarity and Cognitive Ease

Words which we have seen before become easier to see and will give us a greater sense of familiarity and cognitive ease. This experience of familiarity can have a powerful quality of ‘pastness’ that seems to indicate a direct reflection of past experience. However, this quality of pastness is an illusion and may give an impression of familiarity simply because we have seen the same words before. For example, what happens in peoples’ minds when they see or hear the words “deadly radiation?” Since the media has been reporting those words for more than 60 years, most people are unconsciously primed to hear those words as familiar and may lead to cognitive ease. Because of familiarity and cognitive ease, most people will not be inclined to
evaluate the meaning of those words by conscious effort. Therefore those words carry an “illusion of truth.” The conscious mind will then proceed on that impression without further questions or analysis.

Anything which makes it easier for the subconscious association process to run smoothly will bias beliefs. A reliable way to make people believe in something is frequent repetition. Because of cognitive ease, familiarity is not easily distinguished from truth. Authoritarian governments and marketers have always known this. However, more recently psychologists have discovered that you do not have to repeat the entire phrase or idea to make it appear true. Thus, people familiar with the words “deadly radiation” now only need to hear the word “radiation” to arrive at the same conclusion.

Judgments of Truth
Decisions are commonly based on cognitive ease. Our minds are designed to conserve energy. Therefore we tend to avoid efforts to judge information that requires logical analysis for evaluation and consciously takes energy. Psychologists tell us that we all live our lives guided by the impressions of our subconscious mind, even when we do not know the source of these impressions. We will judge a statement as true when we feel a sense of cognitive ease which comes when the words are familiar and linked by association to other beliefs or preferences which we hold, or come from a source we trust or like (the media). Unfortunately because of many factors which can contribute to cognitive ease (including priming and familiarity) it becomes very difficult to distinguish between cognitive ease and the truth. While it is possible for people to overcome some of the superficial factors that lead to cognitive ease and judgments of truth, it requires motivation and effort. Since our conscious mind is programmed to conserve energy it is more likely to adopt the impressions of the subconscious mind and march on.

The Mere Exposure Effect
Repetition induces a comforting feeling of familiarity and therefore cognitive ease. A study of words used in weekly ads showed that the words used most frequently were rated more favorably than words only used once or twice. The mere exposure effect does not depend on any conscious awareness of familiarity. The effect of repetition on liking is profoundly important to our survival. To survive in a dangerous world we have learned to react cautiously to a novel stimulus with withdrawal or fear. Because we have been primed with the words “deadly radiation” for so long these words are no longer novel. They are now familiar and do not lead to any conscious effort to determine their meaning. People do not expect to hear about radiation other than “deadly.” Efforts to leave out or modify the word “deadly” may in fact invite suspicion because to do so would be novel in today’s world.

Conclusions on Cognitive Ease
Studies show cognitive ease, intuition, creativity, gullibility, and increased reliance on the subconscious mind go together. On the other hand, suspicion, vigilance, an analytical approach, and increased effort also go together. When we experience cognitive ease we see the environment as normal which does not require extra vigilance or analysis. For most of the world, normal means “deadly radiation.” Someone trying to tell us that radiation is not deadly is not normal.

Next month we will explore additional factors that contribute to errors in safety decisions.
How Do We Make Decisions for Radiation Safety – Part V?

Ray Johnson, CHP

This month we will continue to draw upon observations from a recent book by Daniel Kahneman (Nobel Prize in economics) “Thinking, Fast and Slow.” Farrar, Straus, and Giroux, New York, 2011. Last month we looked at how we generally accept words which are familiar from repeated use in the media, such as “deadly radiation.” Most people are not inclined to evaluate those words by conscious effort because they accept the “illusion of truth” conveyed subconsciously. Repeated use of such words leads to familiarity and cognitive ease and can contribute to errors in decisions for radiation safety.

What is Normal?
Our subconscious mind is constantly scanning our environment to update our model of what represents normalcy. Our model is constructed from associations and ideas of circumstances, events, actions and outcomes, images, and impressions stored in memory. This model is strengthened by developing patterns over time which become the basis for interpreting the present and predicting the future. We maintain norms for many categories of our lives which serve as references for detecting anomalies. We are especially sensitive to surprises which indicate something outside of normal. While surprises are the basis for humorous jokes, they can also be indicators of danger.

Seeing Causes and Connections
As our subconscious mind attempts to derive meaning from associations in memory, we may construct a seemingly coherent story from unrelated inputs. Finding causal connections is how we understand stories. As we mature we develop impressions of causality which do not depend on reasoning about patterns of causation. Subconscious connections of cause and effect may be readily accepted by the lazy conscious mind which wants to conserve energy by minimizing analytical efforts. Our minds are ever on the alert to identify causes and agents of observed or anticipated events and assign them personality traits and intentions. This may also help explain why people are so willing to accept the words “deadly radiation.” In our coherent story of the world, radiation is the evil bully.

Jumping to Conclusions
The quick associations within our subconscious mind may lead us to jump to conclusions that go beyond the actual circumstances. And yet to assure safety, we are often forced to make instant decisions with limited information, no time to gather more data, and limited understanding of the data available. Such quick decisions are prone to intuitive errors. In our haste for self preservation we may totally miss ambiguities. We tend to interpret events for coherency with stored impressions in the subconscious mind. Sorting our ambiguities and uncertainties is the realm of the slow, deliberate, reasoning, conscious mind which would rather accept the quick conclusions of the subconscious mind. The sudden subconscious awareness of a snake in the grass is probably not the time to think long and hard about the possible danger before automatically jumping back.
We are Primed to Believe
We cannot unbelieve something before we have made an attempt to believe it. Our subconscious will automatically attempt to believe by constructing the best possible interpretation of circumstances with stored impressions. We naturally try to make sense out of nonsense to create a coherent picture. Unbelieving is the work of the conscious mind which is prone to errors when overloaded. When the conscious mind is tired or otherwise engaged (such as in a fight or flight response mode), we are prone to believe falsehoods. Priming may explain why beliefs in radiation myths are so common (note: a myth is something commonly believed which is not technically true). When stimulated to fear by radiation, we are prone to accept the myths commonly perpetuated by the media without any conscious analysis of the circumstances.

Confirmation Bias
Whatever our subconscious believes we will tend to confirm with new information. We screen what we see and hear to ensure our beliefs are “proven” correct. Once we have formed a view, we embrace information that supports that view. We also seek out other people who share common beliefs for further confirmation. Groups tend to polarize around common views and become more convinced that their beliefs are right. What we believe is deeply influenced by the beliefs of the people around us and of the culture in which we live. We also remain social animals who care about what other people think. And if we aren’t sure whether we should worry about a particular risk, whether other people are worried makes a huge difference.

While confirming our view we ignore, reject, or harshly scrutinize information that casts doubt on it. Unfortunately, seeking to confirm our beliefs comes naturally, while it feels strange and counterintuitive to look for evidence that contradicts our beliefs. Worse still, if we happen to stumble across evidence that runs contrary to our views, we have a strong tendency to belittle or ignore it. Isn’t this happening repeatedly as we evaluate candidates for President?

The Halo Effect
This effect describes the way we commonly make associations regarding what we like or dislike about people or circumstances without any actual data. For example, suppose we admire a skillful speaker and we believe a leader should be a skillful speaker. Thus we conclude that a skillful speaker will be a good leader without any other information to support this conclusion. Here is how this might apply to radiation. For many people the word “radiation” is connected subconsciously to associated memories of terrible consequences of atomic bombs. Thus, the word radiation is automatically associated with bad expectations today without any specific information on the current circumstances.

As specialists in radiation safety we know that before we can judge the risk of radiation we have to know what kind, the amount, the exposure conditions, and the dose. However, this type of evaluation requires deliberate rational analysis by the conscious mind which takes time and effort. In the meantime, the subconscious mind of most people will have processed associations with the word radiation instantly and already made decisions for safety.

Why We are Prone to Errors in Decisions for Radiation Safety
Each of the topics briefly described above can lead us to make decisions for radiation safety which may not be supported by the facts. Next month we will continue this series on how we are prone to errors on decisions for safety.
No. 8 – Radiation Safety Psychology

Health Physics Society Newsletter – December 2012

How Do We Make Decisions for Radiation Safety – Part VI?

Ray Johnson, CHP

We are Prone to Errors
This month we will continue to look at ways we are prone to errors in decisions for radiation safety. We previously looked at the “halo effect” where we are tempted to correlate impressions or attributes with something we like or dislike, when there may be no correlation in facts. Thus people often draw negative conclusions about radiation, with no actual data to support those conclusions, simply because they have always heard negative associations with radiation. This is an example of what psychologists call decorrelate error.* It has to do with how we evaluate information relative to what we have heard before. The police know about this phenomenon and therefore they interview witnesses independently to minimize influence between witnesses. This phenomenon also plays out in open meetings where more weight is given to the opinions of those who speak early and assertively.

What You See is All There Is
Since we subconsciously evaluate all incoming information by association with stored memories or impressions, our conclusions are based only on activated ideas. Our subconscious will construct the best possible story from currently activated ideas without seeking out additional information. The success of this process is measured by the coherence of the story, not on the quality, quantity, or relevance of any data. When information is scarce, which is usually the case for radiation, our subconscious will draw upon associations from activated memories, usually leading to a fear response. Although we might change our minds when presented with more data, we are inherently biased by first impressions. Also the evaluation of data is a function of our conscious mind which is inclined to accept the intuitive beliefs of the subconscious mind and seek out or accept information that supports those beliefs. Actually with less information it is easier to construct a coherent story with confidence. Unfortunately, overconfidence may lead to failure to realize that critical information is missing. For example, a crucial piece of information often missing for decisions on radiation safety is the radiation dose received or expected.

Answering Questions Based on Impressions
Our subconscious is constantly monitoring what goes on around us and inside our minds and continuously generates assessments without any special effort. These assessments are primarily to judge threat level. Is everything normal? Should we be responding to something that could affect our survival? Even infants can discriminate friend or foe at a glance (my three-month old granddaughter does not like my beard and glasses). A glance at a stranger’s face is enough to judge dominance and trustworthiness (threat level) simply on the basis of features and expression. For instance, while watching a political ad a friend announced that he did not trust the candidate’s smile and would not vote for him. This initial impression will then color all future evaluations of this candidate’s track record or qualifications. Although facial features cannot predict a person’s performance in office, we are predisposed to select the candidate that seems to portray the attributes that we value.

Reliance on Sets and Prototypes
Our subconscious mind can quickly and effortlessly judge averages, such as the average length of a set of lines. However, our subconscious does not do well when asked for the sum of the
lengths of a set of lines. To answer this question we have to engage the conscious mind to estimate the average length, estimate the number of lines, and then multiply by the average length. When asked to assess something that requires math, we are inclined to substitute a prototype. For example, the fearful reactions to radiation from the Fukushima Daiichi reactors probably had little to do with the number of people exposed to radiation or how much, but rather the reactions were more likely the result of a prototype, namely the horrible image of a single person exposed to radiation from Hiroshima or Nagasaki.

Matching by Intensity
While the subconscious is not good with numbers and math, it is very good at judging intensity which allows associations of colors, sounds, actions, trauma, and threats. We can effortlessly judge each of these qualities by intensity even though they represent completely different scales. For example, strong colors (deep red) and loud sounds (gun fire) are associated with threats and trauma. If asked what color corresponds to radiation, many may say bright red.

Our Subconscious Shotgun
Because our subconscious automatically evaluates everything, sometimes in the process of answering one question, another question is evoked which may be not only irrelevant, but detrimental to the main question. Our evaluations are typically not well aimed but scattered like shotgun pellets. Conflicts with irrelevant answers can disrupt our performance on key questions. Antinuclear activists exercise this phenomenon very well when they throw lots of irrelevant and false information at a technical person, who then feels led to respond to each piece of false data. The goal is to get us so tied up in the trivia that we may miss the key questions and we lose sight of the real issues. Of course they also know how easy it can be to disrupt a technical person by throwing not only a plethora of technically wrong information at us, but with emotional appeal.

Answering an Easier Question
We are rarely stumped. We have a remarkable ability to intuitively judge and arrive at opinions and feelings about virtually everything. We instinctively like or dislike and trust or distrust people before we know much about them. Thus we have answers to questions that we do not understand, relying on evidence that we can neither explain nor defend. When confronted with a difficult question, when our subconscious is not able to come up with a quick answer, we may find an easier question to answer and go with that. For example, people commonly draw conclusions about probabilities of radiation effects (cancer) without understanding probabilities or radiation. Rather than analyzing the math, people will substitute the question, “How do I feel about dying of cancer.” The answer to this question is easy for the subconscious mind without invoking the problem solving functions of the conscious mind. If asked, “How much money should we spend to avoid radiation?” by matching the intensity of our fears with dollars we can conclude that a large amount of money is warranted. No math or complicated analysis is needed for this conclusion.

Why We are Prone to Errors
Each of the topics briefly described above can lead us to make decisions for radiation safety which may not be supported by the facts. Next month we will continue this series on how we are prone to errors on decisions for safety.

How We Make Decisions for Radiation Safety – Part VII

Why We are Prone to Errors – A Quick Review of Past Articles
This series of articles is to help explain how people tend to make quick decisions about radiation safety by the normal functions of their subconscious mind and how that process is prone to errors. Our subconscious mind is constantly scanning inputs from our environment to predict and avoid imminent danger. This process is very fast and could determine our survival for some dangers, such as a striking snake. However, this process does not do well for dangers which are not imminent, such as radiation.

How can you Decide when you do not have Data, Time to get Data, or the Ability to Understand the Data?
This is likely the situation for nearly everyone who makes decisions about radiation safety. And yet, people make such decisions instantly and with great conviction. In his book, *Thinking: Fast and Slow*¹, Daniel Kahneman says we are never stumped for answers to even complex questions. The word “radiation” triggers an instantaneous subconscious search of all knowledge and memories related to radiation to decide if protection is needed. Even technical specialists will use the same subconscious process to arrive at an instant conclusion and then later consciously rationalize their decision after the fact. All fast decisions come from our subconscious mind, because conscious data evaluation takes significant time.

Familiarity and Cognitive Ease
Our subconscious mind is at ease when a scan of our environment shows all is well, no threats or anything new are apparent, and there is no need to redirect our attention or mobilize any conscious thinking or efforts for safety. We are more likely to experience cognitive ease when dealing with situations which are familiar and where we feel comfortable. In this state we tend to be relatively casual and superficial in our conscious thinking. Words heard repeatedly will take on a quality of familiarity as if related to past experience. For example, the commonly reported words “deadly radiation” have been repeated so often that most people hear these words as familiar and therefore they are not inclined to evaluate their meaning by conscious effort. The words “deadly radiation” are heard as “normal.” Efforts to leave out or modify the word “deadly” are not normal and would invite suspicion, extra vigilance, and analysis by the conscious mind. Unfortunately familiarity and cognitive ease often lead the subconscious mind to accept information as the truth without any conscious analysis.

Seeing Causes and Connections
As our subconscious mind attempts to derive meaning from associations in memory, we may construct a seemingly coherent story from unrelated information. We learn to understand stories by finding causal connections. As we mature we develop impressions of causality which do not depend on reasoning about patterns of causation. Subconscious connections of cause and effect may be readily accepted by the lazy conscious mind which does not like to expend energy on analytical efforts. This may further explain why people so readily accept the words “deadly radiation.” In our coherent story of life, radiation is the evil enemy. Quick associations within our subconscious mind may lead us to jump to conclusions of causality which go beyond the actual circumstances. However, once we have made a conclusion of cause and effect, we are not inclined to seek out information to prove that our conclusion is wrong. On the contrary we will try to confirm our conclusion by screening new information to ensure that our beliefs are correct. In this process we are strongly influenced by other people who share the same beliefs.
Steps from Cause to Effect

To help people understand that there are steps from cause to effect for radiation, I like to invite people with concerns for radiation safety to consider the following questions:

1. What kind of radiation is emitted from the source? Is it alpha, beta, gamma, neutrons, or x-rays? Is the radiation source a solid, liquid, gas, or a radiation producing machine, and how much radiation is emitted?
2. Where is the radiation source located and how far away is the source from people?
3. Is the radiation source contained? Many radioactive material sources are sealed in metal capsules.
4. What will happen to the radioactive material if the container is broken?
5. How will anyone be exposed to the radiation, such as external exposure to gamma rays or x-rays, or internal exposure from the ingestion or inhalation of materials emitting alpha or beta particles?
6. Most importantly, how much radiation energy will be deposited in the body and what part of the body may be affected?
7. With answers to these questions we can then estimate possible consequences based on observations of people who have been exposed to radiation and for whom we have observed the effects.

Primarily, our basis for estimating health effects from radiation is from studies of survivors of the atomic bombs in Japan. After observing about 87,000 survivors over the past 65 years, in comparison with a similar number outside the range of the bombs, we now conclude that about 450 people may have died as a result of their radiation exposures.

I explain to people that any conclusions about cause and effect for radiation that do not follow these steps may be gut reactions that are not technically defensible. Unfortunately most people do not know or follow these steps, including many technical people such as medical doctors, and they jump to conclusions about what is needed for safety that may not be technically warranted.

Substitution of Questions

In the previous monthly article, we also saw that when people are confronted with a technically difficult question they may subconsciously respond to a different question, without even knowing this has happened. For example, how do people interpret risk estimates such as the meaning of one cancer death per 1,000 person-rem? Since interpreting the meaning of risk assessments involves an understanding of technical issues, probabilities, and mathematics which is beyond the conscious abilities for analysis by most people, then many will subconsciously substitute a different question. That question may be, “How do I feel about dying of cancer?” This is an easy question for the subconscious mind which does not require any problem solving functions of the conscious mind. The answer may well be that dying of cancer is an unacceptable risk at any level. As with radiation measurements, risk estimates have no meaning until interpreted. And then the meaning is whatever a person may interpret for themselves. Thus, the meaning of risk estimates is not an absolute, but rather exists only in the mind of the beholder.

We are Prone to Errors
In this series of articles we are looking at how quick decisions for radiation safety are prone to intuitive errors. Making quick decisions for safety is an important function of the subconscious mind for our survival. Such quick decisions, however, are typically based on stored impressions and images which may have little relevance to the real world of radiation. This article will continue to review how biases occur in safety decisions as described by Kahneman1.

The Bias of Small Numbers
The subconscious mind is quick to infer conclusions from small samples by connections in associative memory. It automatically and effortlessly identifies causal connections with a few data points, even when those connections are spurious. Random events defy explanations, but collections of random events seem to behave in a highly regular fashion. Small samples tend to yield extreme results more often than large samples. How often have people pointed to “so-called” cancer clusters as proof of effects from a particular radiation source? Trusting in small samples can lead to observations which are only random chance. Kahneman concludes that even scientists are prone to errors related to insufficient sample size.

A Bias of Confidence over Doubt
If we are told that 60% of a sample of 100, 1,000, or 3,000 people held a particular view, we are likely to accept all three reports as equally reliable. We might not accept that 6 out of a sample of 10 is a reliable report. The question is whether the subconscious mind can distinguish degrees of doubt? Studies indicate that it cannot. As we noted in an earlier article (No. 8, Dec. 2012), our subconscious will evaluate all information by association with stored impressions and suppress doubt to construct a coherent story. Unless the conscious mind immediately discredits the report, the associations evoked will be accepted as the truth. While the conscious mind is capable of doubt when evaluating the reliability of two sets of data, the subconscious cannot do that. However, it is difficult for the conscious mind to sustain doubt when the subconscious mind is biased by small numbers (see above) and favors certainty over doubt. Unfortunately even researchers may be biased to believe that small samples are representative of the population. Our subconscious mind is prone to running ahead of the facts to draw conclusions from a few scraps of evidence.

Cause and Chance
Our subconscious mind seeks causes and thus exposes us to serious mistakes in evaluating the randomness of truly random events. For example, six flips of a coin, as independent events, can have any sequence. However, if we find six heads in a row, we might conclude these events are not random. Intuitively we believe that six random flips should result in a distribution of heads and tails. As pattern seekers and believers in a coherent world, a sequence of six heads does not appear random but would seem to indicate some causality or intention. Such conclusions are a normal function of the subconscious mind which is constantly scanning our environment for changes that may warrant concerns. Seeing six heads in a row does not seem normal and therefore triggers a subconscious alert. Thus randomness can appear as a regularity or cluster and lead to serious errors in assigning cause and effect.
Another example could be illustrated by basketball. A player who sinks 10 baskets in a row might be described as “a hot hand.” This inference is irresistible and leads to expectations of further success. Other players, coaches, and fans all accept this conclusion. However, studies of 1,000s of shots have shown that there is no such thing as a hot hand in basketball. The sequence of successful and missed shots fit all the tests for randomness. The idea of a hot hand is entirely in the mind of the beholder and represents a massive cognitive illusion. The tendency to see patterns in randomness is overwhelming. The illusion of patterns strongly affects our views on radiation safety. How many people who may get cancer among the Fukushima evacuees will likely conclude that the Daiichi incident is the cause?

Anchoring as an Adjustment Effect
How much are we influenced by a particular value given to us before we are asked to estimate the value? The answer is that we are dramatically influenced. For example, when considering an offer on buying a house, we are strongly influenced by the asking price. The same house will appear more valuable if the asking price is high than if it is low. Marketers of many products have done a good job convincing us that a higher price equates to a higher value. After all, don’t we get what we pay for?

Another example occurred a couple months after the Fukushima incident. I gave a talk at an AIHA conference in which I predicted that we may not be able to identify any specific health effects due to radiation exposures in Japan\(^2\). At the same time, another source predicted 800,000 cancer deaths would occur in Japan. If you start with my estimate of zero, since everyone knows that radiation causes cancer, you might conclude my number is too low and a few 100s or 1,000s may be more realistic. If you start with 800,000 you may conclude that number is way too high and a more realistic number could be in the tens of thousands. In each case you have to adjust your estimate by rationalizing arguments to move away from the anchoring number. This process involves deliberate processing by the conscious mind.

Anchoring as an Priming Effect
Anchoring can also result from the power of suggestion. The subconscious mind will attempt to construct a coherent world in which the anchor is the true number. If the selected memories or associations evoked are compatible with the anchor, we will tend to believe that number is true. Because of the negative associations evoked by radiation, most people will likely believe that Fukushima will result in a large number of radiation effects. For lack of specific knowledge, when asked about radiation effects in Japan, people are strongly influenced by an anchoring number which seems plausible (not zero). Mechanisms that produce anchoring make us far more suggestible than we would expect or believe. For example, marketers know that by telling you an item is scarce and will be limited to a certain amount per customer, this is likely to lead many to buy up to the limit.

We are all susceptible to the effects of anchoring. The lesson to be learned from insights on anchoring is to remind ourselves that any number put on the table will have an anchoring effect on us. Thus, we should mobilize the rational, analytical functions of our conscious mind to combat the effects of anchoring and priming.

\(^2\)Johnson, R. Japan Nuclear Fears - Real and Perceived Dangers. A presentation at the annual meeting of the American Industrial Hygiene Association in Portland, OR. May 16, 2011.
How We Make Decisions for Radiation Safety – Part IX

More Sources for Errors
We continue in this series of articles to look at ways we are prone to intuitive errors when making decisions for radiation safety. Insights for these articles are drawn from the book by Daniel Kahneman.

Availability Heuristic
This has to do with how people estimate the frequency of some event. Answers to questions of frequency are influenced by how easily instances are retrieved from memory. If retrieval is easy, the event will be judged as frequent. Kahneman’s studies have shown, however, that impressions of ease of recall may occur without actually recalling any specific instance. This occurs because our subconscious mind is quick to substitute a different question when the answer to a posed question is not immediately available. For example, if someone is asked about the safety of nuclear power plants in the US, without any data on US plants, a person may immediately recall Fukushima and conclude that nuclear power is not safe. Personal experience or knowledge also plays a big role. If you know of several people with prostate or breast cancer, it is easy to conclude there must be an epidemic of those cancers. As we have noted in previous articles, once the subconscious mind has drawn a conclusion (even though strongly biased by ease of recall), the conscious mind is not inclined to exert effort to evaluate specific data that may refute the conclusion.

Kahneman says that people are more likely to go with subconscious impressions and be more strongly influenced by ease of retrieval rather than content when:

- They are engaged in another task requiring conscious effort
- They are in a good mood
- They are knowledgeable novices on the subject, rather than true experts
- They strongly believe in intuition
- They feel powerful

An example related to radiation safety has to do with how people generally view risks of radon exposures in their home. Since there are currently few news stories about radon, many will have little to recall about radon from memory and may conclude it must not be an issue any more. As a result, they are likely to underestimate the risks. This conclusion is derived subconsciously without evidence of any data.

The Dynamics of Memory
Large scale emergencies tend to follow patterns of a disaster leading to concerns and then complacency. People along the coast of Japan were in a mode of complacency about the highest flood wave of a tsunami, because they had lost the historical memory of the previous high water mark from several generations ago. Thus, images of a worst case disaster did not come easily to mind. After the terrible devastation and loss of life in the 2011 tsunami, concerns are now at a high level and will continue for another generation or two. As the devastation is restored future generations may fall back into complacency. Hiroshima is another example. Today it is a modern, busy, thriving city. Except for a few buildings preserved for the memory of the bombs, no one could tell by looking at the city today, that it was destroyed in 1945.
The Effect of Media Coverage
It probably comes as no surprise that estimates of risks are strongly influence by media stories. For example, news coverage of damage by tornados may lead many to conclude that tornados are more frequent killers than asthma. In fact asthma kills hundreds or thousands of times more people than tornados. Because of media coverage of the Fukushima nuclear accidents, many will now conclude that nuclear power is exceedingly dangerous, even though no one has actually died from radiation exposures at Fukushima. In fact, they may easily conclude nuclear power is more dangerous than tsunamis, even thought about 20,000 people died or are lost from the tsunami. The media is also biased in its coverage because of people’s demands for more coverage of unusual events. Rare events when publicized in the media may lead people to conclude that these events are common. Public reaction then stimulates more media coverage and finally the government sees a need to investigate and hold hearings which attracts more media coverage.

The Affect Heuristic
Paul Slovic\(^2\) developed the insight that people commonly make judgments and decisions based on their emotions. People make decisions based on what they like or dislike, or how they feel about a subject. Decisions are made about risks as an expression of feelings. Risks are judged as high or low based on feelings without any actual data. We noted in an earlier article that when asked to judge radiation risks, many will respond with an answer to a different question, “How do I feel about getting cancer?” This question can be answered by feelings without requiring any data or conscious evaluation. Emotional appeal is a powerful force in making decisions for safety. Emotions and feelings will win over rational thinking every time. James Tarpinian gave me a quote attributed to Abraham Lincoln, “You can’t reason a man out of a position he didn’t reason himself into.”

Expert vs. Public Views of Risks
While experts tend to evaluate risks numerically as number of lives lost, the public may distinguish between “good deaths” from natural causes, versus “bad deaths” which occur from random events. Thus, the public may have a richer concept of risks than the experts. Slovic argues that risk is not a concept waiting to be measured. Rather risk is a concept invented to help us understand and cope with dangers and uncertainties of life. While experts may view risks in terms of rational weighing of costs and benefits, the public is much more subjective (and often viewed as wrong by experts). For example every police department has data on accidents that occur as a result of use of cell phones in cars. And yet, how many people ignore the statistics and conclude that they can both text and drive at the same time. Conversely, despite all of the expert reports on the likelihood of few radiation related deaths from Fukushima, many evacuees likely believe that their future health is at significant risk from radiation.

Terrorists Take Advantage of the Availability Heuristic
The media plays into the hands of terrorists by continuously reporting the number of casualties from the latest car bomb incident while ignoring the far greater casualties occurring from automobile accidents. Constant reminders and gruesome pictures make terrorist acts seem more common and cause everyone to be fearful. What would possibly happen to the practice of terrorism if the media stopped reporting such events?

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No. 12 – Radiation Safety Psychology

Health Physics Society Newsletter – April 2013

Errors we Make in Decisions for Radiation Safety – Part X

Can we Ignore Public Fears?
Kahneman\(^1\) says he is uncomfortable with the influence of irrational fears on public policy. However, he notes that, “Rational or not, fear is painful and debilitating, and policy makers must endeavor to protect the public from fear, not only from real dangers.” I suspect this may not sit well with most HPs who make radiation safety decisions by logical analysis of the facts. How can we justify the expense of valuable resources for reducing risks that are imaginary? And yet, isn’t this actually happening all the time? How many of us in the field of radiation safety are dealing with real (significant) radiation risks? How many people are we protecting from “real” dangers? How much of what we do for radiation protection is driven by public and regulatory ideas of what is needed to assure safety? How many people believe LNT is true all the way down to zero dose? And, if we believe in LNT, is there any level of dose for which the risk is acceptable?

How Do we Make Predictions of Risks?
When asked to rank order a series of different risks, we have to go into our subconscious data bank of stored impressions on base rates, probabilities, and stereotypes to answer the question. Typically people will answer this question by substituting representativeness or similarity to stereotypes in place of judging probability. Questions of probability are more difficult to answer than issues of similarity. Evaluation of probability requires conscious effort, whereas the subconscious can draw conclusions about similarity with no effort. When we are asked to assess statistical probabilities, a shotgun approach is activated subconsciously to evoke many answers to easier questions. While judgments based upon representativeness of stereotypes may be accurate, just as often they will be false, especially when people ignore base-rate information that points in another direction. Consider how people judge the risks of driving to work every day versus the risk of radiation exposures on the job. Or, how do people judge the risks of flying versus weight control and exercise? How do people judge the risks of radon versus other radiation exposures?

Errors of Representativeness
Even when presented with information which shows that radiation risks are small relative to other sources of risks, many will decide that radiation risks are greatest. There also seems to be a general view that naturally occurring sources of radiation and doctor prescribed radiation present lower risks than man-made radiation sources used in industry and research. Thus, even trained radiation workers may believe that the potential for receiving several millisieverts a year from radon in their homes is OK, while a small fraction of a millisievert in the workplace is not OK. Somehow our homes seem to represent a haven of safety while workplaces represent inherent dangers. These notions of representation may then overshadow actual evidence of risk assessments and how we judge or trust the quality of the risk information. Once again our intuitive subconscious processing of risks can lead us astray relative to good scientific data.

Possible Errors of Stereotypes
Kahneman\(^1\) says there may be some truth in stereotypes that allow us to make good predictions about representativeness. However, stereotypes may be false when we do not take into account actual data. For example, I had a supervisor who was unhappy with comments coming from members of the Health Physics Society (HPS). He consequently branded the Society in a derogatory manner. When he described his negative feelings about the Society, I pointed out that I am a member of the HPS and asked if he felt the same way about me. After reflecting on my question, he said, “No, of course not.” He later decided to join the HPS. How often do we judge individuals by stereotypes of representativeness? How often do we say, “That’s the EPA, or that’s the NRC, or that’s the HPS?” One time my work involved frequent interactions with antinuclear activists representing the Sierra Club, Greenpeace, Friends of the Earth, and others. While I had misgivings about antinuclear activism, after frequent meetings I discovered that these people were trying to make a living, raise a family, and pay their bills just like myself. While our views differed, a comparison of our lives at an individual level showed many similarities.

Coherence, Plausibility, and Probability
These notions are easily confused. While evaluations of probability require analysis by our conscious thinking processes, coherence and plausibility are easily derived subconsciously without any detailed analysis. In particular the uncritical substitution of plausibility for probability can have severe effects on judgments when scenarios are used as tools for forecasting. Adding details to a scenario may make it more plausible without changing the probability. For example, how often do people conclude that their health could be at high risk from radiation exposure based on evidence that radiation can cause harm even though the probability for individuals is very low? When told that the likelihood of effects is 1/xxx,xxx many people will conclude plausibly that they could be the one. Then the precautionary principle kicks in and people conclude that, “It is better to be safe than sorry.” If people can imagine themselves the victim of radiation, then it does not matter what the scientific probability may be. The logic of probability is easily lost.

Causes Trump Statistics
Base rates or probabilities of radiation effects are typically ignored or undervalued when people consider the health of themselves or their families. Most people do not know the probabilities of radiation effects such as reported by the National Academy of Sciences. Even if they knew, because of general lack of understanding of statistical probabilities, they would likely defer to media stories about “deadly radiation.” Even compelling statistics of cause and effect will not change long-held beliefs or beliefs rooted in life experience. Social settings, coherent stories (even when imagined), stereotypes, and plausibility will win every time. Once a view is established by subconscious associations and may be prone to countless errors, the conscious mind resists changes to that view. “My mind is made up, don’t bother me with the facts.”

Errors we Make in Decisions for Radiation Safety – Part XII

The Illusion of Understanding

Kahneman\(^1\) describes narrative fallacy as the result of flawed stories of the past which shape our views of the world and expectations for the future. Narrative fallacies arise from our continuous attempts to make sense of the world. People find stories compelling which give simple explanations that focus on the concrete rather than the abstract, that assign a larger role to talent, stupidity, and intentions, rather than luck or random chance. The media feeds this process by promoting stories of a few striking events. Any recent salient event is a candidate to become the kernel of a causal narrative. We constantly fool ourselves by constructing flimsy accounts of the past and believing they are true. I have suggested many times that most of what people have heard and come to believe about radiation is mythology (a myth is something believed which is not technically true). How many people really understand radiation and its possible effects, and yet most have strong opinions about radiation?

Good Stories are Persuasive

We are easily influenced by stories that provide simple and coherent accounts that explain people’s actions and intentions. We are always ready to interpret behavior as a manifestation of general tendencies and personality traits. In Column No. 7 we discussed the halo effect where to achieve coherence we are inclined to match our view of one significant attribute of a person or organization to represent all of their qualities. For example, the halo effect helps keep stories simple and coherent by exaggerating the consistency of evaluations: good people only do good things and bad people only bad. We may idolize a celebrity and then experience great shock when we discover that they are fallible humans the same as us.

Deadly Radiation

These words commonly used for media stories about radiation have a profound halo effect. By association with stored impressions of radiation events, the word “radiation” now evokes expectations of terrible consequences. In the February HPS school on Fukushima, I raised the question about how many of the evacuees from the area of Fukushima Daiichi may experience severe stress and bodily effects, even cancer, because of expectations based on associated memories of Hiroshima and Nagasaki. Such expectations would be consistent with media stories of mutations, cancer, and death from radiation. These expectations do not require any technical knowledge about radiation and represent an illusion of understanding. Since by normal incidence as much as one third of the evacuees will likely get cancer as some time, how many will conclude that their cancer is the result of radiation from Fukushima? I suspect that most will attribute cancer and other health effects to Fukushima and will expect some form of compensation accordingly. The question may be, “If someone with minimal radiation exposure suffers psychosomatic effects, are those effects less attributable to the Fukushima accidents than the result of actual radiation exposures? What about the probability of causation? If the radiation exposure does not scientifically justify claims of causation, is that the final conclusion about cause and effect?”

Errors we Make in Decisions for Radiation Safety – Part XIII

The Illusion of Knowing
For our everyday comfort we create coherent stories of the world based on the information available to us. If we can create a good story, we believe it. Kahneman\(^1\) notes, however, that it is paradoxically easier to construct a coherent story when we know little and have fewer pieces to fit into the puzzle. This might help explain why some people are so convinced of the hazards of radiation. For example, a person came to me stating, “We have not been telling people the truth about radiation effects.” He had recently heard about radiation-induced bystander effects and this led him to create a story in which radiation was much more dangerous than previously thought. This story confirmed what he had always believed about the dangers of radiation, as if he had always known this to be true. Expressed confidence by people who claim to “know” perpetuates the illusion that the world is more knowable than it really is. The core to this illusion is the belief that the story we create is the real world.

While we learn from surprises and may adjust our coherent story accordingly, we also lose our recall of what our former beliefs may have been. Studies show that when people are asked to recall their former beliefs, they retrieve the current ones instead, and cannot believe they ever felt differently. Can any of you recall what you believed about radiation 20, 30, or more, years ago that may be different than what you believe today? We are all prone to hindsight bias to the extent that we underestimate surprise from past events and believe that “we knew it all along.” Our tendency to revise the history of our beliefs is an example of the cognitive illusion of “knowing.”

The Illusions of Hindsight
Hindsight can be very unkind to those who make decisions on behalf of others. We tend to blame others for decisions that worked out badly and give little credit for successes that appear obvious only after the fact. This is called outcome bias. We judge the quality of a decision not on the basis of whether the process was sound but whether its outcome was good or bad. The worse the consequence, the greater the hindsight bias. For example, a fire department responding to an alarm in a downtown office building, noticed that a GM meter on the truck was showing readings of twice background as they approached. Based on this observation they set up barricades and evacuated several city blocks in the middle of a business day. While that decision may have seemed prudent by the precautionary principle, most HPs would likely conclude by hindsight that this very expensive decision was overly conservative.

A Comforting Process
As our subconscious mind continuously attempts to make sense of the world, we tend to see things as more coherent than they really are. Our illusions are comforting because they reduce the anxiety we would experience if we allowed ourselves the knowledge of uncertainties for the future. While HPs are familiar with uncertainties, most of the world wants to know what is safe or unsafe.

Errors we Make in Decisions for Radiation Safety – Part XIV

The Illusion of Believing
Our subconscious mind is designed to jump to conclusions often with very little evidence. It is not designed to know the size of the jumps. Kahneman\(^1\) says that only the evidence at hand counts. Our confidence in our opinions is a function of the coherence of the story we construct. The quality or quantity of the evidence does not count for much because a very good story can be constructed based on very poor evidence. How many people automatically conclude that radiation is bad with very little (and likely very poor) evidence? Kahneman goes on to say, “considering how little we know, the confidence in our beliefs is preposterous – and also is essential.” We have to believe in something.

Confidence in our conclusions is not usually based on a logical analysis of the probability that our judgment is correct. Confidence is a feeling based on the coherence of information from which we construct a story and the ease of processing that information. While it is not common to admit uncertainty, expressions of high confidence mean we have constructed a coherent story, not necessarily that the story is true. For example, many people are very confident about their views regarding radiation even though they are based on mythology (beliefs not technically true).

Is Seeing also Believing?
In a court of law eyewitness testimony is given the greatest credibility. However, Mlodinow\(^2\) notes that our eyes are designed to focus only on a small area of about one degree of visual angle around the retina’s center. Although we shift our eyes around to obtain a sharper image over a wider area, outside the narrow viewing area the resolution drops off sharply. Thus, the pattern of raw data to our brain is a shaky, badly pixilated picture with a hole in it. Fortunately our brain interpolates the gaps on the assumption that the visual properties of neighboring areas are similar. Thus, until age or other mishaps take a toll, we go through life with the compelling illusion that our vision is sharp and clear. Magicians know this limitation and invite us to focus in one area while they appear to make things happen that we do not see.

Perception, Imagination, and Patterns
Perceptions are not a direct consequence of reality but rather an act of imagination. Perceptions always require imagination because the data that we rely upon for decisions are almost always equivocal and incomplete, such as common perceptions of radiation risks. We use our imagination to fill in gaps in patterns the same way our brains compose visual images. As with visual images, we draw conclusions based on uncertain and incomplete information and we believe our picture is clear and accurate. But is it? Scientists use statistical analysis to identify false patterns. However, most people do not intuitively apply statistical analyses and instead rely on gut instinct. Thus our perceptions of patterns can be both highly convincing and highly subjective at the same time. Many of the perceptions of society are based on shared illusions of patterns which seem to have a definite cause when they are actually the product of random chance.\(^2\)

Why People Do NOT Believe Our Best Radiation Risk Estimates

HPS, Professional Development School, “Estimation of Radiological Risks”

Purdue University, Lafayette, IN, July 10, 2015

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Despite great care in developing our best radiation risk estimates, until these estimates are interpreted, they have no meaning, they are just numbers. After interpretation, the numbers mean whatever the interpreter believes. Thus, the interpretation or meaning of radiation risks can be highly subjective and variable. Specialists in radiation safety may find some common agreements on the meaning of radiation risk estimates because of similar understanding of the technology and basis for such estimates. Unfortunately, most of the world does not have that background and understanding and may interpret radiation risks very differently. Perhaps the primary basis for differences in understanding risk estimates is fear. Our minds are programmed for survival to be constantly alert to any evidence of risks. The media has done a good job over the past 70 years to instill fears of “Deadly Radiation” in virtually everyone. As soon as the word “radiation” comes up, fears follow automatically in the same way that people are instinctively afraid of snakes, heights, and immersion. People often equate radiation with cancer and death. They equate “risk” with “chance” and they are not willing to take a chance on getting cancer. Lacking a technical understanding of risk probabilities, when asked to evaluate a risk estimate, they may substitute a different question, such as, “How do I feel about getting cancer?” This is a question they can readily answer without any knowledge of radiation science or statistics. This approach eliminates any concerns for uncertainty or probabilities. Everyone knows of someone who has had cancer and they are aware of the awful consequences. The prospects of radiation causing cancer become an overwhelming influence on interpretation of risk estimates and decisions for radiation safety.

Our natural human instincts for safety are not well suited to situations involving randomness or uncertainty. Thus, while people may not be certain about the risks of radiation effects, they are certain that they do not want to become a victim of cancer. Research has shown that, when chance is involved, peoples’ thought processes are often seriously flawed. When either information or understanding are lacking this invites competing interpretations. For many people there are no gradations, such a low risk or high risk. Rather there is “zero” risk or the outcome is a sure thing. Unfortunately, misunderstanding of risk estimates may have very negative consequences. This paper will look at how we evaluate risk and the processes that lead us to make poor decisions for radiation safety.
How Do We Make Decisions for Radiation Safety?

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Health Physics Society Annual Meeting, Sacramento CA
Session THAM-E.10, Thursday - 7/26/2012

How often do we evaluate risks as part of a process for decisions on radiation safety? Most of us make decisions based on the requirements of regulations (public and worker dose limits), the requirements of our radioactive materials license, or the requirements of our radiation safety plan. In particular, our radiation safety plan usually spells out how we will implement the principles of ALARA. Our normal goal is to reduce radiation exposures to as low as we can reasonably achieve, without regard to the risks. We know in theory that we are reducing risks by reducing exposures, but how much do we really know factually about risks, especially at low doses and low dose rates? As specialists in radiation safety we follow the theory of the linear non-threshold model for understanding the relationship of radiation dose and effects. However, we also know that this model gets fuzzy below a cumulative dose of 100 to 150 millisieverts (10 to 15 rem).

How much do workers or the public really know about radiation risks. For lack of knowing technically, I suggest that radiation professionals, concerned workers, and the public alike make decisions for radiation safety based on gut instinct. These are the urgings of our subconscious mind intended for our protection. Our subconscious is programmed to detect sources of danger and react automatically to protect us. For protection our minds create images of unacceptable consequences to be avoided. Unfortunately the automatic reactions programmed into our subconscious to avoid imminent dangers of snakes, spiders, heights, dark places, and submersion, etc. are not usually appropriate for dealing with dangers of radiation. Risks of radiation injury are usually not imminent, but matters of future random chance. Because we have primarily only heard bad things about radiation for the past 50 years, many people have now included radiation aversion into their automatic subconscious reactions to avoid danger. This may help explain why we find so many people inherently afraid of radiation and making decisions for safety based on an automatic response of their subconscious minds and not on factual understanding of radiation risks.
Errors in Randomness and Understanding of Stochastic Risk Assessments

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Outline
- More invitations to move outside your comfort zone
- How randomness affects our lives
- Role of randomness, probabilities, statistics, in measurements
- How we are prone to errors

Why Our Natural Intuitive Processes Fail for Radiation Risk Assessments
- More invitations to move outside your comfort zone
- Normal processes for safety decisions
- How randomness rules our lives
- Role of our subconscious mind
- Confidence in our intuition
- Confidence in stories (seeing patterns)
- How our intuition is prone to errors

Risk Assessment Processes
- Built on a house of cards
- Starting with radiation measurements
  - Huge uncertainties – often overlooked
  - Recorded data are believed to be real
- Effects of randomness
- Intuitive evaluation of data
- Flawed processes and common errors

What to Expect in This Session
- Invitation to do some thinking about how safety decisions are made
- Thinking outside of your comfort zone
  - Question the basis of your beliefs
  - How we make safety decisions with limited data and understanding
- How we are prone to errors and biases – HPS News, May 2012 – Aug. 2013

My Approach
- My role is not to be the giver of answers
- My goal is to raise questions
- The best “Answers” are the ones you come up with yourself
- I am only a resource
- I hope to provide insights for a better understanding
- Success for this session will depend upon your initiatives – how you use these insights
- Each of you has the ability to apply insights from this Workshop
Randomness and Radiation Safety

- Dealing with randomness is normal for health physicists
- Radiation is a random phenomenon
  - All measurements are samples from a random distribution and are only best estimates
- The practice of ALARA is to minimize future random chance of cancer
  - Stochastic effects
- We use LNT as a model for safety practices

What the World Wants

- To deal only with absolutes
- Does not want to know about uncertainty and probabilities
- Most people want to know, “Am I safe or not safe?”
- They do not want to know about risk estimates
- When presented with a risk of 1/10,000
  - Many will conclude they are the 1

How People Handle Probabilities

- Not understanding risk probabilities
  - People substitute an easier question
  - “How do I feel about getting cancer?”
- Answer to this question does not require any technical understanding
  - Eliminates dealing with randomness and probabilities

Horrors of Cancer

- Everyone knows of the horrors of cancer
- Prospects of cancer become an overwhelming influence on decisions for radiation safety
- While people may not be certain about the risks of radiation
  - They are certain that they do not want to become victims of cancer

How Do People Make Decisions for Safety?

- When faced with imperfect, incomplete, or uncertain information?
- When chance is involved, people’s intuitive thought processes are often flawed
- We will look at
  - What are the principles that govern chance?
  - The development of ideas about uncertainty
  - How these processes affect safety decisions
  - How our intuition for safety is prone to errors

How Randomness Rules Our Lives
Errors in Randomness and Understanding Stochastic Risk Assessments

Leonard Mlodinow

Our View of the World
- We all create our own view of the world
- We use this view to filter and process perceptions
- We extract meaning from the ocean of data that washes over us each day
- And we often make errors in assessing data for risks

Randomness and Data
- Doctors and patients make mistakes on effectiveness of drugs
- Parents and teachers mistake exam results
- Investors make mistakes
- Sports credit a team’s success or failures to the coach
- Businesses do the same with CEOs
- Statistics show that on the average, firing a coach does not change performance

Human Intuition
- Not suited to situations involving uncertainty (randomness)
- People cannot create or recognize random numbers
- Neuroscience looks at how people make safety decisions when faced with imperfect or incomplete data
- When chance is involved, our gut instinct can be seriously flawed

Opposing Intuition is Difficult
- Our minds are built to identify a definite cause for each event
- Therefore, it is difficult to accept the influence of unrelated or random factors
- Success or failure is often not a matter of great skill or incompetence, but chance
- Are most of us where we are today by chance?

Like a Candle’s Flame
- Our lives are coaxed in new directions by a variety of random events and how we respond to them
- Processes to assess risk of a tiger do not work very well today
- Radiation is not an imminent danger
- The parts of our brain that assess chance also handle our emotions
- The amygdala that responds to fear is also activated for decisions involving uncertainty (More discussion at PEPs on Sun., Mon., Tue)
We Start with a Naïve Realism

Doctrine that things are what they seem

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When Chance is Involved

- Intuitive processes are seriously flawed
- We often make poor decisions when confronted with randomness or uncertainty
- Difficult task to swim against the tide of human intuition
- Because of randomness
  - Success may not be due to skill
  - Failure may not be due to incompetence

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Regression to the Mean

- Rewarding positive behavior works
- Punishment of mistakes does not
- In any random series of events, an extraordinary event will be followed, by chance, with a more ordinary event
- Chance events are commonly attributed to accomplishments or failures

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Typical Patterns of Randomness

- Apparent hot or cold streaks or bunching of data in clusters are often interpreted as a trend
- Coaches and CEOs are often fired because of lack of understanding of randomness, not because of flawed decision making
- Extraordinary events can happen without extraordinary causes

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Adding Details

- If added details fit our mental picture, the more real it seems and the more probable
- However, adding less-than-certain details to a conjecture makes the conjecture less probable
- It is common to assign higher probabilities to contingencies that are described in more detail
**Story of Linda**

- In college she was deeply concerned with discrimination and social justice.
- Today:
  - 1. Linda is active in the feminist movement.
  - 2. Linda is a bank teller and is active in the feminist movement.
  - 3. Linda is a bank teller.
- Which is most probable?

**Probability of Two Events?**

- The probability that two events will both occur can never be greater than the probability that each will occur individually. Why not?

**Rules for Probabilities**

- If two possible events, A and B, are independent, then the probability that both A and B will occur is equal to the product of their independent probabilities.
- If you want to know if either of two mutually exclusive events, A and B, will occur you add the individual probabilities.

**Should You Switch?**

- Let’s make a deal – Monty Hall
- Three doors – 1) Maserati, 2) Works of Shakespeare, 3) Works of Shakespeare
- First guess – Lucky? Chance is 1 in 3
- Host opens a door – shows Shakespeare
- Asks if you want to switch?
- Wrong guess – Chance is 2 in 3
- Odds are 2 to 1 you are in the Wrong Guess and should switch

**Uncovering the Truth**

- The understanding of randomness can reveal hidden layers of truth, but only to those who possess the tools to uncover them.
- Our brains are not wired to do probability problems very well.

**Mistaken Intuition**

- Mistaken intuition is that a small sample will reflect underlying probabilities.
- Gambler’s fallacy – the idea that the odds of an event with a fixed probability will increase or decrease depending on recent occurrences of the event.
- Root of the idea, “His luck has run out”
- A good streak doesn’t jinx you and a bad streak doesn’t point to success due to random chance.
Understanding Randomness

- The key to understanding randomness is not being able to intuit the answer to every problem immediately, but merely having the tools to figure out the answer.
- Most of life is about observing a small sample of outcomes and from that we infer information and make judgments about the qualities that produced those outcomes.

Prosecutor’s Fallacy

- Error of logic
- OJ Simpson trial
  - 4 million women battered annually, 1 in 2,500 were killed by batterer
- Wrong statistic – need probability of battered wife who was murdered, and was murdered by the batterer = 90%.

Truth in the Courtroom

- Oath to “tell the truth, the whole truth, and nothing but the truth” applies only to witnesses, not the defense attorneys, prosecutors, or judge.
- Is it fair to say, “The American Justice System is built on a foundation of not telling the whole truth?”

Statistics

- What is the connection between underlying probabilities and observed results
- Law of large numbers – a large enough sample will reflect the makeup of the population
- Tolerance of error
- Tolerance of uncertainty

Measurement Uncertainty

- Given a series of measurements, what is the best guess of the true value, and what are the chances of your guess being near the true value?

Measurements and the Laws of Errors

- The reading on a radiation instrument is not a definition of the true value, but a measurement of it, which is susceptible to random variance and error.
- One way to get a single number from a set of measurements is to take the average or mean.
- Statistics provides a set of tools for interpretation of data from measurements.
Contradictions of Life

- Although measurements always carry uncertainty, the uncertainty of measurements is rarely discussed when measurements are quoted.
- To understand a measurement means to understand the nature of variation in data caused by random error.

Interpretation of Measurements

- Distribution of data points
  - Sample standard deviation
- Uncertainty, +/- about the mean
- Sample variance – square of the variation
- Variations within the margin of error should be ignored
- A single measurement should not be accepted as reality – but in the context of the spread of possibilities that produced it.

Meaning of Measurements

- A measurement has no meaning without knowing the variation that could occur from repeated measurements.
- Central limit theorem – for large number of observation, the means will be normally distributed. Such as coin flips.
- Law of large numbers

Patterns and Correlations

- The chaos of life produces predictable patterns
- Regression to the mean
- Consistency of relationships – correlation coefficient
- Chi - square test (for normal distribution)
- Much of the order we perceive in nature belies an invisible underlying disorder that can only be understood through the rules of randomness

Perception and Reality

- Human perception is not a direct consequence of reality, but rather an act of imagination.
- Perception requires imagination
- Data that people encounter in their lives is never complete and always equivocal

We Rely on Gut Instinct

- We do not apply statistical significance testing, but rely on gut instinct,
- Our perceptions of patterns of life can be highly convincing and highly subjective
- Many of the assumptions of modern society are based on shared illusions (mythology)
- It is human nature to look for patterns and to assign them meaning, when we find them.
Is Seeing or Hearing Believing?

Can we have faith (trust) in what we see or hear?

Which Line is Longer?

Perception and Reality

- Human perception is not a direct consequence of reality, but rather an act of imagination.
- Perception requires imagination because the data that people encounter in their lives is never complete and always equivocal.

Is seeing believing?

- Good resolution for only 1 degree of arc around retina’s center
- We move our eyes to focus more widely
- Two eyes and brain interpolate to fill the gaps
- We use our imagination to fill in gaps of nonvisual data.
- We draw conclusions based on incomplete data and conclude our picture is clear.

What Do You See?
Heuristics
- Rules – of – thumb or shortcuts we apply in assessing patterns in data and in making judgments in the face of uncertainty
- While optical illusions may not be significant, cognitive biases play a significant role in decision making

How is Randomness Seen?
- People have a very poor concept of randomness.
- They do not recognize it when they see it and they cannot produce it when they try.
- Our minds are wired to assimilate data, fill in the gaps, and look for patterns

Error of Cancer Clusters
- If you divide an area into parcels and look at cancer incidence, some parcels will be higher
- Picture looks worse if you draw the parcel boundaries after distributing the cancers
- Sharpshooter effect
  - Shoot at blank target and draw circles around the hits
  - People resist accepting that clusters are result of randomness

Cancer Clusters
- The wise man looks for meaning, the fool only gets the noise
- Real randomness will often exhibit a pattern and appear to be nonrandom
- Cancer clusters
  - 16 darts hitting a square with equal probability of hitting any place in the square
  - Divide into 16 squares and you will find some with more than one hit and some with none

Does this look like a Cancer Cluster?

Sequence of 200 Tosses of a Coin,
- With X - tails and O - heads:
  0000XXXXX00000000X000X000000X
  X000XXXXX0000X00000000X0000X
  X000XXXX0000XX00000000X0000X
  00X00X00X0000X0000X0000X0000X
  00X0000X0000XX00000000X0000X
  0000XXXX00000000XXXX0000000X
  0000XXXXX00000000X00000000X
Errors in Randomness and Understanding Stochastic Risk Assessments

It’s All About Control
- People like to exercise control over their environment - survival instinct
- One of the most beneficial things we can do for ourselves is to look for ways to exercise control or at least feel like we have some control
- A sense of helplessness and lack of control is linked to stress and onset of disease
- Do people feel in control of radiation risks?

Control vs Randomness
- How is human need to be in control relevant to discussion of random patterns?
- If events are random, then we are NOT in control
- If we are in control, then events are NOT random
- Clash between our need to feel in control and our ability to recognize randomness

Need to Control
- Need to feel in control interferes with the accurate perception of random events
- People pay lip service to the concept of chance but behave as though chance events are subject to control
- Difficult in real life to resist the illusion of control

We Intuitively Look for Patterns
- Intuitive Error - Confirmation Bias
  - When we are in the grasp of an illusion or have an idea, instead of searching for ways to prove our idea is wrong, we usually attempt to prove it correct
  - Major impediment to breaking free from misinterpretation of randomness

Intuitive Errors - Confirmation Bias
- We preferentially seek evidence to confirm our opinion and also interpret ambiguous evidence in favor of our opinion
- Example, we conclude on the basis of flimsy evidence that a neighbor is unfriendly, then further actions in that light stand out and others are easily forgotten

Confirming Patterns?
- Even random patterns can be interpreted as compelling evidence, if they relate to our preconceived notions
- Human brain is very good at pattern recognition, but by confirmation bias we are focused on finding and confirming patterns rather than minimizing false conclusions
- Big step, to question our perceptions / theories. Should we spend more time looking for evidence that we are wrong?
Errors in Randomness and Understanding Stochastic Risk Assessments

Errors of Predictability
- If the future really is chaotic and unpredictable, why, after events have occurred, does it seem as if we should have been able to predict them?
- Hindsight is 20/20, but people behave as if that adage was not true
- In government, after every tragedy, a “should have known” blame game is played

Butterfly Effect
- Can the wings of a butterfly affect global weather?
- Can that extra cup of coffee profoundly affect your life?
- “Chance is a more fundamental concept than causality”
  – Nobel Laureate – Max Born

We Want to See Cause and Effect
- People have a need to see situations in terms of cause and effect
- A wealthy person must have more business sense than a poorer person
  - While there may be no difference in ability, we tend to see them differently
- We miss the effects of randomness in our lives. Because?
- When we assess the world, we tend to see what we expect to see

Expectations
- It is easy for us to fall victim to expectations and also easy to exploit them
- Marketers know how to design ad campaigns to create and exploit our expectations
- People perceive differences in vodkas and are willing to pay more for some brands, even though vodka is legally required to be without any distinctive character

Role of Randomness
- Ability does not guarantee achievement and achievement is not proportional to ability
- It is important to keep in mind the other term in the equation – random chance
- Since chance is always a factor, the more chances you take the more likely you are to succeed.
- If you want to succeed more - double your failure rate

Review - Understanding Randomness
- The key to understanding randomness is not being able to intuit the answer to every problem immediately, but merely having the tools to figure out the answer
- Most of life is about observing a small sample of outcomes and from that we infer information and make judgments about the qualities that produced those outcomes.
Errors in Randomness and Understanding Stochastic Risk Assessments

Are You Sure About That?
- Past events will always look less random than they were – hindsight bias
- We backfit explanations to fit our view
- You can mispredict everything your entire life and still believe you will get it right the next time
- Tease those who take themselves and the quality of their knowledge too seriously

Do We Question Ourselves?
- It takes bravery to remain skeptical
- It takes great courage to introspect, to confront oneself, to accept our limitations,
- It appears that our minds are wired to fool ourselves

Meaning of Probability – for Taleb
- Tenaciously qualitative and literary
- Not quantitative and scientific
- Probability is a branch of applied skepticism, not an engineering discipline
- Probability is not a mere computation of odds on dice with more complicated variants,
- Rather, it is acceptance the lack of certainty in our knowledge and development of methods dealing with our ignorance

All or None?
- Our brain does not easily make out shades of probability, it goes for the over simplifying “all or none” approach
- We go for a certain outcome
- Safe vs unsafe, right vs wrong
- Yes vs No

Is it Luck, or Skill?
- Chance favors the prepared, hard work, persistence, perseverance,
- Certainly necessary, but may be insufficient, because they do not cause success
- You need to buy a lottery ticket to win, but does the trip to the store cause the winning?
- Luck is democratic and hits everyone regardless of original skills
Errors in Randomness and Understanding Stochastic Risk Assessments

Is hard Work the Answer?
- Our brain gets the arrow of causality backwards
- While an intelligent, hard working, persevering person may be successful
- Successful people may not be intelligent, hard working, or persevering
- Millionaires may be persistent hardworking people, but persistent hard working people may not become millionaires

How We Perceive Things
- Taleb is about luck disguised as nonluck – ie skills and randomness disguised as non-randomness, ie, determinism.
- The formation of our beliefs is fraught with superstition
- A Professor may see deep meaning in a mere coincidental occurrence of words,
- An economist may detect regularities and anomalies in data that are plain random

We Want Rationality
- You should make rational choices because that is what is good for you
- We believe in reason and rationality to overcome impediments on our way to becoming a better human race
- By thinking we can control our nature at will and transform it by mere edict to attain happiness and rationality

Tragic Vision
- Belief that the existence of inherent limitations and flaws in the way we think and act requires an acknowledgement of this fact as a basis for any individual or collective action
- Distrust of intellectual “answers” or anyone who is confident that they know anything with certainty

Taleb Says
- Whole life is a fight between my brain (not fooled by randomness) and my emotions (completely fooled by randomness)
- The only success I’ve had is in going around my emotions rather than rationalizing them
- Giving advice means that our cognitive apparatus rather than our emotional machinery exerts some meaningful control over our actions.
- Behavioral science shows this is untrue

Resistance to Randomness
- The degree of resistance to randomness in one’s life is an abstract idea, partly because it is logically counterintuitive and partly because its realization is not observable
- To an accountant, a number is a number
- People who devote themselves to science tend to have an ingrained intellectual curiosity and a natural tendency for introspection
Two Polar Categories

- One extreme is people who never accept the notion of randomness
- The other is people that are tortured by it
- Realism can be punishing
- Heroes are heroes because of their heroic behavior, not because they won or lost
- We are not wired to understand probability
- Mathematical truths make little sense to our minds, especially when examining random outcomes

How Risks are Seen

- People do not like to insure against something abstract. The risk that merits their attention is always something vivid
- How are radiation risks seen?
- Our brains tend to go with superficial clues when it comes to risk and probability, those clues being largely determined by what emotions are elicited or the case at which they come to mind

Shocking Fact – Emotions Rule

- Neither risk detection or risk avoidance are mediated in the “thinking” part of our brain, but largely in the emotional part
- Consequences are not trivial
- Rational thinking has very little to do with risk avoidance
- Much of rational thinking is about rationalizing our actions by fitting some logic to them

Getting Our Emotional Attention

- The description coming from journalism is more than an unrealistic representation of the world, but rather the one that can fool you the most by grabbing your emotional attention
- Sensationalism can divert your attention to the wrong causes
- Cancer and malnutrition suffer from lack of attention

Down on Journalism?

- Journalism may be the greatest plague we face today, as the world becomes more complex and our minds are trained for more and more simplification
- Why argue with a journalist whose pay comes from playing on the conventional wisdom of the hordes
- TV news is about entertainment

Results of Simplification

- Confusion between correctness and intelligibility
- Conventional wisdom today favors things that can be explained instantly “in a nutshell” – a sound bite
- Einstein said that common sense is nothing but a collection of misconceptions acquired by age 18
Errors in Randomness and Understanding Stochastic Risk Assessments

Tools for Toying with Uncertainty
- Monte Carlo methods consist of creating artificial histories using the following concepts
- Alternative sample paths – from mathematics of probability called stochastic processes
- The word “sample” means that you see only one realization among many possible ones (Note for radiation measurements)

Sample Paths
- Random sample path – a succession of virtual historical events, starting at some point and ending in another, subjected to a varying level of uncertainty
- Random should not be mistaken for equal probabilities

How We Learn
- Children learn from their own mistakes, by touching a burning stove.
- No possible warning by others can lead to developing the smallest form of cautiousness
- We have a congenital denigration of the experiences of others, which do not seem to apply to us individually. We are special.
- Reading history does not help us to “learn from other’s mistakes”

Reactions to the Past
- Risk avoidance often comes from experience stored in our subconscious mind
- In many respects we do not learn from our own history (reactions to past events)
- We fail to learn that our emotional reactions to past experience are short lived, yet we retain the biased thinking that a purchase will bring long lasting happiness

“Why Me?”
- Every person believes themselves to be different, which amplifies the “why me” shock of a diagnosis.
- Even when the historical evidence is plentiful
  - Cigarette smoking!
- How well do we do in detection and prevention of a variety of ailments we may be subjected to?

Value of History?
- Those who do not study history are destined to repeat it
- Hind sight is always 20 / 20.
- Things are always obvious after the fact
- Do we actually learn from history?
- Or do we think our circumstances are different, we are smarter, history does not apply or predict my own future?
How Our Minds Work

- Our minds are not designed to understand how the world works, but how to get out of trouble quickly and have progeny
- Hindsight bias – overestimation of what we knew at the time due to subsequent information, “I knew it all along”
- A mistake is not something to be determined after the fact, but in light of information available at that point

Effect of Hindsight bias

- Those who are very good at predicting the past will think of themselves as good at predicting the future, and feel confident about their ability to do so
- 9/11 events teach us that we live in a world where important events are not predictable.
- Yet many ask why we did not know and prepare?

More About Journalism

- Much information given by the media is not only diverting and generally useless, but may also be toxic
- A guiding principle for those who deal with decision making under uncertainty is to minimize exposure to the media
- Is there anything better than “noise” in the mass of “urgent” news bombarding us?
- People do not realize that the media is paid to get your attention

Role of Journalism?

- In today’s culture, people often seem to believe that surely the next batch of news will really make a difference in their understanding of things
- The ratio of undistilled information to distilled is rising and saturating the markets
- Much of journalism is about providing the noise that can capture our attention
- Yet we depend on them for the information we need

Journalists

- Trained in methods to express himself rather than plumb the depth of things
- Selections of journalists favor the best communicator, not necessarily the most knowledgeable
- Commonly mix up absence of evidence with evidence of absence

Noise vs Information?

- Sound is the change in the specific condition of segregation of the material parts, and in negation of this condition, merely an abstract or an ideal ideality, as it were, of that specification. But this change, accordingly, is itself immediately the negation of the material specific subsistence, which is, therefore, the real ideality of specific gravity and cohesion, i.e. heat. The heating up of expanding bodies, just as of beaten or rubbed ones, is the appearance of heat, originating conceptually together with sound.
Thinking vs Intuition?
- We believe we are endowed with a beautiful machine for thinking and understanding
- The problem with thinking is that it causes us to have illusions
- We follow rules because they save time and effort, not because they are the best
- If a caveman took time to study the sabre tooth tiger, he would be eaten
- Our brain uses shortcuts

Shortcuts Save Energy
- If we take time to optimize every step in our life we would need infinite time and energy
- There has to be an approximation process that allows us to stop somewhere
- We stop thinking when we get a near satisfactory solution
- While we are rational, our rationality is bounded
- We have built in rules to stop somewhere

Heuristics - Shortcuts
- When are we not endowed with rational probabilistic thinking and optimal behavior under uncertainty
- Kahneman discovered rules that do not make us rational – called heuristics
- Shortcuts, however, come with side effects, biases
- The more data we have, the more likely to drown in it

Rules for Processing Data
- Our minds work by a series of disconnected rules that may not necessarily be consistent with each other
- These are stored in a rulebook and our reactions depend upon which page of the book we open at a given time
- Our brains may react differently depending on which page we are open to.
- Absence of a central processing system may result in decisions that are in conflict with each other

Intuition Behind Rules
- “Loss of perspective bias”
  - Fact – the counter is reset to zero and each day you start from scratch
- We do not have everything we know in our minds at all times
  - We retrieve knowledge piecemeal as needed, which puts retrieved knowledge in chunks into the local context
  - This means we have an arbitrary reference point and react to differences from that point

Basis for Reference
- Anchoring – comparing to a given reference
- We are influenced by the last data point
- People do not react to their total wealth but the differences according to what number they anchor to
- People put too much confidence in small samples
- What emotions are elicited by events, determines their probability in your mind
Availability Heuristic

- Which is more likely, deadly floods caused by an earthquake in California or fatal floods occurring somewhere in North America?
- Which is more likely, death from terrorism or death from all possible sources.
- The frequency of an event is determined by the ease with which instances of the event can be recalled.

Representative Heuristic

- Gauging the probability that a person belongs to a particular social group by assessing how similar the person’s characteristics are to the typical group members.
- We do not think when making choices, but use heuristics.
- Our decision making contains some lingering habits of cavemen - shortcuts for quick survival actions.

Caveman Survival

- The caveman did not have to compute probabilities.
- Our problems stem from the fact that we have evolved out of that habitat, much faster than our genes. Even worse out genes have not changed at all.
- Gigerenzer says we react better to frequencies or percentages.

Neurobiologists Say

- We have three brains:
  - 1) A very old reptilian brain, that dictates heartbeat and bodily functions
  - 2) A limbic brain – center of emotions
  - 3) Neocortex or cognitive brain
- Difficult to figure out which part of the brain does what exactly.

Role of Emotions

- A man with no emotions could not get out of bed and frittered the whole day away fruitlessly weighing decisions.
- One cannot make a decision without emotions.
- Mathematicians have shown that if we try to optimize every variable,
- It would take a very long time to make a decision on the simplest of tasks
- Emotion gives us a shortcut.

Emotions Affect Our Thinking

- The connection from the emotional system to the cognitive is much stronger that vice versus.
- We feel emotions and then find a cognitive explanation.
- Opinions and assessments concerning risks may be the simple result of emotions.
- We are neither intelligent or strong enough to fight our emotions.
- We need emotions to formulate ideas and get the energy to execute them.
Evolutionary Psychologists
- Agree that people have difficulty with standard probabilistic reasoning.
- They say the reason lies in the way things are presented to us in the current environment.
- Our brains are made for fitness, not for truth.
- Our brains are not made for understanding things.
- Only enough to survive.

Execution is the Challenge
- We know what to do for health:
  - Stop smoking
  - Loose weight
  - Exercise
  - Eat healthy
- All of these actions require changing a habit.
- Habits may not be in our conscious control.

Probability
- Probability is not about the odds, it is about the belief in the existence of an alternative outcome, cause, or motive.
- Probabilities are nothing beyond a subjective, and fluid, measure of beliefs.
- Skeptics say nothing can be accepted with certainty – conclusions of varying degrees of probability can be formed and these supply a guide to conduct.

Dogma
- We accept dogma from fears of what may be true, or what may not be true:
  \[ \frac{x}{\text{Untruth}} \frac{\text{Fears}}{\text{Truth}} \]
- Are we allowed to contradict ourselves?
- Do we lie or merely forget previous positions?
- Do we have to be faithful to our opinions?

Ideas?
- Are we programmed to build loyalty to ideas in which we have invested time?
- Are we married to our ideas?
- If we change our minds, are we traitors?
- The odds in games where the rules are clearly defined can be computed and the risks measured.
- However, in the real world, mother nature does not endow us with clear rules.

? 
- Can one calculate future risks without knowing future uncertainty?
- Do we take science too seriously?
- Could we be idiots who know nothing and are mistake prone, but happen to be endowed with the privilege of knowing it?
Attribution Bias
- It is a human characteristic to attribute successes to skills and blame failures on randomness.
- We believe this so as not to kill self esteem and keep us going in the face of adversity.
- Gives us the illusion of being better than we are which is why 80-90% of people believe they are above average.
- People confuse science and scientists.

Can We Change?
- Ideas do not really sink in when emotions come into play.
- We leave our rational brain in the classroom.
- Self-help books are largely ineffectual.
- Good, enlightened advice and sermons do not register for more than a few minutes when they go against our wiring.

Victim?
- Do not play the victim when diagnosed with cancer.
- Face defeat and death with dignity.
- Do not blame others for your fate.
- The only thing Lady Fortune has no hold over is your attitude.

How Our Brain Works
- Our brain flashes any picture, sound, or feeling automatically which we can respond to on cue, like a Pavlovian dog.
- May be important for survival.
- We do not know how life really is, we only know how we represent it to ourselves - Tony Robbins.
- How do people represent radiation?

Two Systems for Safety Decisions
1. **Conscious Mind** - Reason and rational analysis of facts
   - Favored by technical specialists.
   - May lead to intelligent decisions, but, **very slow** and takes effort.
   - For radiation safety, we often do not have all the facts, time to gather facts, or knowledge to understand them.
2. **Subconscious Mind** - Emotion, instinct, and gut reactions, **very fast**.
   - Does not need all the facts.
   - Origin of most decisions, especially for safety.

Role of Our Conscious Mind < 1%
- **Very Slow**, deliberate, rational, thinks, reasons, makes decisions and choices based on sensory input.
- Source of knowing and awareness.
- Serves as the captain of our ship, the giver of orders.
- Processes information to make decisions.
- Can only deal with one thing at a time.
- Example.
**Subconscious Mind > 99.999%**

- The seat of our intuition, emotions
- Takes orders from the conscious mind without judgments
- A Very Fast super computer
- Functions 24/7 operating the machine we call our body
- Regulates our heart, breathing, digestion of food, healing of cells, etc
- Handles thousands of inputs simultaneously for our health and protection
- Programmed to fear/react instantly to danger

**Fears of Radiation are Involuntary**

- Instinctive fears of heights, snakes, spiders, closed spaces, submersion, public speaking
- Repeated message “Deadly Radiation”
  - Transferred to subconscious mind for protection – frame of reference
  - Radiation is now an instinctive source of fear
  - Fear of radiation – not a conscious choice
  - Subconscious reacts automatically to radiation without consulting the conscious mind
  - Decision to “RUN” is now automatic

**We are Wired to Fear First – Think Second**

- First – fear reactions are subconscious
- Occur near top of spinal cord – amygdala
- Sensory data speeds from five senses
  - Through spinal cord to center of brain – thalamus
  - Thalamus acts as relay between midbrain and larger cerebral cortex
- Amygdala is closer
  - Recognizes danger first
  - Mobilizes body for Fight, Flight, or Freeze
- Before thinking occurs

**Amygdala on Guard**

- Sensory system and amygdala constantly scanning for signs of danger
- Quickly leaps to action at first hint
- Amygdala takes control immediately
  - Fear response, overrides conscious thinking processes - OK for a striking snake
- Not a good way to decide on radiation safety
- Amygdala not programmed for radiation
- Our subconscious has learned other shortcuts to process information quickly
  - Such as remembered impressions

**How We Make Quick Decisions**

- We process, sort, compare, categorize, and analyze information, in relation to –
  - Immediate circumstances – “Radiation”
  - Experiences – what have we heard?
  - Life factors, such as health, wealth, traditions, and lifestyles
  - Loss aversion – we need to be safe
- With all these inputs we come up with instant judgments
  - Quick judgments are crucial to survival
- Based on limited information
  - May not be best in the long term
- Is running away the best answer for radiation?
Errors in Randomness and Understanding Stochastic Risk Assessments

**How our Brain Functions**
- Our brain processes information like a computer.
- We take in fantastic amounts of data and organize it into configurations that make sense to us.
- A computer needs software, structure to perform certain tasks.
- We have developed software for our brains from habitually processing information the same way.

**HP Instant Subconscious Processing**
- 1 R = 1 rad = 1 rem
- $A = A_0 e^{-t}$
- Time
- Distance
- Shielding
- Stimulus
- Response

**Structure for Thinking**
- Software for our brains – patterns for thinking:
  - They provide the structure that governs what we pay attention to.
  - How we make sense of our experiences, and the directions in which they take us.
  - They determine whether something is interesting or dull, a potential blessing or a threat.
- Like computers - our software will give same result every time.

**Mental Patterns – Brain Software**
- People have patterns of behavior.
- They have patterns by which they organize their experience to create those behaviors.
- Only by understanding those mental patterns can we expect to get our message across.
- Software change is needed to get different behaviors.

**Patterns and Expectations**
- The illusion of patterns strongly affects our views on radiation risk assessments.
- Paducah – Gaseous Diffusion Plant – reports of cancer incidence in many neighborhoods.
- How many people in Japan who may get cancer among the Fukushima evacuees will likely conclude that the Daiichi incident is the cause?

**Experience Basis of Beliefs**
- We generate our experiences (beliefs) in life by behavior or thought.
- We store these experiences like files in a computer.
- These files (beliefs) can be played back at any time, if the right stimulus is triggered – “Deadly Radiation”.
- Playback is an automatic function of the subconscious mind.
Role of Beliefs – Brain Software

- Our beliefs are specific, consistent organizational approaches to perception – like software
- Fundamental choices we make about how we perceive and live our lives
- We do not know if our beliefs are true or false
- What we know is if they work and if they support us.

Beliefs and Lies

- Every thing we believe could be a lie, which we have accepted as the truth
- No scientist can prove that our thoughts create our reality, but it’s a useful lie. It’s an empowering belief - Robbins
- How do we derive meaning and understanding?
- Most people in our culture have been programmed to fear radiation

How much of What we Believe is Based on Faith?

- Faith is confidence or trust in a person, thing, deity, view, or in the doctrines or teachings of a religion.
- Belief that is not based on proof, rather more a matter of confidence based on some degree of warrant.
- The word faith is often used as a synonym for hope, trust, or belief.
- Do we have faith in science?

Knowledge and Belief

- Definition of knowledge as “Justified True Belief”
- Justification is the reason why someone properly holds a belief,
  - The explanation as to why the belief is a true one,
  - Or an account of how we know what we know

Errors of the Conscious Mind

- Relies on the subconscious to continuously generate suggestions, impressions, intentions, intuition, and feelings
- When endorsed by our conscious mind, these become beliefs,
  - Impulses turn into actions
- We generally believe our impressions and act on our desires
- That is fine – as long as our subconscious is not biased

Justified Beliefs

- A justified belief is one that we are "within our rights" in holding.
  - The rights in question are neither political nor moral, however, but intellectual.
  - In some way, each of us is responsible for what we believe
  - What do we believe about radiation risks?
  - How sure do we need to be that our beliefs correspond to the actual world?
Is Faith Blind?

- Does faith mean blind trust?
- One who has faith is "not blind, but intelligent" and "commences with the conviction of the mind based on adequate evidence."
- The validity, or warrant, of faith or belief depends on the strength of the evidence on which the belief is based.

An Intellectual View of Faith

- Faith is belief without evidence; a process of active non-thinking.
- Faith degrades our understanding of the natural world by allowing anyone to make a claim based solely on their personal thoughts, and possibly distorted perceptions, that does not require testing, has no ability to make reliable and consistent predictions, and is not subject to peer review.
- Which view applies to radiation safety decisions?

Importance of Truth and Faith

- We have to believe (have faith) in something.
- We need realistic expectations to live.
- Truth is needed for survival,
  - For coping with the world.
- Do we trust our instincts for radiation risk assessments?

How Hard Do we Expect People to Work?

- How much effort should people put into understanding radiation safety?
- How hard should we expect to work - to understand how people make safety decisions?
- What is the incentive to commit this effort?
- Why should people change their views about radiation?

Can We Ignore Public Fears of Radiation?

- Do irrational fears influence public policy?
- Should we protect the public from fear?
- How do we justify expenses for reducing imaginary risks?
- Isn’t this actually happening all the time?
- How many of us are dealing with “real” risks?
- How much of what we do is driven by public views of what is needed for safety?

Stories and the Illusion of Knowing

- We create good stories to explain the world around us — then we believe our story.
- It is easier to construct a good story when we know little and have fewer pieces to the puzzle.
- This might explain why some people are so convinced of the hazards of radiation.
- Stories confirm what we have always believed and what we have always known.
- What do we really know for sure?
Errors in Randomness and Understanding Stochastic Risk Assessments

Gut Instinct and Patterns
- Our perceptions of patterns of life can be highly convincing and highly subjective
- Many of the assumptions of modern society are based on shared illusions (mythology)
- It is human nature to look for patterns and to assign them meaning when we find them
- Most people do not apply statistical significance testing for radiation risk assessments, but rely on gut instinct

Shortcuts for Risk Assessments
- Heuristics – shortcuts we apply in assessing patterns in data and in making judgments in the face of uncertainty
- While optical illusions may not be significant, cognitive biases play a more significant role in decision making, such as radiation risk assessments

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- People have a need to see situations in terms of cause and effect
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- It is important to keep in mind the other term in the equation – random chance.
- Since chance is always a factor, the more chances you take the more likely you are to succeed.
- If you want to succeed more - double your failure rate.

How Randomness Rules Our Lives
- Invitation to move outside our comfort zone.
- Probabilities handled by substitution.
- Intuition does not do well with uncertainty.
- We create a view of the world prone to errors.
- We look for patterns.
- Mistakes in intuition for random events.
- Interpretation of measurements.
- Is seeing believing?
- Confirmation bias, Seeing cause and effect.

Intuitive Failures for Risk Assessment
- Built on a house of cards.
- Beginning with huge measurement uncertainties.
- Recorded numbers taken as gospel.
- Interpretations based on fears of radiation.
- Meaning is whatever people believe.
- Probabilities handled by substitution.
- Our lives are ruled by randomness.
- Intuition does not do well with uncertainty.
- We create a view of the world prone to errors.

Summary
- Conscious and unconscious minds.
- Fear first - think second.
- Unconscious computer runs on patterns.
- Knowledge - beliefs - faith - truth?
- What we believe might not be true.
- Is seeing - believing?
- Should we protect the public from fear?
- Need to feel in control - for survival.
- Confirmation bias.

Summary
- Black Swan events.
- Blindness to randomness - what we don’t know.
- Platonicty and need for stories.
- Narrative fallacies, need to see cause / effect.
- History and loss of details.
- We categorize to simplify.
- Errors of silent evidence (what is left out?).
- Knowledge and confidence.
Errors in Randomness and Understanding Stochastic Risk Assessments

References
- How Risky is it Really, David Ropeik, 2010
- Thinking, Fast and Slow, Daniel Kahneman, 2011
- The Black Swan – The Impact of the Highly Improbable, Nassim Nicholas Taleb, 2010
- Fooled by Randomness – The Hidden Role of Chance in Life, Nassim Nicholas Taleb, 2004
- Human Error, James Reason, 2009
- Why We Make Mistakes, Joseph T. Hallinan, 2009
- Calculated Risks, Gerd Gigerenzer, 2002

Review
- Take a few minutes to review what we have learned in this session
- How might these insights be helpful?
- What was of particular interest for you?
- Share with the class

Questions?

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