How Randomness Affects Our Decisions for Radiation Safety

A Professional Enrichment Program Lecture (PEP – 3D)

Health Physics Society Midyear Meeting Norfolk, Virginia

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by

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(PEP- 3D, Presentation at the HPS Midyear – Feb. 1, 2015)

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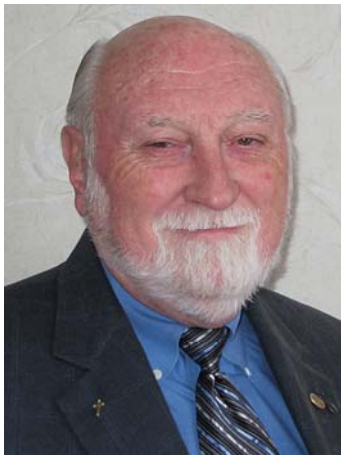
As health physicists we understand that radiation is a random phenomenon. We also understand that our practice of ALARA is to minimize the future random chance of cancer. Thus, dealing with randomness is a normal part of our practice as specialists in radiation safety. Unfortunately, most of the rest of the world wants to deal only with absolutes and does not want to know about uncertainty or probabilities. Most people want specific answers to questions such as, "Am I safe or not safe?" "Will I be harmed or not harmed?" Most people do not want to hear about risk estimates. When presented with a probability of cancer as a risk of one out of some number of those exposed, they will often conclude that they are the one. Or, not understanding risk probabilities, they may substitute an easier 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 randomness or probabilities. Everyone knows of someone who has had cancer and they are aware of the horrible consequences. The prospects of radiation causing cancer become an overwhelming influence on 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.

How do people make judgments and decisions when faced with imperfect, incomplete, or uncertain information? Research has shown that when chance is involved, people's thought processes are often seriously flawed. What are the principles that govern chance, the development of ideas about uncertainty, and how those processes play out in decisions for radiation safety? We will look at how we make choices and the processes that lead us to make mistaken judgments and poor decisions when confronted with randomness and uncertainty. When information is lacking, this invites competing interpretations. Unfortunately, misinterpretation of data may have very negative consequences. How often is past performance a good indicator of the future? The human mind is built to identify a definite cause for each situation and it can have a hard time accepting the influence of unrelated or random factors. According to Mlodinow, "Random processes are fundamental in nature and ubiquitous in our everyday lives, yet most people do not understand them or think much about them." This PEP session will explore the role of chance in the world around us and how chance affects our decisions for radiation safety.



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- BS - Civil Engineering, University of Vermont (1961)
- MS - Sanitary Engineering, Massachusetts Institute of Technology (MIT) (1963)
- PSE - Professional Sanitary Engineer Degree, MIT and Harvard University (1963)
- PE – Licensed Professional Engineer, Vermont (1965 – present)
- PhD Studies, Radio and Nuclear Chemistry, Rensselaer Polytechnic Institute (1966–1972)
- Greater Washington Institute for Transactional Analysis - Counseling (1977–1980)
- CHP – Certified Health Physicist, American Board of Health Physics (1983–present)
- Johns Hopkins Fellow, Organizational Systems and Communications (1984–1985)
- FHPS - Fellow of the Health Physics Society and Past President (2000)
- Past President, American Academy of Health Physics (2013)
- Commissioned Stephen Minister – Counselor, United Methodist Church (2003–present)

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, 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 analysis 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.
1970 - 1985	Chief, Radiation Surveillance Branch, EPA, Office of Radiation Programs. Directed studies of radiation exposures from all sources of radiation in the US, coordinated 7 Federal agencies for nuclear fallout events, QA officer 8 years. Head of US delegations to I.A.E.A and N.E.A. on radioactive waste disposal. ANSI N-13 delegate (1975-1985). Retired as PHS Commissioned Officer (0-6) in 1985 with 29 years of service.
1963 - 1970	U.S.P.H.S. Directed development of radiation monitoring techniques at DOE National Labs, nuclear plants, and shipyards in the US and Chalk River Nuclear Laboratory in Canada.

Health Physics and Professional Activities

Health Physics Society (HPS) plenary member 1966; President-elect, President, Past President (1998-2001), Fellow (2000), Treasurer (1995-1998); Secretary (1992-1995); Executive Cmte. (1992-2001), Chair, Finance Cmte. (1996-1998); Head of U.S. delegation to IRPA X (2000). RSO Section Founder and Secretary/Treasurer (1997-2000); Co-founder and President, Radon Section (1995-1996). Co-Chair Local Arrangements Cmte. Annual Meeting in DC (1991); Public Info. Cmte. (1985-1988); Summer School Co-Chair (2004); Chair, President's Emeritus, Cmte (2006); Chair, Awards Cmte. (2002); Chair, History Cmte. (2005-2012); Historian (2012-Pres.) Continuing Education Cmte. (2005-2012). Academic Dean for HPS Professional Development School on Radiation Risk Communication (2010). PEP, CEL and AAHP Instructor; Journal Reviewer; Treasurer, AAHP (2008 – 2011). AAHP President-elect, President, Past President (2012-2014). Baltimore-Washington Chapter: President (1990-1991) and Honorary Life Member; Newsletter Editor (1983-2005); Public Info. Chair (1983-1991), Science Teacher Workshop Leader (1995 – Pres.). New England Chapter HPS, Newsletter Editor, Board of Directors, Education Chair (1968-1972). President, American Association of Radon Scientists and Technologists (1995-1998) and Honorary Life Member, Charter Member; Board of Directors; Newsletter Editor (1990-1993). Founder and first President, National Radon Safety Board (NRSB) (1997-1999). Member of American Industrial Hygiene Association (1997-Pres.) (Secretary, Vice Chair, Chair, Ionizing Radiation Committee, 2009-2012), Conference of Radiation Control Program Directors (1997-Pres.), Studied H.P. communication styles and presented Myers-Briggs seminars to over 3500 H.P.s since 1984. Over 35 professional society awards. Licensed Professional Engineer since 1965. Certified Health Physicist since 1983.

Publications

Authored over 500 book chapters, articles, professional papers, training manuals, technical reports, and presentations on radiation safety. Author of monthly column, "Insights in Communication" HPS Newsletter 1984 – 1989, 1994 -2001, and 2012- 2013.

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No. 1 – Radiation Safety Psychology

Health Physics Society Newsletter – May 2012

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 out 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 out 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.

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No. 3 – Radiation Safety Psychology

Health Physics Society Newsletter – July 2012

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.

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No. 4 – Radiation Safety Psychology

Health Physics Society Newsletter – August 2012

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

Ray Johnson, CHP

Last month this column drew upon observations from a recent book by David Ropeik, ***"How Risky is it, Really? Why Our Fears Don't Always Match the Facts."*** The McGraw Hill Companies, Inc. 2010 (Amazon - $13.60). This month I would like to introduce readers to another recent book by Daniel Kahneman (Nobel prize in economics) ***"Thinking, Fast and Slow."*** Farrar, Straus, and Giroux, New York, 2011.

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 is 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.

No. 7 – Radiation Safety Psychology

Health Physics Society Newsletter – November 2012

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.

- Daniel Kahneman, ***"Thinking, Fast and Slow."*** Farrar, Straus, and Giroux, New York, 2011.

No. 9 – Radiation Safety Psychology

Health Physics Society Newsletter – January 2013

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[2]

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.

[1]Kahneman, D., "Thinking, Fast and Slow." Farrar, Straus, and Giroux, New York, 2011
[2]Johnosn, R, Psychological and Mental Health Aspects of Ionizing Radiation Exposure, Encyclopedia of Environmental Health, J. Nriagu, Editor, Elsevier Science, Amsterdam, Holland, March 29, 2011

No. 10 – Radiation Safety Psychology

Health Physics Society Newsletter – February 2013

How We Make Decisions for Radiation Safety – Part VIII

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 Kahneman[1].

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 indentifies 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. Kehneman 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.

[1]Kahneman, D., "Thinking, Fast and Slow." Farrar, Straus, and Giroux, New York, 2011

[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.

No. 11 – Radiation Safety Psychology

Health Physics Society Newsletter – March 2013

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[1].

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 "bath 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?

[1]Kahneman, D., "Thinking, Fast and Slow." Farrar, Straus, and Giroux, New York, 2011
[2]Slovic, P., Finucane, M., Peters, E, and MacGregor. D., in "Heuristics and Biases," Gilovich, T., Griffin, D, and Kahneman, D., Editors. Cambridge University Press, New York, 2002.

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.

[1]Kahneman, D., "Thinking, Fast and Slow." Farrar, Straus, and Giroux, New York, 2011

How Randomness Affects Our Decisions for Radiation Safety

PEP- 3D 2:00 - 4:00 pm
Feb. 1, 2015

Ray Johnson, MS, PSE, PE, FHPS, CHP
Director
Radiation Safety Counseling Institute
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301-370-8573

Overview of this PEP Session

- Invitation to move outside your comfort zone
- How randomness affects our lives
- Role of randomness, probabilities, statistics
- Interpreting radiation measurements
- How we are prone to errors

2

PEP WAM-2
Why Our Natural Intuitive Processes Fail for Radiation Risk Assessments

- Normal processes for safety decisions
- Strategies to reduce complexity (randomness)
- Role of our subconscious mind
- Confidence in our intuition
- Confidence in stories (seeing patterns)
- Beliefs based on mythology (stories)
- What is the truth? CEL - Wed. 7 am

3

What to Expect Today

- Invitation to do some thinking about how safety decisions are made ?
  - Question the basis of our beliefs ?
  - How do we make safety decisions with limited data and understanding ?
- Interpretation of radiation measurements ?
- How we are prone to errors and biases – HPS News, May 2012 – Aug. 2013

4

Four Topics for Today

- How Randomness Affects our Lives
- Randomness and Measurement Uncertainties
- Randomness and Uncertainty in Safety Decisions
- Common Errors in Safety Decisions

5

My Approach

- My role is not to be the giver of answers
- My goal is to raise questions and encourage further reading and study
- This PEP session is to meet your goals according to your interests
- I am only a resource
- Success for this session will depend upon your initiatives – how you use insights
- Each of you has the ability to apply insights from this PEP session

6

You are Responsible for Learning

- You learn by how you process information, not on what I say
- Not just me speaking and you listening
- Not about magic answers
- Its about better understanding, insights
- The best "Answers" are the ones you come up with yourself

7

Tips from a Elder Mentor

- A successful business man in his 70s was asked for his top three tips for success, he said:

1. Read something no one else is reading
2. Think something no one else is thinking
3. Do something no one else is doing

8

Have You Been Puzzled By - - ?

- How people can make such fast decisions for safety with little data or understanding
- How they can be so sure of their decisions
- How illogical they may seem
- How emotions affect safety decisions
- How people lack a number sense
- Lack of understanding of magnitudes and probabilities
- Lack of understanding randomness

9

Focus for Today

- NOT on technology of radiation safety issues, You are radiation experts
- Focus on understanding how randomness affects radiation measurements and safety decisions
- How safety decisions are prone to errors
- An invitation to move outside your comfort zone

10

Your Comfort Zone

- Familiar
- Language
- Feelings
- Views
- Secure
- Employment
- Family
- Friends
- Home

11

Outside Your Comfort Zone

- Unfamiliar
- Views and Beliefs
- Fears and feelings
- Credibility
- Threats and Risks
- Cultural factors
- Education factors
- Life styles
- Economic factors
- Languages

12

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

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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

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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

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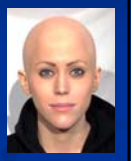
Horrors of Cancer

- 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

16

How Do People Make Decisions for Safety ?

- When faced with imperfect, incomplete, or uncertain information?
- When chance is involved, people's 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 we are prone to errors

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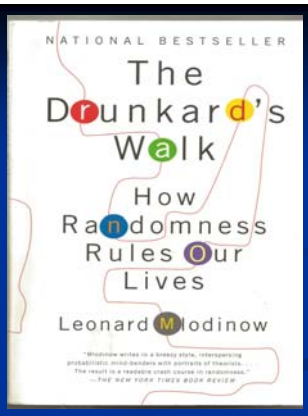
How Randomness Rules Our Lives

First Vintage Books Edition, May 2009



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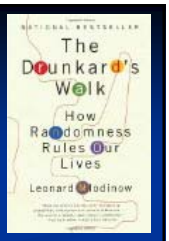
Leonard Mlodinow



- The Drunkard's Walk – How Randomness Rules Our Lives
- Anecdote of lottery winner
  - 7 X 7 = 48
- "We create our own view of the world and then use it to filter and process our perceptions, extracting meaning from the ocean of data that washes over us
  - And we are often prone to errors"

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Human Intuition

- Not suited to situations involving uncertainty
- People cannot create or recognize random numbers
- Neuroscience looks at how people make decisions when faced with imperfect or incomplete data
- When chance is involved, our intuition may be prone to substantial errors

21

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 ?**

22

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
- 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 WAM – 2)

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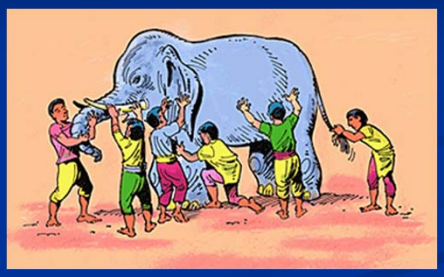
We Start with a Naïve Realism

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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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

26

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

27

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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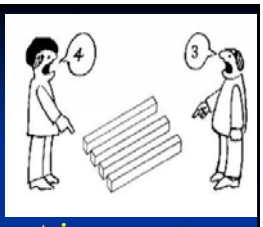
Adding Details



- 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

29

Should You Switch?

- Let's make a deal – Monty Hall
- Three doors – Maserati, Works of Shakespeare, 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

30

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.
- We determine the "truth" intuitively

31

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

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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.

33

Scientists and Probabilities

- Seek to determine the true value of a physical quantity, given a set of measurements
- Probability – predictions based on fixed probabilities
- Statistics - Inference of these probabilities - based on observed data

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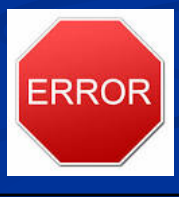
Statistics

- 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



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Radiation Measurements

- We need measurement data as a basis for decisions on radiation safety
- Given a series of measurements, what is your best guess of the true value, and what are the chances of your guess being near the true value?

36

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
- Although measurements always carry uncertainty, the uncertainty of measurements is rarely discussed when measurements are quoted

37

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

38

Meaning of Measurements

- A measurement has no meaning without knowing the variation that could occur from repeated measurements
- To understand a measurement means to understand the nature of variation in data caused by random error

39

Issues with Interpretation of Measurements

- Technical factors
  - What can go wrong with instruments?
- People factors
  - What do the numbers mean ?
- Combinations of factors
  - Lack of technical understanding of measurements and fears of radiation

40

Randomness and Measurements

- Steps for defensible measurements
- Interpretation may be more about attitudes and risk perceptions, than about technology
- Two axioms on interpreting measurements
- A few anecdotes about interpretations
- Interpretation as a response to fears
- Why take chances? “Precautionary Principle”
- Dealing with uncertainty
- Many factors can cause measurements to be misleading

41

Good Decisions for Radiation Safety

- We rely upon good measurements for type and amount of radiation
- Big questions ?
  - Is our instrument telling us what we think it is ?
  - What can go wrong ?
  - How good do the data need to be ?

42

What Do We Want to Measure?

- Exposure – mR / hr ?
- Activity – cpm ?
- Issues - a few examples ?
  - Attempts to assess risk on basis of cpm measurements
  - Measurements of beta energy in mR / hr
  - Exposure measurements made in contact with a source

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Understanding Radiation Measurements

- Radiation is a random event
  - Random in time and direction
- What does this mean for measurements ?
- How do we determine the quality or uncertainty of a measurement ?
- How good does the measurement have to be for a defensible decision ?
- How much money are we willing to spend ?

44

Practical Guidance

- What affects data quality ?
- How to interpret measurements ?
- Engineer's view of process for acquiring, interpreting, and defending radiation data
- May set goals with best intentions
  - Not knowing what can go wrong. that could result in inappropriate decisions

45

Goals for Measurements

- Improvements in quality
- May not consider how good the data need to be
  - What will data be used for?
- Measurements take on a life of their own
- Samples may be collected haphazardly
- Quality of measurement may exceed quality of sample
  - Example - swipes, wipes, or smears

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Quality Requirements

- MDAs set far below action levels
- Action levels set below MDAs
- Quality requirements imposed without regard to decisions and action levels
- What quality is needed?
  - Within a factor of ten ?
  - With 4 to 6 significant figures ?

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Steps for Defensible Measurements

- 1. Deciding what to measure ?
  - Exposure (mR/hr) or activity (cpm) ?
- 2. Choosing the proper instrument
- 3. Verifying instrument performance
- 4. Using the instrument properly
  - According to calibration ?
- If you have been careful with above steps,
  - There are still countless pitfalls
  - You now have measurements to interpret

48

Two Axioms on Measurements

1) "Measurement results have no meaning until interpreted for a particular purpose"

They are just numbers

2) "Measurements only have a meaning in terms of how they are interpreted"

The meaning is whatever people believe

49

Psychology of Radiation Measurements

- Interpretation may have as much to do with attitudes and perceptions as it does with technology
- Same measurements may have different meanings for others
- Examples:
  - Technician at nuclear plant, "We got a hot one here!"
  - Industrial worker saw GM meter go off scale
  - Granite counter tops
  - Firemen observing twice background
  - Screaming GM meter

50

Common Aspect of Scenarios

- If its measureable, it must be bad!
- Interpretation of measurements is often a matter of responding to fears
- One person's answer for defending conservative decision, "Precautionary Principle"

  "Why take chances?"
- Common mindset

  Measurement = "Deadly Radiation"
- Risks of NOT taking action
  - Fears, criticism, responsibilities
  - Making a mistake

51

Dealing with Uncertainty

- Most people do not want to deal with uncertainty, they want absolute values
- They typically do not ask questions to evaluate the data or to determine if the data are defensible
- Tendency is to assume all recorded data are of high quality and suitable for making decisions
  - When the number is written down, it becomes reliable

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Uncertainty in Measurements

- Radiation is statistically random
- Decay constant – $\lambda = 0.693 / T_{1/2}$
  - probability per unit of time that a decay will occur
- There are no absolute measurements of radiation
- No measurement is a single value
- All are "best estimates"
- What is the best quality standard available from NIST?
  - Since all measurements are made by comparison, we can never be better than the standard

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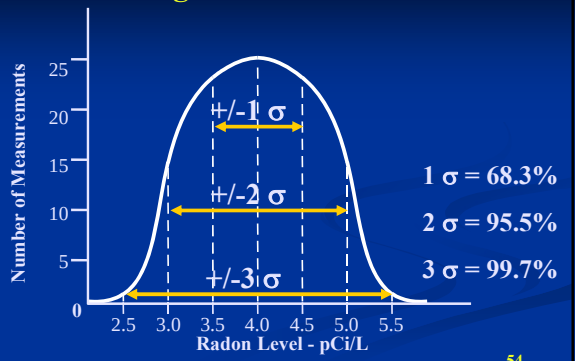
Meaning of Standard Deviation



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Standard Deviation

- The standard deviation of a single radiation measurement is approximately the square root of the total counts observed

$$\sigma = \sqrt{N}$$

- e.g. for 2500 counts in 5 minutes

$$\sigma = \sqrt{2500} = 50 \text{ counts}$$

- Activity is 2500 / 5 = 500 cpm
- ± 50 / 5 = 10 cpm
- or 500 ± 10 cpm or 500 ± 2%

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Standard Deviation of Count Rate

Count rate: n = N / t

$$\sigma = \sqrt{N}/t = \sqrt{n\ t}/t^2 = \sqrt{n}/t$$

e.g. for 10,000 counts in 10 minutes

n = 10,000 / 10 = 1,000 cpm

$$\sigma = \sqrt{1{,}000}/10 = 10$$

9/10 error = 1.65 σ

= 1.65 x 10 = 16.5 cpm

Activity = 1,000 ± 16 cpm

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How Do We Quantify Uncertainty

Estimates based on variations of sample count rates and background

Standard Deviation =

$$\sigma = \sqrt{\frac{N_{s+b}}{T_s} + \frac{N_b}{T_b}}$$

N_{s+b} = cpm of sample + background
N_b = cpm of background
T_s = sample counting time
T_b = background counting time

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σ for 3 Day AC at 4 pCi/l

N_{s+b} = 161 cpm
N_b = 109 cpm
T_s = 5 minutes
T_b = 15 minutes

$$\sigma = \sqrt{\frac{161}{5} + \frac{109}{15}} = 6.3 \text{ cpm}$$

Coefficient of Variation

$$Cv = \frac{\sigma}{N_s} = \frac{6.3}{52} = 12\%$$

* 4 ± 12% or 4 ± 0.5 pCi/l

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Reporting Conventions

4.0 pCi / l (no indicator of uncertainty)

4.0 ± 0.5 pCi / l (uncertainty as std. dev.)

4.0 pCi / l ± 12% (uncertainty as CV)

Confidence levels:

68 % ≈ 1 σ
95 % ≈ 2 σ
98 % ≈ 3 σ

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Quality for Portable Instruments

- NIST standard may be within + / - 5 %
- Calibrations may be within + / - 10 %
- Rule-of-thumb, + / - 20 %
- Allowance for uncertainty affected by:
  - Choosing right instrument
  - Is it working properly
  - Is it used properly
  - How does the instrument respond vs energy

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Significant Figures ?

pCi / l	CV - %
4	25%
4.0	2.5%
4.4	2.3 %
11	10 %
11.1	1%
100	1×10^2
111	1×10^2
135	1×10^2

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Choosing Right Instrument

- What is your need for data ?
- Exposure or activity measurements ?
- What decisions do you want to make ?
- May have to rely on available meter
- Could be marginal or totally inadequate

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Verifying Instrument Operation

- How do you know if your instrument is working properly ?
- Battery check
- Check source response
  - Appropriate source ?
- Possible probe or cable failure ?

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Proper Instrument Usage

- Calibration conditions
  - Reproduce calibration conditions
- Geometry conditions
  - How was meter calibrated ?

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Factors Affecting Uncertainty

1. Wrong detector or wrong probe
2. Instrument not working properly
3. Instrument not used properly
4. Calibration conditions
5. Energy dependence
6. Background interference
7. Backscatter and self absorption
8. Reading the wrong scale and mR / hr for beta
9. Minimum detectable activity (MDA)
10. Operator factors: fatigue, speed of probe movement, thoroughness of scan,

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More Factors Affecting Uncertainty

- Radiation is random
- Variation in standards
- Calibraion uncertainty
- Sensitivity of instruments
- Counting time
- Amount of radiation
- Background / variations
- Geometry
- Uniformity of samples
- Sample location
- Sample selection bias
- Sample preparation
- Volume and weight errors

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Questions for Interpretation ?

- What decision do you want to make ?
- How good do the measurements need to be ?
- What do the numbers mean ?
- Are the measurements defensible ?
- How much resources are you willing to commit on the basis of these measurements ?
- What is the risk of making a mistake ?
  - What if you act or do not act ?
  - How will you be held accountable ?
  - Possible litigation ?
  - Upset workers ? Union ? Management ?

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Making Good Decisions

- How to avoid decisions that may not be warranted by the data, false positives
  - Be skeptical, ask lots of questions before decisions
- Repeat measurements for confirmation, with other people and other instruments ideally
- Typical when finding actionable levels
  - Most want to take immediate action
- No one wants to be criticized
  - For not taking action

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Defending Results

- Ask lots of questions
- How do you know if the data are any good ?
- Right instrument, working properly, used properly, calibration, energy dependence, geometry ?
- Report results with estimates of all sources of uncertainty,
  - Be careful of significant figures
- Always repeat for confirmation,
  - Before reporting or making expensive decisions

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Randomness and Safety Decisions

- Begins with measurements and many sources of (unknown) uncertainty
  - Many things can go wrong
  - Numbers recorded are taken as gospel
- Interpretation of measurements
  - Subject to individual perceptions
  - Related to fears (radiation = cancer)
- Decisions for action
  - Precautionary Principle

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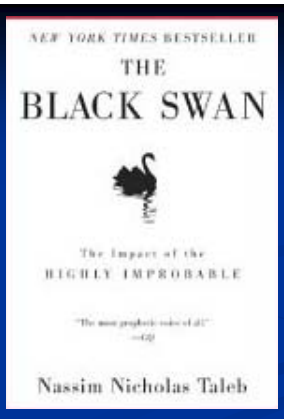
More Effects of Randomness That Affect Safety Decisions



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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

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Is seeing believing?

- Good resolution for only 1 degree of arc around retina's center
- Move 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

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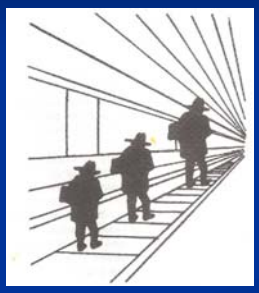
Errors of the Conscious Mind
Common Illusions



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What Do You See?

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We Look for Patterns

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

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Shortcuts and Illusions

- 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 (illusions) play a significant role in decision making

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How is Randomness Seen

- People have a very poor conception 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

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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 a circle around the hits
  - People resist accepting that clusters are random

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Its All About Control

- People like to exercise control over their environment
- 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

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Control vs Randomness

- How is human need to be in control relevant to a 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

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Need to Control

- Our 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

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We Look for Patterns

- Rule for construction of a sequence of three numbers and the sequence 2,4,6 satisfies the rule
  - Can you come up with sequences that qualify?
  - What is the rule?
- Sources of 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

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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

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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 and theories. Should we spend time looking for evidence that we are wrong ?

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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

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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

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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. When we assess the world we tend to see what we expect to see

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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 required to be without any distinctive character

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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

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Role of Thinking

- Our minds do not seem made to think and introspect
- Good thing, otherwise an introspective ancestor would have been eaten by a lion
- Consider that thinking is time consuming and often a great waste of energy
- We actually do much less thinking than we think we do.

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Power of Stories

- We are gullible about stories and our preference for compression of narratives
- Metaphors and stories are far more potent than ideas and easier to remember
- We focus on what makes sense to us
- Living today requires more imagination than we are made to have
- We lack imagination and repress it in others

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Summary of Effects of Randomness for Safety Decisions

- Randomness is ubiquitous and usually not recognized
- Decisions on radiation safety begin with measurements that are very prone to errors
  1. Numerous uncertainties
  2. Mostly ignored for recorded data
- Interpretations are related to perceptions
- Many of our perceptions and beliefs are based on illusions

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Questions ?

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Please fill out the evaluation form

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