Beats & Bytes: Striking the Right Chord in Digital Forensics
(OR: Fiddling with Your Evidence)

Ryan D. Pittman, Resident Agent in Charge, NASA OIG Computer Crimes Division
Cindy Murphy, President, Gillware Digital Forensics
Matt Linton, Chaos Specialist, Google Inc.

SANS DFIR Summit 2017
Austin, TX

"The theory of relativity occurred to me by intuition, and music is the driving force behind this intuition. My parents had me study the violin from the time I was six. My new discovery is the result of musical perception." – Albert Einstein (as cited in Suzuki, 1969, p. 90)

Abstract

This paper will present results from a recent survey of DF/IR professionals and seek to provide relevant observations (together with published psychological, sociological, and neurological research) to discuss the similarities and intersections of DF/IR and music, as well as identify potential correlations between being a successful DF/IR professional and playing music. It will also discuss numerous challenges facing DF/IR professionals today and how learning to play and enjoy music can help DF/IR personnel both overcome some of those challenges and be more effective in their chosen field.

Keywords: Digital forensics, incident response, music, musician, neurology, plasticity, perception, learning

Beats & Bytes: Striking the Right Chord in Digital Forensics

Professionals in the Digital Forensics and Incident Response (DF/IR) fields face a host of challenges on a daily basis, many of which do not involve technical tasks (such as cracking passwords or locating malware). On the contrary, these problems often relate much more closely to how DF/IR professionals can learn to hack a very different type of computer: their own brains! It takes a special type of person to be a successful DF or IR professional, as developing strategies and mechanisms to combat stress, loneliness, disgust, and fatigue (sometimes on a daily basis, and often all at once) become just as important as knowing how to shift the bits and bytes to find the evidence. As DF/IR professionals themselves, the authors noted that many of the skills and techniques needed by effective DF/IR personnel are also needed by good musicians, and vice versa. Beginning with the presentation of results from their recent survey of DF/IR professionals, the authors will use relevant observations and published psychological, sociological, and neurological research to discuss the similarities between DF/IR and music, as well as correlations between being a successful DF/IR professional and playing music (or singing). In addition, the authors will discuss numerous challenges facing DF/IR professionals today and how learning to play and enjoy music can help DF/IR personnel both overcome some of those challenges and be more effective in their chosen field.

DF/IR Music Survey

Background

The idea that artistic pursuits are often a corollary of professional or scientific success is not new. As early as 1878, future Nobel Laureates such as J.H. van't Hoff (Chemistry, 1901), Santíago Ramon y Cajal (Physiology or Medicine, 1906), and Wilhelm Ostwald (Chemistry, 1909) began positing that scientific success and engagement in creative avocations (i.e., hobbies, such as music or poetry) go hand-in-hand, often in disproportionate frequency to that of the general public (Root-Bernstein et al., 2008). Subsequent scientific studies set out to formally observe and catalogue the phenomenon, leading psychologists like Edward Thorndike (1911) to conclude, "Artistic ability, as in music, painting, or literary creation, goes *with* scientific ability and matter-of-fact wisdom. The best abstract thinker will be above the average in concrete thought also" (as cited in Root-Bernstein et al., 2008, p. 52).

Root-Bernstein et al. (2008) published one of the more complete discussions of the theorized relationship between success in scientific fields and artistic expression, using both reviews of previously published research and original research methods (wherein they broadened and diversified their examined samples beyond that of previous researchers). The results of their original research will be discussed in greater depth later in this paper, but it was noted that Root-Bernstein et al. cited another study by Yale psychologist Stanley Milgram and his colleagues (1997), summarizing Milgram's conclusion that, "… having at least one persistent and intellectually stimulating hobby is a better predictor for career success in any discipline than IQ, standardized test scores, or grades" (as cited in Root-Bernstein et al., 2008, p. 52). However, other than attempting to generalize their findings to high-performing scientists (e.g., Nobel Laureates, members of the Sigma Xi, etc.), Root-Bernstein et al. did not seek to expand their conclusions to other professions or less elite scientific strata.

When two authors of this paper (Murphy and Pittman) first met in person at a Digital Forensic Research Workshop (DFRWS) meeting in 2013, in Monterey, CA, various twists-and-turns of conversation (and a happy accident) led to a realization that not only were they digital forensic examiners by trade, but they were both also musicians (and learning to play more than just their primary instrument). A discussion followed in which Murphy and Pittman shared personal anecdotal evidence that suggested a large number of digital forensic professionals were also musicians. Not long after, Pittman and the third author of this paper (Linton; himself an incident response professional and musician) engaged in a similar discussion. While the authors were all generally aware of research linking music with positive psychological and physiological effects, and were also superficially familiar with research such as that presented by Root-Bernstein et al. (2008), they wondered if there was any evidence that DF/IR professions and musical pursuits went hand-in-hand.

It soon became clear that the authors were not the only ones to have intuited a possible relationship between DF/IR and music. Several years ago, Frank MacLain (2011) wrote an article, on his *Forensicaliente* blog, entitled “Is Scottish Fiddle Like Digital Forensics?” While the main thrust of the article sought to draw parallels between playing his instrument and becoming a proficient digital forensic professional, MacLain described a recent job interview during which he was asked about how he spent his free time (outside of DF). After he mentioned he played the Scottish Fiddle, “The guy interviewing me commented that a lot of people in DFIR play music” (MacLain, 2011, para. 1). MacLain went on to wonder, “Now, I had not heard that before, and I have kind of wondered if it is really that prevalent, and why it might be. Is it something about DF that attracts musicians, or vice versa,” before moving on to a different question and never really coming back to his original ponderings (MacLain, 2011).

Although the authors were unaware of MacClain’s (2011) musings (if the reader will forgive the pun) when they originally discussed the concept of this paper, the inherent questions seemed obvious: Is there actually some correlation between being a musician and a successful DF/IR professional and, if so, why? And, beyond any mere observable correlation, could music be used by those in the DF/IR field to positive professional effect? The new research discussed below (conducted by the authors), and the related discussion of other published external research, are an attempt to begin answering those questions.

Research Approach

In their attempt to collect relevant data, the authors developed a 13-question anonymous survey (provided for reference in Appendix A to this paper) using Google Forms. Survey questions were a combination of dichotomous (i.e., "Yes" or "No"), multiple choice, and open-ended questions designed to elicit answers from respondents pertaining to their current professional positions (e.g., primary job function, longevity in their position, etc.), whether or not they played a musical instrument (and related data), and their feelings on music, as well as whether (or not) and how they felt music affected their professional work. The survey also included a "for fun" question ("What are the top five songs on your playlist [i.e., to listen to] when you do a forensic exam or incident response?"), resulting in an "Ultimate DF/IR Playlist" (i.e., responses were aggregated and deduplicated by the authors, and presented for the reader's enjoyment in Appendix B to this paper, as well as via a public Spotify playlist called "Ultimate DF/IR Playlist").[1]

The authors used a hybrid (purposive-snowball/convenience) non-probabilistic sampling method in their research. Once the questions were drafted, the link to the survey was sent with a request for responses through channels the authors knew would provide exposure to DF/IR professionals (e.g., professional group contacts, DF/IR listservs, etc.), along with requests that respondents pass the link on through their own professional circles, in order to increase exposure. Once the link was distributed by the authors (on 3/16/2017), no further restriction was placed on

[1] The authors note that, for the sake of expediency, the survey instrument used in their study was not exposed to rigorous statistical or academic validity testing before it was used. Additional research could be conducted using a similar instrument that has first been subjected to that scrutiny as a means of potentially identifying and mitigating any question or sampling bias.

the number or type of respondents. For example, any non-DF/IR professionals and/or non-musicians (reached within or via the groups to which the survey was originally targeted) were likewise encouraged to respond, and were identified via screening questions, such:

Which of the following best describes you?
1. Digital Forensics Professional
2. Incident Response Professional
3. Both
4. Neither

The survey remained live, allowing respondents to submit responses, until 4/17/2017.[2]

Survey Data Review

The authors received a total of 206 responses submitted via the survey link, with the last response submitted on 4/6/2017.

Vocational demographics. Of the 206 total respondents: 120 described themselves as DF Professionals, 18 as IR Professionals, 66 as Both, and two as Neither. Stated another way, 204 respondents described themselves as DF/IR professionals (i.e., either DF Professionals, IR Professionals, or Both).

[2] No technological means (e.g., IP, MAC, or email address screening) was used in an attempt to prevent multiple survey responses from being submitted by the same respondent. However, while the authors could think of no reason why respondents would want to submit the survey multiple times, answers from all responses were screened manually in an attempt to identify any duplicate responses likely submitted by the same person. None were found.

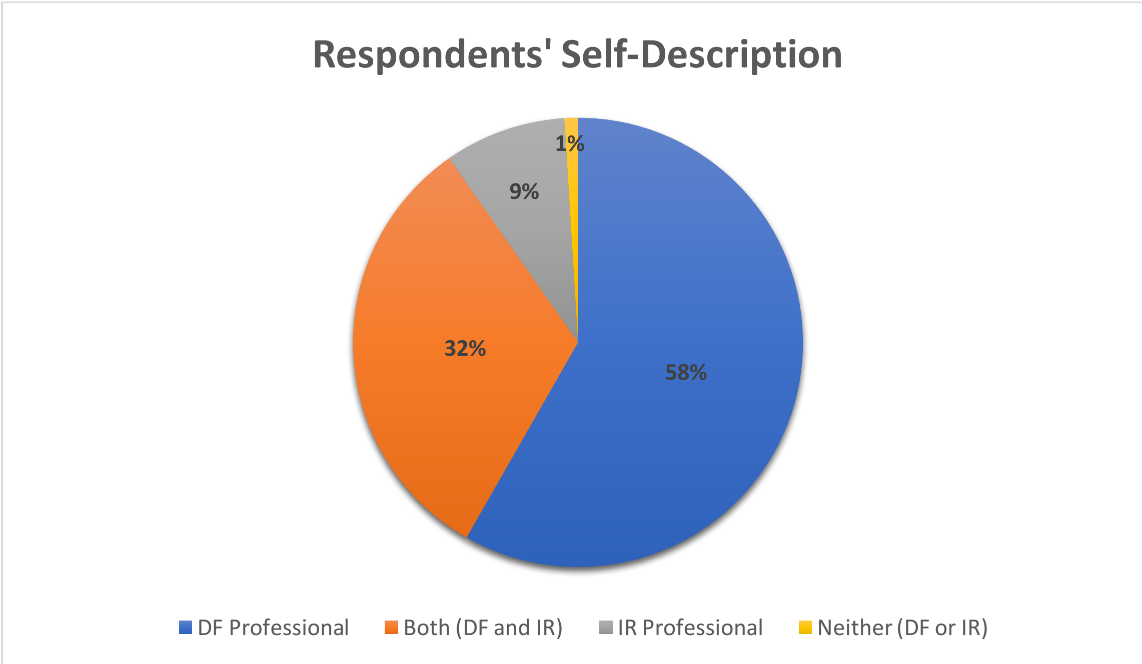

Figure 1. Proportional breakdown of how all 206 respondents described themselves

When asked to state how long they had been a DF/IR Professional, the subgroup of 204 (described above) provided responses (multiple choice) in the following proportion:

- 0-2 years: 25 respondents (12%)
- 3-5 years: 40 respondents (20%)
- 6-8 years: 43 respondents (21%)
- 9-11 years: 25 respondents (12%)
- 12-15 years: 30 respondents (15%)
- 15+ years: 37 respondents (18%)
- I was there for the UNIX epoch:[3] 4 respondents (2%)

The distribution appeared somewhat evenly spread; however, the majority of respondents (110) stated they had been practicing their DF/IR profession for eight years or less.

Musical participation. When asked whether they "practice or perform music regularly (e.g., play a musical instrument, sing in a choir or band, etc.)," 99 respondents answered "Yes" and 104 respondents answered "No" (with two respondents not providing any answer). When

[3] The "UNIX epoch" is the number of seconds that have elapsed since 00:00:00 GMT, January 1st, 1970 (not counting leap seconds). As such, the UNIX Epoch is said to have started on that date and corresponds with a UNIX time value of "0".

adjusted to exclude the two respondents that previously characterized themselves as neither a DF nor an IR professional, the distribution of those self-described DF/IR professionals that “practice or perform music regularly” was:

- Yes: 97 respondents (48.5%)
- No: 105 respondents (51.5%)
- No Answer Given: 2 respondents (1%)

Normative data. The authors felt this distribution was remarkable; however, in order to create a meaningful comparison, the authors sought normative data detailing the distribution of musical avocations among the general public (in the U.S. and globally). Unfortunately, such data proved somewhat difficult to find.

Some seemingly relevant information was available via data vendor website Statista.com. According to that site, the number of people playing a musical instrument[4] in the U.S. increased gently over time, from 15.74 million people in 2002 (roughly 5% of the U.S. population that year) to 18.08 million people in 2010 (roughly 6% of the U.S. population that year) (“Number of people playing a musical instrument…”, n.d.). Getting more specific, Statista.com further reported on the share of U.S. adults (240.3 million total) playing a musical instrument in the U.S. in 2012, broken down by age group; the age group with the highest percentage of adults that year playing an instrument was “18- to 24-year olds” but, even then, the proportion was only 20.6% of people in that age group (and was over 8% higher than the proportion of those in the next closest age group) (“Share of adults playing a musical instrument…”, n.d.). Some comparison data from England was likewise available via Statista.com, which showed that, in 2015/2016, the

[4] It was unclear to the authors whether Statista.com (or the other sources of the statistics cited herein) included or considered “voice/singing” in their definition of “musical instrument” for the purposes of their data collection, as the authors did in their survey. However, as discussed in the below “Focused Analysis” section, only one respondent to the authors’ survey (out of 206 total) stated that they considered themselves a musician by virtue of voice or singing alone (to the exclusion of any other instrument).

percentage of the adult population in England[5] that had played a musical instrument in the last year (for their own pleasure) was only 10.1% ("Share of adults who played a musical instrument…", n.d.). Finally, data was located at Statista.com that showed the percentage of U.S. adults in 2012 who reported they had taken at least one music lesson or class in their lifetimes was only 35.6% ("Share of adults taking a music lesson…", n.d.). These statistics appear compelling on the surface, and are certainly relevant to the authors' argument; however, it must be noted that the data are provided by Statista.com without much context or information regarding their original source or method of collection.

Most other statistics located by the authors were provided by music industry or music trade groups, with some seeming to diverge from the proportions reported by Statista.com. For example, The Associated Board of the Royal Schools of Music (ABRSM; a registered charity and music examination board based in London, U.K.) published a breadth of statistics (based on very large sample sizes) in their 2014 "Making Music: Teaching, learning, and playing in the UK" research report, which appeared to show that playing music is much more prevalent in the U.K. than may have been assumed. The research report stated that 34% of U.K. adult respondents (~17.2 million people) reported currently playing a musical instrument, while 49% reported they were either currently taking (5%; ~2.5 million U.K. adults) or had formerly taken (44%; ~22.2 million U.K. adults) music lessons or school music classes (Associated Board of the Royal Schools of Music [ABRSM], 2014).

In another example, between 2005 and 2009, the National Association of Music Merchants (NAMM) and the International Music Products Association funded telephonic polls in the U.S., Australia, the U.K., and Germany, which produced the following results.

---

[5] According to a 2011 Census in the United Kingdom, the total population of England that year was ~53 million people. However, no reliable data could be found regarding what proportion of those ~53 million were adults.

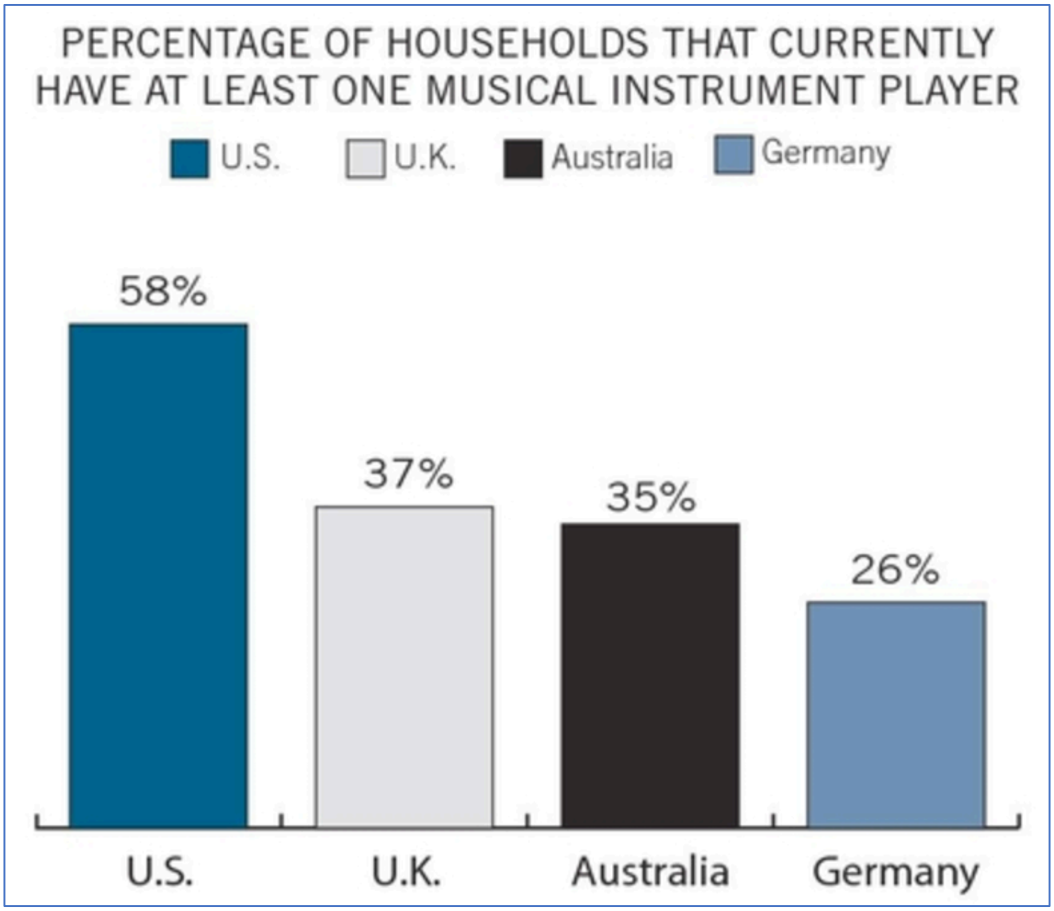

Figure 2. Comparison of U.S. (2009), U.K. (2005), Australian (2007), and German (2008) household musical instrument use (National Association of Music Merchants [NAMM], 2011, p. 212)

Interestingly, NAMM's explanation of the above graph in their report stated, "… more than half of the U.S. population play musical instruments" (NAMM, 2011, p. 212). However, that conclusion does not appear to be supported by their collected data, as "58%" represents the proportion of *households* (and then, just those participating in the Gallup Poll) that reported having at least one musical instrument player; however, the data are likely not an accurate accounting of the total *individuals* in those households that play instruments. Apart from the seemingly spurious conclusions drawn in the report, the statistics reported by NAMM were broad and product-focused, and thus produced more questions for the authors than they answered (e.g., What was the average size of the households polled; and, How many of those found to play instruments were adults, as contrasted with the number of child musicians in the household?).

Perhaps the most reliable normative data source located by the authors was a U.S. Census Bureau (2011) report, which showed that (of the total U.S. adult population in Fall 2009, ~225.9 million people) approximately 17.8 million American adults (or, only about 8%) reported having played a musical instrument within the last year.

Focused analysis. Despite the fact that specific, relevant (and verifiably reliable) normative data regarding musicians in the general population was somewhat scarce, the authors considered their survey findings quite remarkable. Discounting the dubious NAMM (2011) report conclusions regarding its "58%" finding, most of the other relevant statistics cited (from Statista.com, ABRSM, and the U.S. Census Bureau) at least seemed to suggest that the percentage of adults in the general population that play musical instruments is somewhere between 6% (at the low-end estimate) and 34% (at the high-end estimate), with the true number likely being somewhere in the middle. Further, the authors felt the strength of the U.S. Census Bureau (2011) finding that, in 2009, the true percentage of adults in the U.S. who had recently played a musical instrument was only ~8% should not be overlooked, due to the considered reliability of this source in comparison with others.

When viewed in comparison to the normative data above, the 48% of DF/IR professionals that reported playing a musical instrument in the authors' research survey seemed to be *substantially* higher than the proportion in the population at large.

The authors' conclusions are far from definitive, as there is too much uncertainty surrounding the actual number of musicians in the general population, but the survey data suggests more than a casual relationship between being a DF/IR professional and playing a musical instrument. At a minimum, the authors' survey results make it clear that more focused, scientific efforts should be undertaken in an attempt to illuminate a more solid direct relationship. As behavioral geneticist and statistician Joseph P. Hegmann was fond of saying, "Correlation doesn't equal causation, but when you see correlation, it's sure worth taking a harder look" (J. P. Hegmann, personal communication, November 30, 2011).

Additional discussion & possible explanations. If the authors assume the accuracy of their conclusions, based on the above findings, then another question would logically follow: Are there possible explanations for the higher percentage of musicians among DF/IR professionals than in the general population?

While DF/IR professionals can possess a wide range of different skills and specialties, those that are successful in these fields often share certain characteristics. For example, they tend to have minds with a scientific bent, they are tenacious with generally inquisitive natures, and they are critical thinkers (Siewert, 2015). This is not surprising, as they are practitioners of the forensic and computer sciences on a regular basis, called upon to seek answers, formulate and test hypotheses, innovate, solve problems, and continually adapt and learn. Members of both professions could fall into one or more categories of scientists (such as "Investigator Scientist" or "Technician Scientist") as defined by groups like The Science Council (2017). The authors, therefore, found utility in viewing DF/IR professionals as scientists for the sake of this discussion.

However, that is not to say that successful DF/IR professionals are not also in touch with their creative (some might say, "scientifically creative") sides. Wiles, Reyes, and Varsalone (2011) put it succinctly when they wrote:

> The investigative process is more than a rigid set of procedures. Intuition and creativity play as great a role for the forensic examiner as do sound methodologies. Fact finding in

> a wildly diverse technological realm requires a great degree of technical prowess as well as a flexible mind; forensic examiners often must be artisans of technology creation and deconstruction. Raw technology skill does not empower the investigator to understand the interaction of man and machine: intuitive awareness of how the tools of technology and human nature, human thought processes, and human frailties interact allows for much of the artistry and creativity of forensic investigation to be revealed. (p. 15)

There is a host of research relating science (specifically, those engaged in scientific professions and scientific creativity) and creative pursuits. For example, the authors of the aforementioned Root-Bernstein et al. (2008) study analyzed their collected data on high-achieving scientists in numerous different ways, all of which showed "… very significant relationships between success as a scientist and evidence of adult arts and crafts avocations" (p. 53). Further, their data suggested that "… successful scientists accrue a wider range of skills… than the average person or the average scientist" (p. 54). Chamorro-Premuzic & Furnham (2005) and McRae (1987) were cited by Root-Bernstein et al. (2008) as establishing a strong correlation between demonstrated creativity and openness to experience, placing it in a domain characterized by Goldberg (1993) and McRae & John (1992) as requiring "… an unusual degree of curiosity, desire for learning, problem solving, and a desire to think carefully about ideas" (as cited in Root-Bernstein et al., 2008, p. 60).

Nobel Laureates in the study were found to be at least two (and as many as 18) times more likely to be practicing musicians, composers, or conductors than other members of the U.S. public. Specifically, Root-Bernstein et al. (2008) found that physical scientists, in particular, were drawn to music, avoiding most other arts (such as poetry and theater). The study concluded that "… probabilistically speaking, it is noteworthy that increasing success in science is accompanied by developed ability in other fields such as the fine arts" (Root-Bernstein et al., 2008, p. 56). Ramon y Cajal (1951) even went so far as to say that the phenomenon of scientists exploring seemingly unrelated fields (such as music) and integrating them into their core of scientific creativity is necessary for their success (as cited in Root-Bernstein et al., 2008).

It is also likely that successful computer scientists (and scientists in general) are drawn to music because there are parallels between the practices. These parallels allow scientists to create networks of enterprise, or integrated activity sets, "… to connect the knowledge and skills gained thereby… that can be brought effectively to bear in raising and solving important scientific problems" (Root-Bernstein et al., 2008, p. 56). Root-Bernstein et al. (2008) further pointed out that American astronomer and National Academy of Science member Jesse Greenstein asserted musical problems could most definitely inform scientific problems. They provided numerous other examples, such as Boris Chain and Charles Martin Hall (who both proclaimed that playing their instruments led to scientific inspirations), American physicist Richard Feynman (who used "acoustic images" to solve scientific problems), and even Albert Einstein (who played whenever he reached a mathematical "dead end" and credited much of his Theory of Relativity to "musical perception") (p. 59). It was likewise noted that a very large number of modern composers have science and engineering backgrounds, for which Root-Bernstein et al. (2008) cited nine specific examples.

From a more specific (and perhaps more practical) perspective, it does not take much imagination to see direct correlations between areas in which DF/IR professionals should be proficient and music. For example, some skills would seem to translate directly from one to the other, such as pattern matching and problem solving, or conversion between standard units and coding languages (i.e., converting between decimal and hexadecimal numbers, or from PHP to Perl, is not unlike transposing a piece of music from the Key of G to the Key of C on the fly when playing music with others). Other skill areas are a little more esoteric but no less important, such as the ability to multitask, resiliency in the face of mistakes, and flexibility to adapt to unforeseen changes (MacLain, 2011). And, both pursuits need a great deal of practice, requiring an understanding of how to practice correctly, in order to start really getting better (Kageyama, 2012; MacLain, 2011).

Finally, it is worth noting that many readers might immediately jump to the conclusion, as the authors initially did, that having a greater openness to new experiences, showing more creativity as a scientist, and possessing a wider array of creative interests than less successful scientists or the general public is purely a function of general intelligence (e.g., high IQ). It stands to reason that scientists with higher IQs would "just plain be smarter" and, therefore, more successful. However, Root-Bernstein et al. (2008) went out of their way to cite evidence [Cole & Cole (1973); MacKinnon & Hall (1972); Roe (1966); Root-Bernstein, Bernstein, & Garnier (1993)] that showed any such assumption would likely be wrong. They argued, based on their research, "Eminent scientists do not differ in IQ (as measured by various tests) from their less-successful colleagues" (Root-Bernstein et al., 2008, p. 60). Furthermore, Terman (1954) was unable to find any relationship between creativity and high IQ (as cited in Root-Bernstein et al., 2008). These findings reinforce the authors' conclusion that it is the confluence of science and creative pursuits (such as music) that more contributes to scientific achievement, rather than the converse (i.e., one's level of intelligence being responsible for their engagement – or success – in both science and their artistic avocation).

Other survey results. Apart from the excerpted results discussed above, which are important to the authors' conclusions but represent only three of the 13 total questions asked, survey respondents provided a great deal of other interesting information.

For example, when asked which discipline (i.e., DF/IR or music) they began practicing first, the 99 (out of 206 total) respondents who characterized themselves as musicians answered (multiple choice) in the following proportion:

- DF/IR: 16 respondents (16%)
- Music: 81 respondents (82%)
- No Answer Given: 2 respondents (2%)

When asked how long they have been engaged in their musical avocation, the same subgroup group of 99 respondents answered (multiple choice) in the following proportion:

- 0-2 years: 7 respondents (7%)
- 3-5 years: 6 respondents (6%)
- 6-8 years: 7 respondents (7%)
- 9-11 years: 5 respondents (5%)
- 12-15 years: 13 respondents (13%)
- 15+ years: 59 respondents (60%)
- No Answer Given: 2 respondents (2%)

In contrast to the data related to how long respondents had been practicing DF/IR (i.e., a majority [~53%] stated they had been practicing DF/IR for eight years or less), an overwhelming majority of respondents (~78%) stated they had been practicing their musical hobby for nine years or more (with approximately 60% saying they had been playing for 15 or more years).

When asked how many instruments they played, the same subgroup of 99 respondents answered (multiple choice) in the following proportion:

- 1: 22 respondents (23%)
- 2-3: 51 respondents (52%)
- 4-6: 18 respondents (18%)
- 7-9: 2 respondents (2%)
- 10+: 2 respondents (2%)
- Voice Only: 1 respondent (1%)
- No Answer Given: 3 respondents (2%)

When asked about type of instrument, the same subgroup of 99 respondents was allowed to provide a free-form response (which permitted more than one answer) regarding which instrument(s) they were able to play. The authors reviewed all of the responses and placed them into the following categories (by the total number of respondents that gave an answer – or portion of an answer – that fell into each category):

- Voice/Sing: 38 respondents (38%)
- Guitar: 53 respondents (54%)
- Bass (Electric or Upright): 22 respondents (22%)
- Piano/Keyboard: 27 respondents (27%)
- Drums/Percussion: 21 respondents (21%)
- Bowed Strings (Fiddles/Violins/Cellos/etc.): 9 respondents (9%)
- “Other” Strings (Banjos/Mandolins/Ukuleles/etc.): 15 respondents (15%)
- Brass Instruments (Tuba/Trumpet/Trombone/etc.): 14 respondents (14%)
- Woodwind Instruments (Flute/Clarinet/Saxophone/etc.): 14 respondents (14%)
- Harmonicas and Whistles: 13 respondents (13%)
- No Answer Given: 3 respondents (3%)

While the majority of respondents in the subgroup claimed to play the guitar (54%), there were several other unique responses. Among the answers to this question that the authors found most interesting were those given by respondents that stated they played the bagpipes, the tin whistle, the Irish whistle, the accordion, the xylophone, the marimba, or the melodica. One respondent even stated he or she played music via performing as a mixing/sound technician.

When asked whether or not (or, in what way) they played using written (visual) music notation, the same subgroup of 99 respondents answered (multiple choice) in the following proportion:

- By ear (i.e., no use of written music): 13 respondents (13%)
- Using written music: 16 respondents (16%)
- Kind of Both (e.g., using just written chord notation): 26 respondents (27%)
- Both (i.e., by ear and with written music): 17 respondents (17%)
- All three (i.e., by ear, using chord notation, and written music): 25 respondents (25%)
- No Answer Given: 2 (2%)

The survey asked the same subgroup of 99 respondents about the genre of music they most liked to play/sing, again allowing them to provide a free-form response (which permitted more than one answer). As with the question regarding which instruments respondents could play, the authors reviewed all of the responses and placed them into the following categories (by the total number of respondents that gave an answer – or portion of an answer – that fell into each category):

- Rock [Classic/Hard/Alternative/Metal/Punk/etc.]: 31 respondents (15%)
- Pop [Top 40/Folk/80s/etc.]: 14 respondents (7%)
- Country/Bluegrass: 6 respondents (3%)
- World Music: 5 respondents (3%)
- Classical/Jazz/Big Band/Instrumental: 15 respondents (7%)
- Techno/Electronic/Dance: 2 respondents (1%)
- Hip Hop/R&B/Rap: 0 respondents (0%)
- Religious/Gospel: 1 respondent (1%)
- Funk/Blues: 7 respondents (3%)
- Multiple Types: 36 respondents (18%)
- Other/Uncategorized/Undetermined: 6 respondents (3%)
- No Answer Given: 83 respondents (40%)

All 206 respondents were asked, “In what ways (if any) do you think engaging in musical pursuits helps your professional pursuits?” The answers (understandably) were varied and (in some cases) extensive, making them difficult to generalize. However, among the responses were the following excerpted answers:

- “… music allows me to shift focus when I'm stuck on problems and completely clear my mind so I can return to them in a better frame of mind for starting over.”

- “… both fields - music and DF – [require] creativity and flexibility of the mind… doing and enjoying music helps to develop and strengthen those attributes.”

- “… doing digital forensics and IR requires some creativity and a natural curiosity to try and find out how things work… the same could be said for music.”

- “Music, first and foremost, is a stress reliever. It makes me feel good, makes me feel like I am creating something worthwhile, and reminds me that the world is not all crime and sickness. Plus, it helps with my ordered, logical thinking that serves me well in my investigations.”

- “Memory maintenance… and organization.”

- “I think it helped me be a more analytical thinker to help me in my digital forensics work today.”

- "Helps with having a creative approach to problem solving."

- "… a mixture of concentration and relaxation. Music refreshes the mind. You can start with fresh energy in new tasks."

- "I play because I like how I feel and how it makes others feel around me."

- "Music tells a story. Your exam should also tell a story. A good exam will have the readers stand up, sing along and whip out their lighters."

Finally, all 206 respondents were asked a question about listening to (rather than playing) music during their forensic examinations. The survey asked, "Does your playlist change depending upon the kind of examination you are working on," and respondents answered (multiple choice) in the following proportion:

- Yes: 47 respondents (23%)
- No: 79 respondents (38%)
- Music is a total distraction during an exam. I prefer quiet: 29 respondents (14%)
- No Answer Given: 51 respondents (25%)

Respondents that stated their playlists changed depending on the type of examination they were conducting provided a variety of reasons why, including:

- They felt that a particular type of music (e.g., classical or trance/techno) was better suited to particular types of tasks (e.g., those requiring deeper concentration or "brain work");[6]

- They felt that a particular type of music (e.g., hard rock or jazz) was better suited to a particular type of case (e.g., child pornography or intrusion examinations);[7]

- They felt that a particular type of music (e.g., high-energy or slower instrumental) was primarily dictated by their mood (e.g., manic or pensive) or the time of day (e.g., morning or evening).[8]

[6] This was the most common answer.
[7] This was the second most common answer.
[8] This was the third most common answer.

In summation, the authors feel the above findings (along with their analyses and related discussion) are intriguing, certainly warranting follow-up and additional study. And, while the findings help answer the authors' original research question ("Is there actually some correlation between being a musician and a successful DF/IR professional and, if so, why?"), their second question ("… beyond any mere observable correlation, could music be used by those in the DF/IR field to positive professional effect?") must still be addressed.

Music as a Tool for DF/IR Professionals

Challenges Facing DF/IR Professionals

Digital forensic examination, in most cases, is not an activity for the faint of heart. And, while examiners face a myriad of technical issues and obstacles (forcing them to be part investigator, part IT guru, and part problem-solver) on a daily basis, they must also find a way to deal with the sometimes less tangible effects that accompany often high-stress and mentally abusive tasks. John Irvine (2010) penned a particularly apt description (published first on his own, now-defunct website, and later reprinted by *Forensic Focus*) of what being a digital forensic examiner is like:

> Sure, the title varies by job and location — digital forensic analyst, media exploiter, computer forensic investigator — but the job is always the same. Computer forensic examiners delve deeply into computers that have either been the victim, instrumentality, or witness to a crime. It's not at all like what you see on "CSI." Computer forensics can be tiresome, dreary, boring, and downright drudgery. Performing a competent analysis can take days, weeks, or even months depending upon the subject, the condition and state of the hard drive, or the importance of the case. For that time period, the examiner is literally trying on the subject's life, wearing it like a costume for eight or more hours a day. Everything someone likes, hates, is interested in, fantasizes about, or fetishes goes through his or her keyboard at one point or another. Think about every email message you've ever written…every chat you've ever typed…every website you've ever visited…every phrase you've ever searched for online. (para. 1) Now think about me reading and seeing it all. (para. 3)

Criminologists Holt and Blevins (2011) conducted a study at Michigan State University that found digital forensic examiners also experience stressors ranging from understaffing and budget cuts, to employers that do not really understand the examiners' role. "It turns out, [examiners'] levels of stress are directly tied to role conflict where they have different demands on their time and unclear standards for completing a task" (as cited in Michigan State University, 2011, para. 9).

Incident responders deal with somewhat different stressors (though, it should be noted, many also engage in forensic examination as part of their roles), and their jobs can take a similar toll. NCR Corporation's Product Management Director Lenny Zeltser put it rather plainly, in a recent *TechTarget* article, when he was quoted as saying, simply, "… most incident response scenarios can be classified as stressful" (Richards, 2016, para. 13). Another IR professional put it a slightly different way:

> You ever play that game when you were a kid, called 'Which is Worse?'. You think of two terrible alternatives and then you have to choose one of them - whichever seems least bad to you. Being Incident Commander for a complicated IR engagement is basically encountering a new game of 'Which is Worse?' every five minutes until the engagement is complete - but it isn't theoretical, it's business decisions. (M. Linton, personal communication, May 1, 2017)

Such stress, then, is understandable, with incidents like data breaches having the potential to cause government organizations and private companies unwanted public embarrassment and potentially millions of dollars in employee labor and lost revenue; it was estimated that the compromise of the U.S. Department of Veterans Affairs cost at least $25 million to deal with, while estimates put the total cost of the Sony hack in 2011 at around $2 billion (Miller, 2011). In the IR community, it is well known that such pressures, often combined with combatting a "faceless" and better equipped adversary, can lead to frustration and burnout (Ragan, 2014).

The authors know, from experience, the difficulties inherent in dealing with DF/IR stress, which, when combined with exacerbating factors (e.g., “full brain” – when you feel you could not possibly learn anything new without losing something older; feeling disconnected from friends, family, and others outside the profession; or feelings of apathy, tiredness, depression, and/or loss of the ability to concentrate), can be hard to overcome. There is no magic pill to make DF/IR professionals immune to these stresses and related conditions. However, developing and implementing successful mitigation strategies can be vital to a DF/IR professional’s mental health (Siewert, 2015). Going further, the authors posit that learning to play a musical instrument is not only an extremely effective way to deal with the rigors and stresses of DF/IR, but that it could also have positive effects on DF/IR professionals’ long-term career success.

Music and Mental Health

American music legend “T Bone” Burnett said, in a recent keynote speech on the value of art and the artist, “Music confounds the machines” (as cited in Chandler, 2016, para. 29). Taken in context, the authors interpreted Burnett’s statement to mean that music is an expression of feeling and emotion, made by things with a “soul,” ultimately something of which (in his opinion) machines were not capable. Applied more broadly, however, Burnett’s statement can be interpreted to mean that music (and, more specifically, making music) is something gloriously “human,” as essential to our identity as a species as forming social groups and working for a collective good. While Burnett was obviously speaking from his experience, research has shown that he may not be that far off.

While the question of why humans make (and listen to) music has never been definitively answered, researchers have found that there are aspects of it that are both biological and sociological in nature. In Huron’s (2003) work entitled “Is Music an Evolutionary Adaptation?”, he presented evidence that led him to theorize:

> Music might have originated as an adaptation for social bonding – more particularly, as a way of synchronizing the mood of many individuals in a large group. That is, music helps to prepare the group to act in unison. … brain structures related to music are linked to social and interpersonal functions… (p. 68)

He further discussed research regarding the body's release of oxytocin (a hormone closely related to child birth, sexual orgasm, and other human and animal bonding circumstances) when a person listens to or makes music. Huron concluded that if such research is accurate (which he believed it was), it has "important repercussions for instances of peer-group bonding and social identity" (p. 71).

In her related work, "Brain Specialization for Music: New Evidence for Congenital Amusia," Peretz (2003) argued that biological theories regarding the foundations of music for humans have justly gained recent legitimacy. She reviewed evidence, among which was the discovery that certain human brain structures seem to exist because of and are dedicated to music, in concluding that, "Music seems to serve needs that are so important to humans that their brain has dedicated some neural space to processing it" (p. 201). A host of other neurological research has been done, enabled by advances in brain imaging technologies, that has underpinned recent biological theories regarding music and the brain, validating (or, at least, supporting) Peretz's and others' key conclusions (Parsons, 2003; Altenmüller, 2003; Suomen Akatemia, 2011; Honing, ten Cate, Peretz, and Trehub, 2014).

It stands to reason, then, that if music has both a sociological and biological basis, it could potentially have the power to affect (and be affected by) things such as mood, stress, fatigue, or clinical depression. Research cited by Huron (2003) showed that humans may be inherently aware of the power of music to affect mood. In one study, 47% of respondents said they used music to eliminate or temper a bad mood; in another, 41% stated they used music to increase their energy and alertness levels; while in yet another, 53% said they used it to reduce nervousness, tension, or anxiety.

These results are not surprising, considering the observed neurological effects of music on the brain. As an example, researchers at the Academy of Finland "… found that music listening recruits not only the auditory areas of the brain, but also employs large-scale neural networks" (Suomen Akatemia, 2011, para. 4). One of the study's researchers, Professor Petri Toiviainen, stated, "Our results show for the first time how different musical features activate emotional, motor and creative areas of the brain" (as cited in Suomen Akatemia, 2011, para. 5). Other findings have suggested that music enters the mind through the brain stem, which some neuroscientists have suggested is the root of sentience in humans. Scientists in the Netherlands recently conducted a study wherein they showed test subjects "neutral" faces and asked them to describe whether they thought the faces were happy or sad. They found that subjects who viewed the faces while listening to happier music often felt they were looking at a happy face, while those listening to sadder music more often felt they were looking at a sad face (Bergland, 2012).

As the authors previously discussed, DF/IR professionals are often subjected to negative stimuli in the form of stressors inherent in their jobs. These stressors can have a significant negative impact on mood and even manifest in more serious psycho-medical conditions. As Siewert (2015) pointed out, "The almost inevitable fallout from working these positions is some sort of psychological damage, most commonly referred to as Post-Traumatic Stress Disorder or PTSD" (para. 3). The effects of long-term exposure to these negative stimuli have just recently begun to be recognized and serious research will likely be undertaken to further explore the links between DF/IR and mental health. However, it is clear to the authors that, in the interim, developing strategies to deal with these conditions is vital to DF/IR professionals' mental health and long-term professional viability.

Listening to (and, particularly, playing) music could be used to help DF/IR professionals mitigate the effects of regular exposure to stress and negative stimuli. The American Psychological Association (APA) recommends strategies such as developing healthy responses to stress, taking time to recharge, and learning how to relax (American Psychological Association, 2017). Google Inc., a prominent international employer in the Tech industry, has taken this advice to heart and finds it so essential to long-term employee health that it carved out formal spaces, such as music-equipped "dark pods" and an entire multi-story building stocked with musical instruments and rehearsal spaces for the use of its employees, as well as providing reimbursable on-site music lessons with professional instructors (M. Linton, personal communication, May 1, 2017).

Suchinskas (2010) suggested a more direct link between making music and reducing stress:

> …casual music-making can short-circuit the stress response, research shows, and keep it from becoming chronic. Researchers now know that playing a musical instrument can switch off the stress response, improving physical and emotional health. Studies showing the de-stressing benefits of music-making are piling up: It reduced the prevalence of burnout in nursing students and long-term care workers… (p. 1) It does take time for the benefits of music-making to create lasting changes in your cells. Studies have found that playing an hour a week for six weeks can lower the stress response. (p. 2)

Even more promising is recent research that has specifically focused on using musical instruments and music lessons as a clinical treatment for PTSD (a condition to which many DF/IR professionals are susceptible). In one example, Guitars for Vets, a nonprofit organization started in Milwaukee, Wisconsin, in 2007, spearheaded efforts to reduce PTSD symptoms for afflicted military veterans using music instruction, with very promising results. An initial study found that the program was successful in reducing PTSD symptoms (in particular, helping veterans ward off depression) and improving quality of life for patients (Sizemore, 2013; U.S. Department of Veterans Affairs, 2014). Patients are referred by their doctors and receive 10 weeks of guitar lessons from volunteer instructors in the program, at the end of which they receive a new guitar of their own with which to keep playing. Participants spoke glowingly about the program, saying that playing music gave them a peaceful feeling and helped them not focus on bad memories (Sizemore, 2013). Durig, one of the volunteer guitar instructors in the program, stated the program's concept and goals most succinctly:

> Learning guitar is an ideal form of therapy because of the demands it places on the student. This kind of musical training causes the two sides of the brain to talk to each other – the left, the logical side, and the right, the creative side. [Music] is one of the few disciplines that requires you to use both. The object isn't to make [a participant] a famous guitar player. The object is to make him happy. That is a good enough goal in itself. (Sizemore, 2013, p. 3)

Making music can also be used as a form of meditation, for relaxation and stress relief. Mark Nauseef (n.d.), a musician and percussionist (who has played with the likes of The Velvet Underground, Ronnie James Dio, Thin Lizzy, and Andy Summers of The Police) wrote on his website about playing music to reach a state of "intense but relaxed concentration" that allows a person to reach "… a sanctuary within yourself were[sic] you can go which is away from or outside your normal state of active mind" (para. 1). He compared it to yoga, using music as the point of awareness or object of the meditation.

Music Builds Brain Plasticity

In addition to potentially being a crucial support for DF/IR professionals' mental health and well-being, exciting research has also shown making music can improve brain plasticity, which is a concept intimately linked to the authors' previous discussions of high achieving scientists and their musical (creative) avocations. In his work entitled "The Brain that Makes

Music and is Changed by It," Alvaro Pascual-Leone (2003) defined plasticity as an "… experience-dependent modification in neural structure…" (p. 397). Put another way,

> Plasticity is a fundamental organizational feature of human brain function. This brain plasticity underlies normal brain development and maturation, skill learning and memory, recovery from injury, as well as the consequences of sensory deprivation or environmental enrichment. (Wan & Schlaug, 2010, p. 566)

The precise neurological reasons (and research underpinnings for) why playing music can increase brain plasticity are legion and a bit complex to explore in great depth within the scope of this paper.[9] However, the authors wish to highlight a few key findings that have particular relevance to this discussion.

Numerous studies have shown that practicing music (such as piano) is a reliable way to enhance the structure of the brain's white matter (i.e., subcortical tissue connecting grey matter, which contains nerve fibers rich in myelin, a protein that increases the speed at which nerve impulses are transmitted) (Portland Chamber Orchestra, n.d.). Research has also shown that musicians have larger grey matter (i.e., dense brain tissue made up primarily of neurons) in areas of motor, auditory, and visual-spatial regions of the cerebellum and cortex (Lieff, 2013; Wan & Schlaug, 2010). These advantages can manifest in building new skills, thereby providing non-musical benefits. For example, Root-Bernstein et al. (2008) found that increasing success in science had a positive correlation to developed ability in non-related fields (such as arts and music). They made the point that if one assumed the two general disciplines (i.e., science and creative arts) were independently segregated, then more development in one discipline would likely mean less chance of development in the other; however, they found the reverse was

[9] The authors urge the reader to review the works by Schellenberg (2003), Wan & Schlaug (2010), Herholz & Zatorre (2012), and others listed in this paper's References section for in-depth scientific discussions of the neurology of brain plasticity.

actually true (i.e., there was a direct relationship between development in arts and increased scientific success).

The most remarkable neurological changes resulting from playing music have been noted in the brains of children; however, it has been well documented that adults also experience positive changes in brain plasticity and other positive neurological improvements (if a bit less dramatically than in their younger counterparts) (Lieff, 2013; Wan & Schlaug, 2010). Mental capacities such as perception, performance, and language can all be positively affected by playing music, increasing brain efficiency and requiring fewer neuronal units to encode information, even into old age. In addition, musical training has been found to decrease memory loss over a lifetime (Lieff, 2013). Wan and Schlaug (2010) concluded that "… musicians appear to be less susceptible to age-related degenerations in the brain, presumably as a result of their daily musical activities" (p. 8), which could give hope to those with a family history of dementia, Alzheimer's Disease, and related maladies.

Further, playing music was uniquely found to increase metaplasticity in adults, which is "… a brain change from training that allows efficient learning and plasticity in other areas than the primary training" (Lieff, 2013, p. 5). Some researchers have theorized that this metaplasticity arises, in part, from positive transfer, a process by which "… previous experience in problem solving makes it easier to solve a new problem, typically by accelerated learning" (Schellenberg, 2003). This idea is echoed (in practical implementation) by Kageyama (2012), who essentially proposed a problem-solving model (based on the familiar Scientific Method) as a technique for getting the most out of his musical practice time. It was noted, however, that while changes in adult brain function can be scientifically observed and measured after as few as three hours of music practice, the practice must continue in order to avoid the reversal of short-term changes (Lieff, 2013).

With regard to the positive effects of music on brain plasticity, the authors wish to highlight a distinction, at this point, between playing music and merely listening to music (which was previously discussed as having a large – potentially positive – effect on mood). There has been a somewhat recent tendency (particularly among the media and the general public) to summarize existing research relating music and the brain as “music makes you smarter.” This is, in large part, due to a study published by Rauscher, Shaw, and Ky (1993), which reported to show that a 10-minute exposure to Mozart led test subjects to perform significantly better (temporarily) on spatial-reasoning tasks (in comparison to two other control groups, which listened to a relaxation track or to silence for the same period); the phenomenon became known as the “Mozart Effect,” named after the composer of the sonata to which the subjects listened (Schellenberg, 2003).

It was theorized that exposure to Mozart’s sonatas, which are particularly sequential and emphasize rhythm and pitch, affected the brain by putting it in the ideal state to solve spatial-reasoning (sometimes called spatial-temporal reasoning) problems. The findings caused quite a stir, as spatial-reasoning is associated with tasks such as successfully theorizing and strategizing (such as in chess, when the most successful players think many moves ahead). More broadly, spatial-reasoning is key in particular mathematical and scientific subject areas, such as geometry and calculus, which require the writing of mathematical proofs and the transition and transformation of shapes or figures in space-time (Zhan, 2008).

Attempting to relate math and music, on both practical and neurological levels, is not without precedent. For example, the philosopher Pythagoras (known for his keen mathematical and geometrical observations) famously stated, “There is geometry in the humming of the strings, there is music in the spacing of the spheres” (as cited in American Mathematical Society, 2017, para. 1). In another example, a group of researchers recently used advanced brain imaging technologies to show that, “People who appreciate the beauty of mathematics activate the same part of their brain when they look at aesthetically pleasing formulae as others do when appreciating art or music” and suggested a neurological tie between the two very different intellectual expressions (Weston, 2014, para. 1).[10]

The Rauscher, Shaw, and Ky (1993) study captured the public’s attention; who would not be excited by the prospect that listening to classical music could make them smarter (or better at math, at least)? The Governor of Georgia at the time, Zell Miller, even went so far as to use public funds to purchase classical music CDs to be given to the mother of each newborn baby in his state. Similarly, Florida mandated that listening to classical music be a part of everyday instruction in all state-run preschools (Schellenberg, 2003).

The authors would never argue that additional exposure to classical music (at any age) is a bad thing; as they have previously discussed, just listening to music does have numerous potential positive effects on mood, etc. However, while the results of the Rauscher, Shaw, and Ky (1993) study are intriguing on the surface, most subsequent attempts to validate their conclusions have failed. Schellenberg (2003) neatly encapsulated the current scientific view of the Mozart Effect:

> Closer examination of the method of Rauscher et al. raises questions about the validity of their findings. The choice of comparison conditions is particularly problematic. Sitting in silence or listening to a relaxation tape for 10 min is less arousing or interesting compared to listening to Mozart. Moreover, mood-states are known to influence performance on problem-solving tasks, with superior performance associated with

---

[10] The study found that Leonhard Euler’s identity ($1 + e^{i\pi} = 0$), “which links five fundamental mathematical constants with three basic arithmetic operations each occurring once” was found to be the most ‘beautiful’ mathematical formula (Zeki, Romaya, Benincasa, & Atiyah, 2014, Beauty Ratings section, para. 2).

> positive affect. Thus, the effect could have arisen from differences in arousal or mood rather than from exposure to Mozart. (p. 432) In short, the Mozart Effect is a radical claim about cognitive processes that is difficult to reconcile with known principles and findings in cognitive psychology. It comes as no surprise, then, that attempted replications have produced mixed results. (p. 433)

Despite the fact that the Mozart Effect may not be everything that many originally hoped it would be, a substantial amount of modern research has suggested that playing music (e.g., taking music lessons, practicing regularly, etc.) can have very real long-term side effects. For example, Schellenberg (2003) noted, “Positive associations imply that improving one’s musical ability through formal lessons would be accompanied by non-musical benefits,” such as improvements in domains like language, mathematics, and spatial-reasoning (p. 438). Schellenber’s conclusion (that there is a positive correlation – if not definitive causation – between playing music and associated non-musical benefits) has been supported by a host of other researchers, such as Hassler, Birbaumer, & Feil (1985), Lamb & Gregory (1993), Douglas & Willats (1994), and Gromko & Poorman (2008), just to name a few.

If playing music is truly a way for DF/IR professionals to measurably improve brain plasticity (as the large body of research suggests), it represents some interesting possibilities. DF/IR professionals are forced to constantly learn and adapt to fresh digital technologies, new criminal and threat actor techniques, and advancing investigative and security tools. In short, plasticity (i.e., the brain’s ability to stretch and grow, enabling new information and skills to be more easily learned) is essential to most successful DF/IR professionals. As such, anything that has the potential to support or improve DF/IR professionals’ brain plasticity should be further explored.

Team Building

Being a DF/IR professional can sometimes be isolating. As the authors have already discussed, despite the fact that people in these professions need connection and support more than many others, they often disconnect or withdraw from conventional support systems. Such isolation also might not always be their own doing; as Irvine (2010) put it, "People who only have known me for a short time might find me to be paranoid, disturbed, or even a little deviant" (para. 11). It would not be unusual for potential friends to withdraw rather than choose to engage with someone who presented as "paranoid, disturbed, or even a little deviant." The phenomenon is not unlike that experienced by police officers who (as two of the authors of this paper know full well, having been police officers themselves) sometimes have trouble connecting with others outside their profession, as they are in a constant state of stress, fight-or-flight, which can manifest in ways that contribute to their isolation (Wilson, 2016).

So, if being in a DF/IR profession is so potentially deleterious to meaningful, positive connections with others, how can high-functioning individuals hope to find others with which they can form high-functioning teams? This is an important question, considering that both DF and IR often rely on functional, effective teams to realize effective task completion. For example, in his article pertaining to IR personnel burnout, Ragan (2014) quoted the Motorola Solutions Security Operations Center (SOC) Incident Response Team Lead, Lesley Carhart, who pointed out,

> Incident responders and handlers need to coordinate their efforts… (para. 13) While the first thought under stress can often be to lash out at nonresponsive teams, it is very likely in most incident response roles that we will interface with the same people repeatedly. We should never burn bridges. Another tip is to make good connections… (para. 15)

Ragan supported the idea that this type of team building can reduce stress and make all related functions more successful (and sustainable).

The secret to the type of team building described by Ragan (2014) may lie in building community and connections through non-professional interests and hobbies. In addition to bringing colleagues together to effectively tackle professional tasks, creating such connections can have the added benefit of limiting general feelings of isolation that can be caused by such stressful work. In his blog post entitled "5 Reasons Everyone Should Have a Hobby," Howell (2014) asserted that hobbies provide opportunities for creativity not always presented in the workplace, help participants build confidence together that can translate back to their professions, reduce negative stress, and allow participants to socialize via a mutually enjoyable activity. Apart from building effective teams, Howell also clearly supported the idea that being well-rounded as an individual (and developing skills outside of strict professional settings, via a hobby) correlated directly to longer-term career success.

The authors know first-hand that playing music is an excellent way to not only build individual skills that can be translated to the DF/IR professions (as previously discussed) but also build effective teams and foster a sense of community among colleagues. As previously argued, DF/IR professionals may be more inclined towards playing music than the general public, making playing music together a natural next-step. In a recent Canadian National Arts Centre (NAC) article, Geneviève Cimon, Director of Music Education and Community Engagement at the NAC, stated music shows that "… how you communicate, how well you listen, how inclusive you are with others can help build a strong community" (as cited in National Arts Center, 2014, para. 5).

Musicians playing together in a group can learn to work together, support each other in success and failure, teach each other needed skills, and feel connected (by beat and rhythm), in addition to elevating their moods and focusing on something other than individual stress. As one psychologist/musician put it:

> Being in close synchrony with others is powerful. When a group is playing well together, there is a joyous feeling of unity, being part of a larger whole instead of a lonely individual. The awareness of one's pitiful individual ego can nearly disappear. I have found that other kinds of creative collaborations have a lot to learn from music groups. (Jolkovski, 2016, p. 1)

Playing together can give all participants the opportunity to experience how a cohesive group can use collective strengths to compensate for individual weaknesses; for example, if one musician frequently fails to play an E chord correctly, but the others can play the E chord consistently, the weakness is rendered non-critical, in a way that it would not be if the musician was playing solo. Such experiences have parallels in high-functioning DF/IR teams, where members with particular expertise in certain areas (e.g., UNIX file system examination, physical memory acquisition, or malicious binary analysis) can compensate for other members who are not as strong in those areas, thereby helping ensure task accomplishment and overall team success.

While it is unlikely that professional DF/IR colleagues who play music together will get so good that they cut a record, leave their jobs, and have to start fighting off paparazzi, the positive benefits for DF/IR professionals that choose to play or jam in a group – even casually – are, in the authors' opinions, too beneficial not to explore. And, hey, the authors can hope!

Conclusion

Via presentation of their survey data and subsequent analyses, as well as discussion of existing research and prevailing theories linking playing music with non-musical benefits, the authors have sought to illustrate the positive effects that music (listening, and especially playing) can have on the human brain and show how those effects can be applied by DF/IR professionals to assist them in their vocations. While playing music is not a panacea or magic bullet for DF/IR professionals, it can be an aid to their skill development and mental health, contributing to their success and quality of life in their personal and professional pursuits. And, as the authors' own research suggested, DF/IR professionals are more likely than the average person to also be musicians, it also seems likely many in the field are already taking advantage of the benefits gained by playing music. However, the authors feel that they have successfully made the argument that every DF/IR professional should consider taking up an instrument, if only to "hack" their own brains.

Additional Research Opportunities

This paper has shown the need for additional research to attempt to establish more definitive causal links, in addition to the existing body of research supporting strong direct correlations, between playing music and the resulting observable psychological, sociological, and cognitive neurological effects.

In addition, research seeking to more particularly apply general existing psychological, sociological, and neurological theories relating music and non-musical effects to particular professions, as the authors have done here with DF/IR, could be beneficial.

Finally, as noted previously, the authors also see the opportunity to repeat this research using instruments and additional experiments (similar to the survey used in their research presented in this paper) subjected to additional, rigorous vetting designed to mitigate the effects of any possible question or sampling bias, as a means of strengthening the basis for conclusions.

References

Altenmüller, E. O. (2003). How many music centres are in the brain? In I. Peretz & R. J. Zatorre (Eds.), *The Cognitive Neuroscience of Music* (pp. 346-353). Oxford: Oxford University Press.

American Mathematical Society. (2017). Mathematics & music. *Math Samplings.* Retrieved from http://www.ams.org/samplings/math-and-music

American Psychological Association. (2017). Coping with stress at work. *Psychology Help Center.* Retrieved from http://www.apa.org/helpcenter/work-stress.aspx

Associated Board of the Royal Schools of Music (ABRSM). (2014, September). ABRSM: 4. The statistics. *Making Music: Teaching, Learning, and Playing in the UK.* Retrieved from http://gb.abrsm.org/en/making-music/4-the-statistics#

Bergland, C. (2012, December 29). The neuroscience of music, mindset, and motivation. *Psychology Today*. Retrieved from https://www.psychologytoday.com/blog/the-athletes-way/201212/the-neuroscience-music-mindset-and-motivation

Chamorro-Premuzic, T., & Furnham, A. (2005). *Personality and intellectual competence*. Mahwah, NJ: Lawrence Erlbaum Associates.

Chandler, S. (2016, September 22). Music confounds the machines. *No Depression: The Journal of Music Roots.* Retrieved from http://nodepression.com/article/music-confounds-machines

Cole, J. R., & Cole, S. (1973). *Social stratification in science*. Chicago: University of Chicago Press.

Goldberg, L. R. (1993). The structure of phenotypic personality traits. *American Psychologist, 48,* 26-34.

Holt, T. J., & Blevin, K. R. (2011). Examining job stress and satisfaction among digital forensic examiners. *Journal of Contemporary Criminal Justice, 27*(2)*,* 230-250. doi:10.1177/1043986211405899

Honing, H., ten Cate, C., Peretz, I., & Trehub, S. E. (2015, March 19). Without it no music: Cognition, biology, and the evolution of musicality. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *370*(1664), 1-8. doi: 10.1098/rstb.2014.0088

Huron, D. (2003). Is music an evolutionary adaptation? In I. Peretz & R. J. Zatorre (Eds.), *The Cognitive Neuroscience of Music* (pp. 57-75). Oxford: Oxford University Press.

Irvine, J. (2010, January). The darker side of computer forensics. *Forensic Focus.* Retrieved from https://articles.forensicfocus.com/2011/07/18/the-darker-side-of-computer-forensics/

Jolkovki, M. (2016, October 4). Why playing music in a group can be so great when it's good and so wretched when it's bad. [Web log]. Retrieved from http://workingthrough.com/blog/260-why-playing-music-in-a-group-can-be-so-great-when-its-good-and-so-wretched-when-its-bad

Kageyama, N. (2012, July 28). The most valuable lesson I learned from playing the violin. *The Creativity Post.* Retrieved from http://www.creativitypost.com/arts/the_most_valuable_lesson_i_learned_from_playing_the_violin

Kuchinskas, S. (2010). How making music reduces stress. *WebMD Magazine.* Retrieved from http://www.webmd.com/balance/stress-management/features/how-making-music-reduces-stress#1

Lieff, J. (2013, February 25). Music training and neuroplasticity. [Web log]. Retrieved from http://jonlieffmd.com/blog/music-training-and-neuroplasticity

MacKinnon, D. W., & Hall, W. B. (1972). Intelligence and creativity. *ProcXVIIth International Congress of Applied Psychology, Liege, Belgium,* (Vol. 2, 1883-1888). Brussels, Belgium: EDITEST.

MacLain, F. (2011, August 13). Is Scottish fiddle like digital forensics? [Web log]. Retrieved from https://forensicaliente.blogspot.com/2011/08/is-scottish-fiddle-like-digital.html?m=1

McRae, R. R. (1987). Creativity, divergent thinking, and openness to experience. *Journal of Personality and Social Psychology, 52,* 1258-1265.

McRae, R. R., & John, O. P. (1992). An introduction to the Five-Factor Model and its applications. *Journal of Personality, 60,* 175-215.

Michigan State University. (2011, May 11). Digital forensic examiners face stress, role-conflict. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2011/05/110511114305.htm

Miller, M. H. (2011, May 4). Data theft: Top 5 most expensive data breaches. *The Christian Science Monitor*. Retrieved from http://www.csmonitor.com/Business/2011/0504/Data-theft-Top-5-most-expensive-data-breaches/1.-tie-Sony-to-be-determined

National Arts Centre. (2014, December 11). How music builds community. *NAC Stories*. Retrieved from https://nac-cna.ca/en/stories/story/how-music-builds-community

National Association of Music Merchants [NAMM]. (2011). People's attitudes towards music: Combined survey comparison. *2011 NAMM Global Report.* Retrieved from http://www.nxtbook.com/nxtbooks/namm/2011globalreport/index.php?startid=167#/212

Nauseef, M. (n.d.). Music practice as meditation. *Articles.* Retrieved from http://www.marknauseef.com/articles/mnmeditation/meditation.htm

"Number of people playing a musical instrument in the U.S. from 2002 to 2010 (in millions)". (n.d.). *Statista: The Statistics Portal.* Retrieved from https://www.statista.com/statistics/192834/people-playing-a-musical-instrument-in-the-us/

Parsons, L. M. (2003). Exploring the functional neuroanatomy of music performance, perception, and comprehension. In I. Peretz & R. J. Zatorre (Eds.), *The Cognitive Neuroscience of Music* (pp. 247-268). Oxford: Oxford University Press.

Pascual-Leone, A. (2003). The Brain that Makes Music and is Changed by It. In I. Peretz & R. J. Zatorre (Eds.), *The Cognitive Neuroscience of Music* (pp. 396-409). Oxford: Oxford University Press.

Peretz, I. (2003). Brain specialization for music: New evidence from congenital amusia. In I. Peretz & R. J. Zatorre (Eds.), *The Cognitive Neuroscience of Music* (pp. 192-203). Oxford: Oxford University Press.

Portland Chamber Orchestra. (n.d.). What happens when the brain plays a musical instrument? *Every Brain Needs Music.* Retrieved from http://portlandchamberorchestra.org/what-happens-when-the-brain-plays-a-musical-instrument/

Ragan, S. (2014, April 30). Avoiding burnout: Ten tips for hackers working incident response. *Security Industry*. Retrieved from http://www.csoonline.com/article/2149900/infosec-careers/avoiding-burnout-ten-tips-for-hackers-working-incident-response.html

Ramon y Cajal, S. (1951). *Precepts and counsels on scientific investigation: Stimulants of the spirit* (J. M. Sanchez-Perez, Trans.). Mountain View, CA: Pacific Press Publishing Association.

Rauscher, F. H., Shaw, G. L., & Ky, K. N. (1993, October 14). Music and spatial task performance. *Nature, 365*(6447)*,* 611. doi:10.1038/365611a0

Richards, K. (2016, March). The incident response process is on the clock. *TechTarget Essential Guide.* Retrieved from http://searchsecurity.techtarget.com/feature/The-incident-response-process-is-on-the-clock

Roe, A. (1966). *The making of a scientist*. New York: Dodd Mead.

Root-Bernstein, R. S., Bernstein, M., & Garnier, H. (1993). Identification of scientists making long-term, high-impact contributions, with notes on their methods of working. *Creativity Research Journal, 6*(4), 329-343.

Root-Bernstein, R., Allen, L., Beach, L., Bhadula, R., Fast, J., Hosey, C., Kremkow, B., . . . Weinlander, S. (2008). Arts foster scientific success: Avocations of Nobel, National Academy, Royal Society, and Sigma Xi members. *Journal of Psychology of Science and Technology, 1,* 51-63. doi:10.1891/1939-7054.1.2.51

Schellenberg, E. G. (2003). Does exposure to music have beneficial side effects? In I. Peretz & R. J. Zatorre (Eds.), *The Cognitive Neuroscience of Music* (pp. 430-448). Oxford: Oxford University Press.

"Share of adults playing a musical instrument in the United States in 2012, by age group". (n.d.). *Statista: The Statistics Portal.* Retrieved from https://www.statista.com/statistics/381509/share-of-adults-playing-a-musical-instrument-by-age-group-us/

"Share of adults who played a musical instrument in the last year in England from 2005/06 to 2015/16". (n.d.). *Statista: The Statistics Portal.* Retrieved from https://www.statista.com/statistics/555767/adults-playing-musical-instruments-uk-england/

"Share of adults taking a music lesson or class during their lifetime in the United States from 1982 to 2012". (n.d.). *Statista: The Statistics Portal.* Retrieved from https://www.statista.com/statistics/195460/participation-in-music-classes-and-lessons-in-the-us-since-1982/

Siewert, P. J. (2015, February 27). Selecting a competent digital forensic examiner. [Web log]. Retrieved from http://prodigital4n6.blogspot.com/2015/02/selecting-competent-digital-forensic.html

Sizemore, B. (2013, December 28). Veterans tap healing power of music in Hampton. *The Virginian-Pilot Online.* Retrieved from http://pilotonline.com/news/military/veterans-tap-healing-power-of-music-in-hampton/article_1616a875-71f1-59ec-bc1b-58fd445e704b.html

Sommer, B. (n.d.). Sampling: Types of samples. *University of California, Davis.* Retrieved from http://psc.dss.ucdavis.edu/sommerb/sommerdemo/sampling/types.htm

Suomen Akatemia (Academy of Finland). (2011, December 6). Listening to music lights up the whole brain. *ScienceDaily*. Retrieved from www.sciencedaily.com/releases/2011/12/111205081731.htm

Suzuki, S. (1969). *Nurtured by love: The classical approach to talent education*. Van Nuys, CA: Alfred Music.

Terman, L. M. (1954). Scientists and non-scientists in a group of 800 gifted men. *Psychological Monographs, 68*, Whole No. 378.

The Science Council. (2017). 10 types of scientists. About *Us.* Retrieved from http://sciencecouncil.org/about-us/10-types-of-scientist/

U.S. Census Bureau. (2011). Section 26: Arts, recreation, and travel. *Statistical Abstract of the United States: 2011.* Retrieved from https://www.census.gov/prod/2011pubs/11statab/arts.pdf

U.S. Department of Veterans Affairs. (2014, January 6). Music therapy program helps relieve PTSD symptoms. *Research News.* Retrieved from https://www.hsrd.research.va.gov/news/research_news/music-010614.cfm

Wan, C. Y., & Schlaug, G. (2010, October). Music making as a tool for promoting brain plasticity across the life span. *Neuroscientist, 16*(5)*,* 566-577. doi:10.1177/1073858410377805

Weston, D. (2014, February 13). Mathematical beauty activates same brain region as great art or music. *University London College News*. Retrieved from https://www.ucl.ac.uk/news/news-articles/0214/13022014-Mathematical-beauty-activates-same-brain-region-as-great-art-Zeki

Wiles, J., Reyes, A., & Varsalone, J. (2007). *Best damn cybercrime and digital forensics book period.* Burlington, MA: Syngress Publishing, Inc. (Elsevier)

Wilson, L. (2016, June 16). 10 realities of being married to a police officer. [Web log]. Retrieved from http://prodigital4n6.blogspot.com/2015/02/selecting-competent-digital-forensic.html

Zahn, C. (2008, January 16). The correlation between music and math: A neurobiology perspective. [Web log]. Retrieved from http://serendip.brynmawr.edu/exchange/serendipupdate/correlation-between-music-and-math-neurobiology-perspective

Zeki, S., Romaya, J. P., Benincasa, D. M. T., & Atiyah, M. F. (2014, February 13). The experience of mathematical beauty and its neural correlates. *Frontiers in Human Neuroscience, 16*(68). Retrieved from https://doi.org/10.3389/fnhum.2014.00068

Appendix A

DF/IR Music Survey

Which of the following best describes you?
1. Digital Forensics Professional
2. Incident Response Professional
3. Both
4. Neither

How long have you been a DF and/or IR professional?
1. 0-2 years
2. 3-5 years
3. 6-8 years
4. 9-11 years
5. 12-15 years
6. 15+ years
7. I was there for the UNIX epoch

Do you practice or perform music regularly (e.g., play a musical instrument, sing in a choir or band, etc.)?
1. Yes
2. No

For how long (i.e., how many years) have you played?
1. 0-2 years
2. 3-5 years
3. 6-8 years
4. 9-11 years
5. 12-15 years
6. 15+ years

(*cont. on next page)

Do you play by ear, using written music, using tabs and/or chord diagrams or all three?

1. By ear - I hear it, I feel it, I play it. I don't want to be constrained by a bunch of dots on paper. "Music? I am a bluegrass player... You're lucky I can read the newspaper!"
2. Using written music - I like to have reference materials available. There are musical rules that should be followed and a right way to play a song. I can sight read and I'm proud of it!
3. Kind of both. I like tabs and chord sheets to give me hints about where things are going, but written music is too formal and hard to follow.
4. Both. I like to express myself in my own way musically, but also appreciate the art, tradition, and structure of written music.
5. All three. It's all good.

How many instruments do you play? (NOTE: Voice is one instrument.)

<short answer text>

What instruments do you play?

<short answer text>

Which did you begin practicing first?

1. DFIR / Computers
2. Musical Performance

What are the top five songs on your playlist (i.e., to listen to) when you do a forensic exam or incident response?

<long answer text>

Does your playlist change depending upon the kind of examination you are working on?

1. Yes
2. No
3. Music is a total distraction during an exam. I prefer quiet.

If yes, please explain why / in what manner.

<long answer text>

When you play music, what is your favorite type to play or sing?

<long answer text>

In what ways (if any) do you think engaging in musical pursuits helps your professional pursuits?

<long answer text>

Appendix B

"Ultimate" DF/IR Playlist

Song/Artist	Song/Artist	Song/Artist
One Night in Bangkok/Murray Head	Livin' on a Prayer/Bon Jovi	Don't Stop Believin'/Journey
Thriller/Michael Jackson	Relax/Frankie Goes to Hollywood	Breaking the Law/Judas Priest
Not Ready to Make Nice/Dixie Chicks	Vidrar Vel Til Loftarasa/Sigur Ros	Silence/Delerium
Ballroom Blitz/Tia Carrera	Die Mutherf**cker Die/Dope	One/Metallica
Ballad of the Green Berets/Barry Sadler	Barnburing/Gangstagrass	Radar Love/Golden Earring
Avatar Soundtrack/James Horner	Honey I'm Good/Andy Grammer	The X-Files Soundtrack/Elektra Records
Riddle of Steel (Conan the Barbarian Soundtrack)/Basil Poledouris	Apocalypse (Battlestar Galactica Soundtrack)/Bear McCreary	Public Enemy (Starcraft 2: Wings of Liberty Soundtrack)/Blizzard Music
Pretty Vegas/INXS	We're Not Gonna Take It/Twisted Sister	Unforgiven/Metallica
Turn the Page/Metallica	Inaudible Melodies/Jack Johnson	You and Tequila/Kenny Chesney
Schism/Tool	Give it All/Rise Against	Don't Fight It/Kenny Loggins
Pain Killer/Little Big Town	Knee Deep/Zac Brown Band	Comfortably Numb/Pink Floyd
Brothers in Arms/Dire Straits	Selling England by the Pound/Genesis	Space Oddity/David Bowie
Finale (Game of Thrones Soundtrack)/Ramin Djawadi	Enjoy the Silence/Depeche Mode	Adagio (Remix) (Tron: Legacy Soundtrack)/Daft Punk
Blue Lights/Fictional	Standing/VNV Nation	New World Order/Ministry
Changes in Latitudes, Changes in Attitudes/Jimmy Buffett	A Pirate Looks at Forty-Redemption Song/Jimmy Buffett	From Past to Present (Elder Scrolls Soundtrack)/Jeremy Soule
It's Five O'clock Somewhere/Jimmy Buffett	Margaritaville/Jimmy Buffett	All Along the Watchtower/Jimi Hendrix
Chop Suey/System of a Down	The Red/Chevelle	Sandstorm/Darude
Bodies/Drowning Pool	Thieves/Ministry	Stairway to Heaven/Led Zepplin

Song/Artist	Song/Artist	Song/Artist
Time to Say Goodbye/Sarah Brightman & Andrea Bocelli	Sound of Silence/Disturbed	Chandelier/Twisted Measure
Wrong Side of Heaven/Five Finger Death Punch	46 & 2/Tool	Anesthesia/Type O Negative
Mayonnaise/Smashing Pumpkins	Marrakesh Express/Crosby, Stills, & Nash	Another Brick in the Wall/Pink Floyd
Animals/Maroon 5	Nights in White Satin/The Moody Blues	Hallelujah/Leonard Cohen
Rock and Roll Ain't Noise Pollution/AC/DC	We Didn't Start the Fire/Billy Joel	Soldier of Fortune/Deep Purple
When a Blind Man Cries/Deep Purple	Create/OVERWERK	Spitfire/The Prodigy
Blood and Thunder/Mastodon	Pursuit/Gesaffelstein	Retaliate/VNV Nation
Call the Ships to Port/Covenant	We Stand Alone/Covenant	Bullet/Covenant
Feuer Frei/Rammstein	Dream On/Aerosmith	Wheels/Foo Fighters
Get By/Talib Kweli	Aqua Vitae/Future World Music	One Particular Harbor/Jimmy Buffett
Memories That You Call/Odesza	Earth Scraper/Celldweller	Ender's War (Ender's Game Soundtrack)/Steve Jablonsky
Welcome to the Jungle/Guns N' Roses	All the Things/Dual Core	Destroy Everything You Touch/Ladytron
Untrust Us/Crystal Castles	Hasty Boom Alert/Mike Paradinas	Xtal/Aphex Twin
Interceptor/Mitch Murder	Requiem for a Dream/ Kate Chruscicka	Lydia/Highly Suspect
The Kill/Thirty Seconds to Mars	Genghis Khan/Miike Snow	The Funeral/Band of Horses
Comptine d`un autre ete/Yann Tiersen	Reverie/Debussy	Hot Potato/The Wiggles*
La Valse d'Amelie/Yann Tiersen	With or Without You/U2	Dubstep Mix/Snatt & Vix
Jake the Peg/Rolf Harris-The Wiggles*	Tie Me Kangaroo Down Sport/Rolf Harris-The Wiggles*	Invention Number 13 (for Two Voices)/Bach
Toot Toot Chugga Chugga Big Red Car/The Wiggles*	Barbie Girl/Aqua	Maximal Crazy/Tiësto
Ping Pong/Bassnectar	Wicked Games (feat. Anna Naklab)/Parra for Cuva	Youth/Daughter

Song/Artist	Song/Artist	Song/Artist
The Boxer (feat. Mumford & Sons and Paul Simon)/Jerry Douglas	All Fired Up/Pat Benatar	Lose Yourself/Eminem
6th Symphony/Beethoven	Rhapsody in Blue/George Gershwin	War of the Worlds (Musical)/Jeff Wayne
Uprising/Muse	For Those About to Rock/AC/DC	Catch Hell Blues/The White Stripes
Doing It Right/Daft Punk	Far Alone (feat. Jay Ant)/G-Easy	Harder, Better, Faster, Stronger/Daft Punk
Deadpool Rap/Teamheadkick	Blood in the Cut/K.Flay	Madness/Muse
Unstoppable/Sia	Can't Stop the Rock/Apollo 440	500 Miles/Jefr Tale
Roar/Katy Perry	Pretty Girl at the Airport/Avett Brothers	Don't Carry It All/The Decemberists
That Sea, the Gambler/Gregory Alan Isakov	My Oh My/Punch Brothers	Helplessness Blues/Fleet Foxes
Be Me/Tedashii	She Waits/Louden Swain	Gamma Ray/Beck
Open Water/Lade	Hostage Down/Dual Core	Scully's Theme (The X-File Soundtrack)/Mark Snow
Amo Bishop Roden/Boards of Canada	Babushka/Steve Vai	Under Ice/Kate Bush
Sentient/Perturbator	Future Club/Perturbator	Apocryphon/The Sword
The Tristar/Dynatron	Oblivion/Mastodon	Rock Lobster/B-52's
Echo Beach/Martha & the Muffins	Lust for Life/Iggy Pop	It's a Long Way to the Top/AC/DC
Subterranean Homesick Blues/Bob Dylan	Libertango/Tine Thing Helseth	Africa Bamba/Santana
Haydn Trumpet Concerto/Tine Thing Helseth	Sweet Transvestite (Rocky Horror Picture Show Soundtrack)/Tim Curry	Nuclear Blues/Blood, Sweat & Tears

*This respondent may have just been joking, but there is no accounting for individual tastes… So, if The Wiggles work for you, go for it!

**These songs are also available for your listening pleasure via a public Spotify playlist called "Ultimate DF/IR Playlist".

Honorable mentions covering "Anything by XYZ artist…" responses (i.e., no specific songs listed):

Artist Name	Artist Name	Artist Name
Bruce Springsteen	Pyotr Ilyich Tchaikovsky	Igor Stravinsky
Zac Brown Band	Arctic Monkeys	Rage Against the Machine
Volbeat	Enya	Bad Religion
Eminem	The Beatles	Van Morrison
Michael Jackson	Animals as Leaders	Plini
Vivaldi	Intervals	Dave Brubeck
Duke Ellington	Miles Davis	Keb' Mo'
Phil Collins	AC/DC	Rammstein
Rush	Agnes Obel	Pentatonix
Johann Sebastian Bach	Thievery Corporation	Lindsey Stirling
Disturbed	Led Zepplin	OVERWERK
Nostromo	The Honey Dewdrops	Billy Joel
Thrasher	Chris Stapleton	Al Stewart
Heart	10,000 Maniacs	James Taylor
Alison Krauss	Rascal Flatts	Emmylou Harris
Linkin Park	Frank Sinatra	KC and the Sunshine Band
Johnny Cunningham	Wolfstone	Leahy
Donald Black	Jerry Holland	Grateful Dead
Phish	The Civil Wars	Alice in Chains

Artist	Artist	Artist
Pink Floyd	Dokken	Bon Jovi
Limp Bizkit	Domenico Scarlatti	Frédéric Chopin
Neil Young	Thelonious Monk	Charles Mingus
Horace Silver	Richard Cheese	Carl Orff
Ray Charles	Ben Folds	Wayman Tisdale
Johann Strauss II	Arvo Pärt	Erma Franklin