How Cognitive Bias Can Prolong a Troubleshooting (or Debugging) Effort

Ankur Gupta
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Introduction

Allow me, if you will, to tell a story of how my biased thinking prolonged a troubleshooting effort and resulting in a pretty serious waste of my time – not to mention leaving me without mobile phone service in my office for over a year.

One day I noticed that I wasn't receiving calls on my Verizon mobile phone at work. Then I realized text messages were also getting lost. When I began receiving emails asking why I was unresponsive I started taking a closer look. In the mornings and evenings my phone was working fine, but during the day nothing incoming was getting through.

I futzed with my phone some, tried different network settings, and turned on and off various features and apps, but there was no change. It looked like I had plenty of signal strength. I tried calling out and discovered that outgoing calls were affected as well.

I stood up in my cubicle, waved my phone around a bit, then walked outside. I found I could make calls from the hallway, the reception desk, conference rooms, near the windows – pretty much anywhere else in our building. But when I went back to my desk… good signal, bad results.

I had never had reception problems with my carrier before, particularly at my desk, where I have been on many two or three hour long conference calls and training sessions on a rock-solid connection. I have a rather comfortable hands-free headset that worked really well for the longer calls and for all the occasions that required two hands to write down floods of information as we document our clients' processes. There were cell towers within sight of my building so there was never any worry about dropping a call.

What in the world could be happening?

Initial Assumptions

Being an engineer, I started listing hypotheses to test.

- ✓ Hypothesis 1: Verizon was having network issues or maybe the construction near our building was now blocking my signal.
- ✓ Hypothesis 2: Someone in the building had a cellular jammer running.

- ✓ Hypothesis 3: New neighbors moved into the offices adjacent to ours and their renovations included adding new walls. Maybe those were blocking my signal.

Given that any one of those could be true, I thought about how I could test them. Waiting for a while was one approach to all three because, for one thing, Verizon might fix their network (if that was the problem). Plus, our planned office move would be happening soon anyway. In addition, my Verizon contract was ending soon, at which point I could trade in my 3G phone for a new 4G LTE phone anyway. So I figured that the problem would most likely be resolved without further effort on my part. I decided to wait.

Attempted Solution 1 – Wait & See

Time passed and I got my new LTE phone. No change.

More time passed and Provaré moved to a new office in a nearby suburb. The new space was in a spacious business park in a lightly wooded area with a series of small lakes where I once saw a blue heron flying by. No large buildings or heavily walled neighbors to worry about. By the time our lease expired, we had labeled all of our boxes and systematically labeled all of our IT assets so that everything could be plugged back in exactly as it was before. We got everything moved, plugged in, and settled into our new location over a weekend so we were up and running again by Monday. My new office was near a long open hallway and not too far from an outer wall with a wide array of windows. When I sat down at my desk, I found once again my ability to actually use my mobile phone was still effectively zero. And yet the indicated signal strength was still high enough that it should have been working fine.

So it wasn't the phone, it wasn't the location, and there was no nearby "jammer." Hmmm...

Attempted Solution 2 – Actual Troubleshooting

So if I wanted to be able to use my mobile phone in my office, I had to do some real troubleshooting. It seemed to me that the mostly likely answer at this point was that something in ***my*** office was causing interference with my phone. Adding weight to this theory, shortly after our move, our salesperson had mentioned in our daily standup meeting that he was suddenly having similar mobile phone problems in his office. In our new building, his desk and mine were on opposite sides of the same wall. I then realized that pressed up against my side of our shared wall was a set of brand new PC workstations we built from scratch a few months earlier. Wait a minute! My interference problem started at about the time we got those new machines! Aha!

So the troubleshooting began.

Obviously, I reasoned, the problem originated in one of the new computers. I turned the computers off one by one, and found I could dial out from my mobile as soon as I turned off one particular machine, which quickly earned the nickname ***Radiation King***. The others were not causing any problems, but as soon as I turned Radiation King back on, it was behaving exactly as a jammer would – killing my ability to use my phone.

I brainstormed with Provaré's founders, who are both engineers with tons of mobile telecom experience. (Between the two of them they had helped build and optimize cellular networks for Bell South Mobility, Cingular Wireless and AT&T Wireless.) They were equally perplexed as to the cause.

I turned to Google to find out if anyone else had similar issues, but the problem was so rare that I found only a single relevant case. Not only did it involve much different hardware, but the newest post in the discussion was several years old at this point.

The most frustrating part was that the problem PC was one of 5 identical machines that we had built at the same time. Five ***identical*** machines and this was the only one with the problem.

I reasoned one of the new components may be defective and could be generating a high EMI (electromagnetic interference), and this was somehow interacting with my mobile phone's frequency.

After a good bit of experimentation, I noticed to my amazement that the problem only occurred **after** Windows had loaded. While viewing the motherboard's UEFI screen, there was zero interference. So from the UEFI screen, I attempted changing the clock rates of – well – pretty much everything where such a thing was possible. My motherboard had an option to activate a feature called Spread Spectrum. I did some more research, and found: "Spread Spectrum varies the clock speed in order to eliminate EMI". This looked promising! Why would this feature exist unless EMI had been a problem in the past? I enabled this feature, ***knowing*** that I had stumbled onto the solution. But again, I was disappointed.

Ah, there's a BIOS update available! Maybe that would fix it! Nope.

Finally, I ordered a new case and I managed to unplug and unscrew the Radiation King's guts and moved it into the new case. I left the side panels off and powered it on. I placed my mobile phone directly on the case and dialed out. I figured this close proximity with the covers off should maximize the interference, and if it works at this close range, it would work from the rest of the office.

It worked! I could make calls with the machine running. I dialed a phone number where I was guaranteed to be left on hold for some time: 1-800-COMCAST. The connection remained stable for several minutes.

My good feelings were dashed when I put the covers back on, tightened some screws, placed the phone on my desk and dialed out again fully expecting the same triumphant result.

Mobile Network Not Available

At this point, I was so frustrated I actually considered purchasing a large piece of steel from the hardware store just to shield it from me and the rest of the office. (Lead would be too impractical.) But I knew that the radiation had to be coming from some single component of the machine. If I could just figure out which component, I could replace it. Obviously, the 4 other test machines didn't have this problem, so whatever it was, it was clearly an anomaly.

Attempted Solution 3 – Let Go of My Bias

After literally replacing every part and cable inside of the *Radiation King* PC one at a time, including the case itself, without solving the problem, even I in my biased state of mind had to conclude that the radiation wasn't coming from coming from ***inside*** the case. I now had to consider what was

coming from outside of the case. I had to admit that my bias toward the "obvious" source of the problem had kept me on the wrong path for – well – more time than I would like to admit.

I set my phone to dial out and started unplugging cables one by one. Only when the DVI cable leading up to one of my monitors was unplugged would the call get connected. Once I had a stable connection, I plugged the DVI cable back and the call would drop immediately.

> *OK, a little background on my setup is necessary at this point.*
>
> *I have two monitors on my desk: an NEC 223WXM-BK and a Samsung 226BW. Each of them has both DVI and VGA inputs. Both monitors allow me to switch between these inputs.*
>
> *At Provare, each test engineer has two PCs at his desk. One is for doing things like email, word processing, internet browsing, - pretty much what anyone at any business would use a PC for. The other is a PC for testing client software. As I said earlier, my "Radiation King" PC was one of 5 identical machines. The reason that they are all identical is so that we can install an instance of an operating system (with or without office or other optional applications) make an image of that OS in its cleanly installed state, and restore it later, not only to the machine on which it was originally installed, but on any of the others as well (or instead). That way, we can always test our client software on identical clean environments where the danger of interaction with other potentially buggy software is eliminated.*
>
> *So the bottom line is that I had 2 PCs (my main desktop and my test PC) and two monitors (my NEC and my Samsung). Before we built these new machines, I had one monitor connected to each PC, both using VGA.*
>
> *But when these new machines were built, I had a great idea. Since both PCs had both VGA and DVI outputs and both monitors had both DVI and VGA inputs, I could connect one PC to the DVI input on one monitor and connect the other PCI to the opposite ports on the two monitors and I would always have 2 monitors on both machines! Brilliant! (See Figure 1 on the next page)*
>
> *I decided to connect my Test PC ("Radiation King") through the DVI output to the NEC 223WXM-BK and through the VGA output to my second monitor (the Samsung 226BW). I then connected the VGA output of my desktop PC to the Samsung 226BW, and then the DVI output of this machine to the Samsung 226BW.* (See Figure 1 below for a diagram)

But then I suddenly realized that I had made a classic mistake. And it makes me want to kick myself, because I know better. I hadn't kept the test environment fixed while changing only one variable at a time.

- ✓ I hadn't always plugged both of my monitors back into the PC
- ✓ I hadn't always placed my phone in the same location every time, during every test, on every day

At this point, I was "pretty sure" the DVI cable itself was defective or poorly shielded. (Alas, it still gets worse. Keep your seat). Testing the cable from the Radiation King on the "good" PC (connected to the NEC 223WXM-BK) resulted in mobile phone interference as expected. Upon inspection, the DVI cable was a cheap, house-brand cable and had no ferrite bead (the little cylinder that is made into many electronic cables that suppresses electrical noise). But wait a minute, the DVI cable from the "Good PC" to the Samsung monitor was the same make and model.

One more bias to let go of… That's right, it wasn't the cheap cable.

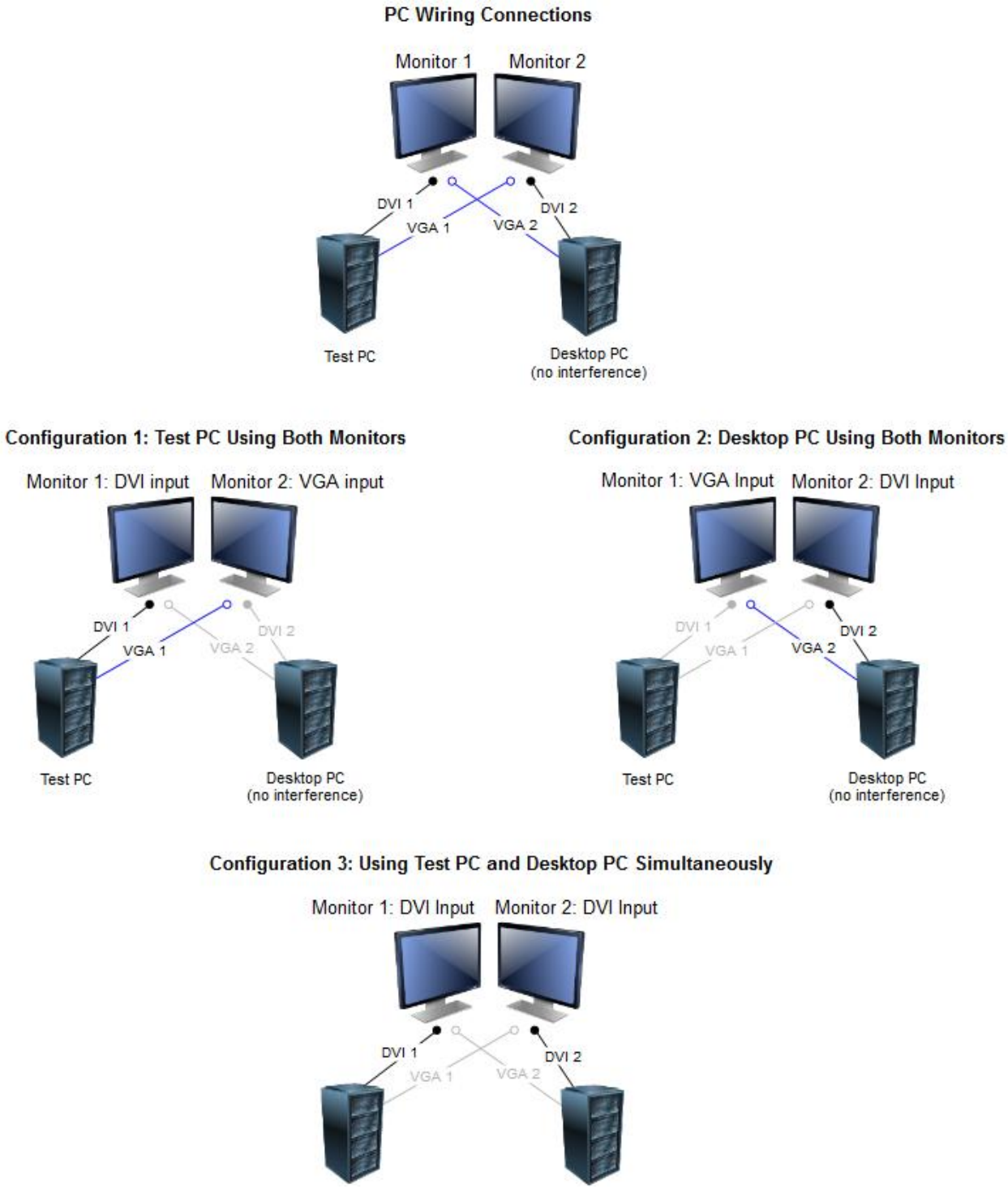

Figure 1: PC-Monitor Connections

I needed to test one more theory: could it be the monitors themselves? Connecting the DVI cable from the "good" PC and plugging it into the Radiation King and the NEC 223WXM-BK ruled out the cable because I was getting interference again. This was confirmed when I tested the suspect cable by using it to connect my "good PC" to my Samsung 226BW monitor and I could still make calls. My Samsung 226BW, whether connected to the Radiation King via DVI or VGA, did not generate any interference at all. I tried it back and forth a few times and proved that the problem wasn't the DVI cable itself causing the interference; it was one of the monitors that was sitting on my desk all along. The problem followed the NEC 223WXM-BK monitor itself – but still only with DVI.

My cognitive bias towards a hardware problem inside the (falsely accused) "Radiation King" had caused me to not even consider the monitor as a potential source. Whenever I would turn on what I thought was a defective PC, I was viewing it through the monitor connected on a DVI port to that PC. The same monitor, connected through a VGA port to another PC, ***did not*** create any interference. So when I was using my "good" PC, I was using the culprit monitor's VGA port, which was not causing any interference. Before our office move, since we labeled all of our cables to be plugged in exactly the same way, I had the same configuration in both offices. This created the illusion that the problem followed the PC which was reinforced by my biased thinking.

Residual Curiosity Leads to a Surprisingly Easy Fix

But now I was really curious. Why was I only getting interference ***after*** Windows started?

I could always dial out as my PC booted, and if I hit F2 I could get to my motherboard's UEFI screen and adjust boot settings, processor, memory, or hard drive settings. Since the UEFI screen operates at a considerably lower resolution than the resolution I have set for Windows, I now suspected that the resolution might be part of the problem. To fully prove this point, I went into my Windows display settings with the intent of changing the resolution to see if it would affect the interference.

I found to my surprise Windows had set my display refresh rate to 59 Hertz. (Windows sometimes selects this resolution automatically, ostensibly to reduce flicker on some monitor/video card combinations.) I changed it to 60 Hz and tried making a call. It connected immediately and the call was clear. With my phone in the exact same place, I changed it back to 59 Hz. The call dropped immediately and I couldn't make another one while the refresh rate was set to 59 Hz.

I was able to reproduce this behavior several times from both directions, sometimes starting with a 59 Hz refresh rate while starting a call, then switching to 60 Hz and watching it connect as soon as I made the change.

Final Takeaways:

- ✓ **During any kind of troubleshooting, never assume the solution.** Hypotheses are great – and necessary. But make sure that all of the possibilities are covered. I assumed the cause was coming from inside the case so I missed the real cause for a long time.
- ✓ **When testing a solution, stay as absolutely consistent as possible.** Not keeping the test scenario absolutely consistent between variable changes (re: monitors and cables) led me to believe I had a solution, even though it was the test that changed, not the problem.

- ✓ **When troubleshooting anything, it's always a best practice to change one variable at a time, even when we are tempted to take shortcuts.** Sometimes these shortcuts are based in the bias that you think you already know the solution.

Epilog – Refresh Rates, DVI, and RF Frequencies

A little more research on the DVI specification described what is referred to as the pixel-clock frequency, and this frequency maxes out at 165 MHz. The pixel-clock frequency automatically changes depending on the monitor's resolution, color bit accuracy, and refresh rate, so it stands to reason that a change in refresh rate could alter the frequency of any RF noise that might be generated. And yet 165 MHz is still far lower than my carrier's LTE carrier frequency, of 1700 MHz, or of the frequency of the 3G phone I had before (which might well have also been in the 1700 MHz band).

I'm not versed enough in the DVI specification to say how a 165 MHz clock could potentially interfere with a much higher frequency. I have read there are 10 bits of data being transmitted for every clock pulse and that the total DVI data bandwidth is 4.95 Gb/s, but it also seems that several bits are transmitted in parallel.

At this point, I've reached the limit of what I can learn from Google and Wikipedia on this topic, so I can't offer any technical explanation as to exactly how the 59 Hz refresh rate creates RF noise that interferes with a 1700 MHz cell phone signal while a 60 Hz refresh rate does not. But the experimental results seem pretty clear. I have located the original specification written by the Digital Display Working group (DDWG) and am poring over it in my spare time, but truthfully, I don't expect any revelations. If there is anyone reading this with more working knowledge in this area, I would absolutely love to discuss it further!