DURMS
Durham Undergraduate Research in Music & Science

What Comes Next? Non-Musicians and Cadential Recognition in the Solution of Musical Puzzles

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ABSTRACT

This report summarises the findings of an online experiment examining cadential recognition in non-musicians. Participants (*N*=39) undertook musical jigsaw puzzles, completing unfinished cadential passages using one of three chordal options. These consisted of *perfect authentic cadences* (PAC) and *half cadences* (HC) of both major and minor tonality, presented to one group of participants in the classical piano genre, and to the other group as Bach chorales. Results showed that non-musicians could accurately recognise PAC's with greater accuracy than HC's. The tonality and timbre of each cadential excerpt did not affect the accuracy of recognition, nor did the amount of time spent listening to music per week and the genre most listened to. This study examined more variables than any other study, paving the way for further research into cadential recognition and harmonic expectancy specifically in non-musicians.

1. INTRODUCTION

Cadential formulae are widely explored within the realms of Western musicology, with a greater integration into the field of music psychology within the last 30 years. Many aspects of cadential theory have been applied to psychological studies, with particular emphasis on harmonic expectancy and harmonic priming (Bigand & Pineau, 1997; Sears et al., 2014; Sears et al., 2018; Tillmann & Marmel, 2013), and how these things are affected by melodic contour, rhythm, and harmonic hierarchy (Bigand & Pineau, 1997). Cadences are often associated with musical closure; cadences ending on the tonic - such as *perfect authentic cadences* or PAC's (V - I) - are more 'expected' than those ending on the dominant or subdominant - such as *half cadences* or HC's (I - V) - and provide a greater indication of closure (Bigand & Pineau, 1997; Caplin, 2013; Krumhansl, 1990; Sears et al., 2014; Sears et al., 2018; Tillman et al., 1998; Tillman & Marmel, 2013). Perception of cadences has been studied in both musicians and non-musicians, and comparisons between these two groups are certainly visible in many studies.

Bigand (2003) reviews previous studies in the field to provide an overview of differences between musicians and non-musicians in processing small changes in musical excerpts. He outlines many conclusions regarding harmonic expectancy in particular, including generalisations that the ability to process changes in musical material is similar between the groups. Bigand also draws the interesting conclusion that perhaps the gaps due to lack of musical training in non-musicians could be filled by extended exposure to musical material, suggesting that non-musicians can improve musical ability through listening, though this is never proved or discussed in depth.

Bigand and Pineau (1997) studied harmonic expectancy in non-musicians respectively. Three experiments were undertaken, two of which were directed at non-musicians and the final experiment comparing data between non-musicians and musicians. The first used 8-chord reductions of Bach Chorales, with the first 6 chords altered to resemble the dominant key. In this context, the endings of each chord sequence resembled either a PAC (ending on I) or a I - IV progression. Upon hearing these excerpts, participants rated the degree of completion in each sequence on a number scale, which revealed a greater rating of completion for excerpts ending on chord I than excerpts ending on chord IV. The second experiment used the same stimuli, though this time participants were to indicate whether they believe the final chord to 'belong' or 'not belong' with the preceding chords. Over 99% of participants believed the final tonic chord to belong, whereas only 18% of participants recorded the subdominant chord to belong. Reaction times were also shorter in response to the tonic chord. This experiment highlighted the importance of the tonic in closure, and emphasised non-musicians' perception of this.

Two studies from Sears at al. (2014; 2020) also follow the trend exploring expectancy and closure ratings within their experiments. Excerpts of Mozart piano sonatas were presented to participants in both studies, with an equal number displaying PAC's, HC's, *imperfect authentic cadences*, *deceptive cadences*, and *evaded cadences* (Sears et al., 2014; Sears et al., 2020). Participants were to rate the expectancy that the end of the excerpt was 'imminent', or coming within the next few seconds; the scale ranged from 'very weak' to 'very strong'. The age, the number of hours they spent listening to music, and the musical ability of each participant was recorded before the experiment. They were then categorised into 'musicians' and 'non-musicians' which was important in analysis. Results differed between the two studies, with PAC's receiving the greatest expectancy levels than all other cadences in both musicians and non-musicians in the 2014 study. The 2020 study, however, revealed that non-musicians' responses were similar in all cadence types. This is interesting considering similar stimuli was used in each experiment, though the reasoning for this difference was put down to the experiment being too difficult for non-musician participants.

Though we know much about harmonic expectancy, harmonic priming, and musical closure from previous study, there are certainly further elements to explore. If we try to understand the factors that may affect the abilities of non-musicians for example, the literature available provides little insight. Bigand (2003) does tell us that in many instances musicians and non-musicians perform in very similar ways, but believes that repeated exposure to music could fill in the gaps that musical expertise fills in musicians. Though he makes this claim, he doesn't explore this within any of the outlined studies in great

detail. Sears et al. (2014) also find themselves in this situation; the amount of time spent listening to music per week was recorded, though never explicitly included within their analysis. It is therefore necessary to explore this ambiguous notion further in order to understand if exposure to music does affect non-musicians harmonic expectancy and perception of cadences. Ambiguity also lies in participant samples exhibited in these studies. The term 'non-musician' is enigmatic in nature, and in some cases non-musician participants have some - 1 year or less of - musical training (Sears et al., 2014; Sears et al., 2018). In order to understand how non-musicians perceive cadences more conclusively, more studies must be undertaken investigating those with no musical training whatsoever. Most studies in this field are based around expectancy ratings in already existing cadential figures, though no studies appear to explore non-musicians' ability to indicate *what comes next* in cadential figures. Would non-musicians be able to complete cadential passages of different types when they are unfamiliar with the specific formulae they abide by? These elements provided the basis for this study.

This study aims to confirm non-musicians' ability to recognise cadential closing functions, and unearth whether the amount of time spent listening to music per week (which will be referred to as LPW) has a positive effect on the accuracy of recognition. It will also explore more variables such as the effect of timbre, tonality, and type of cadence on accuracy of recognition, as well as discovering whether there is any connection between the genre most listened to in participants and accuracy.

2. METHOD

Design. This study involved a quantitative online experiment aimed at non-musicians with no musical experience only. The questions consisted of musical jigsaw puzzles (inspired by Tillmann et al., 1998). The independent variable was the accuracy of scores, indicated by choosing the correct answer to each puzzle. The dependent variables were timbre of musical excerpts, amount of time spent listening per week in hours (LPW), and the genres listened to, indicated by participants in the initial survey. Participants undertook the experiment online through a Qualtrics survey, without the presence of the researcher.

Participants. One hundred and one participants were recruited through social media platforms, though only 39 presented valid responses and were therefore retained in the analysis. Participant age ranged from 18-72 years (M= 28, SD=15) who all declared that they had no instrumental or theoretical musical training. LPW ranged from 0 to 90 hours (M=25.45, SD= 24.24) with the most commonly listened-to genre being *pop*. The experiment was shared to friends and family, and then shared on to others on Facebook. It was also advertised on the Durham University Virtual Learning Environment, where music students could share it to non-musician family and friends.

Materials/Stimuli. The experiment was created using Qualtrics. Participants did not require any specialist equipment, though access to a device that played audio was necessary for completion. A short survey was presented before the experiment began, including consent and demographics. The experiment was made up of musical jigsaw puzzles; each question consisted of a short excerpt of a classical piano piece or a Bach chorale, lasting around 8 seconds each, and 3 singular chords that could each be selected as answers. Excerpts consisted of a cadential passage with the final chord removed. These were taken from YouTube clips, recorded and cropped to size using Audacity audio editing software. They were then uploaded to Soundcloud as mp3 files and embedded into Qualtrics. These excerpts were chosen as they represented examples of PAC and HC as outlined by Caplin (2013). Chordal answers were generated in Sibelius Ultimate using MIDI Piano and Choir sounds, recorded and cropped using Audacity, uploaded to Soundcloud and embedded into Qualtrics. The chordal answer choices consisted of a tonic, dominant, and subdominant chord in the context of the excerpt's global key signature. There were a total of 8 questions in Piano timbre, 8 questions in Choral timbre, and 1 practice question. The practice question used a piano rendition of the well-known nursery rhyme *Twinkle, Twinkle, Little Star*.

Procedure. Participants were asked their age, LPW, and the genre they listen to most out of a list of 14 (Rentfrow & Gosling, 2003). A practice question was then presented, where participants could familiarise themselves with the format of questions. Qualtrics allocated each participant into one of 2 groups for the experiment. The first group responded to piano music excerpts (N= 21, *Age* M=26, SD= 25, *LPW* M= 29.66, SD=25) and the second group responded to choral excerpts (N=18, *Age* M=30, SD=15, *LPW* M=20.61, SD=23). Each group answered 8 questions of their corresponding timbre presented in a random order. Both groups answered 2 Major PAC questions, 2 Minor PAC questions, 2 Major HC questions, and 2 Minor HC questions for a fair analysis. Participants could not progress without completing every question, but could leave and return to the experiment at any point.

3. RESULTS

Descriptive statistics were calculated using Microsoft Excel, and all inferential statistics and plots were calculated and generated in RStudio.

The results of this study revealed that non-musicians can accurately recognise cadences. The average score was 63.46% (SD=21.34) with the lowest overall score being 12.5%, indicating that not a single participant failed all of the puzzles. The piano group produced an average score of 66.66% (SD= 18.68), with the choral group producing an average score of 59.72% (SD= 25.08). A t-test was conducted comparing the scores of the two groups which produced a non-significant result (t(31.85)=-0.99, p=0.32), suggesting that timbre has no significant effect on accuracy of cadential recognition. We also discovered that the tonality of a cadence has no significant relationship to accuracy of results in all cases. Four t-tests were conducted to compare the scores of different cadence types, as indicated in Figure 1. The difference in score between Major and Minor PAC's is non-significant (*Major PAC* M=80.77, SD=29.50, *Minor PAC* M=78.21, SD=32.03; t(38)=5.30x10^{-1}, p> 0.05) which was also the case between Major and Minor HC's (*Major HC* M= 39.74, SD= 40.03, *Minor HC* M=53.85, SD=28.98; t(38)=-1.99, p > 0.05). Comparisons between Major

PAC's and Major HC's ($t(38)=5.28$, $p < 0.05$) and Minor PAC's and Minor HC's ($t(38)=4.22$, $p < 0.05$) show a different result, with significant differences between the scores. We can gather from this statistical evidence that although tonality of cadences does not affect accuracy of cadential recognition, the type of cadence does, with HC's receiving a lower accuracy score than PAC's.

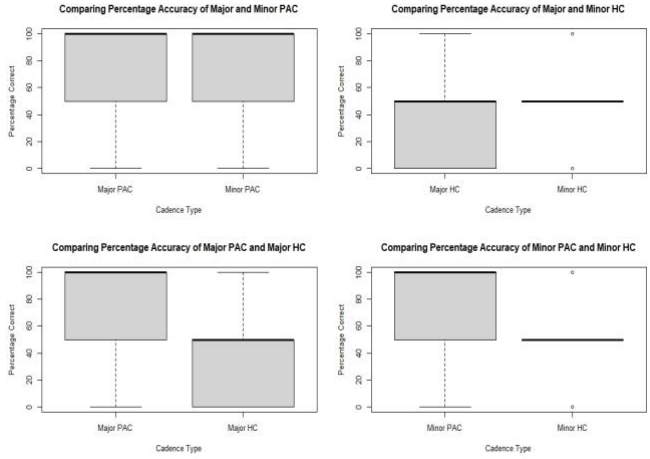

Figure 1. Comparing percentage accuracy of all cadence types

A Spearman's Rank Correlation Coefficient was conducted to analyse the relationship between LPW and score accuracy. The results of this test revealed a very small degree (r=0.06) as indicated in Figure 2. With a degree so small, it is sensible to conclude that there is no significant correlation between LPW and score accuracy.

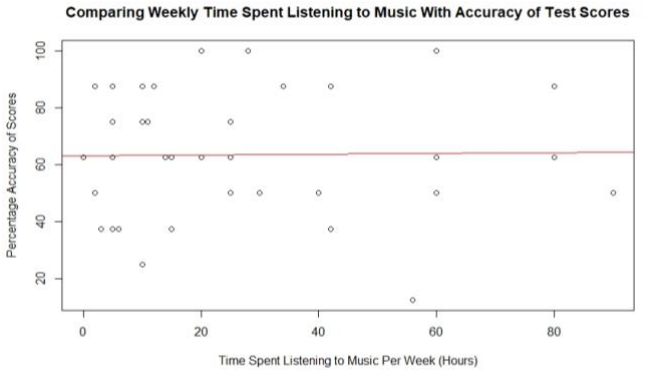

Figure 2. Comparing weekly time spent listening to music (LPW) with accuracy of test scores. The red line presents a gradient of 0.06.

Figure 3 presents the scores in relation to the genres chosen by all participants. An ANOVA was conducted to unearth any relationships between these scores and genres. The test revealed some outlying results; participants 23 and 32 had high leverage on the data, and had a Cook's distance of over 0.5. This was because they were the only participants to choose a genre (23= Classical, 32= Country), represented in Table 1 (see Appendix). Due to their high leverage on the data, these data points were omitted. The ANOVA without participants 23 and 32 was much clearer, as indicated in Table 1 (see Appendix).

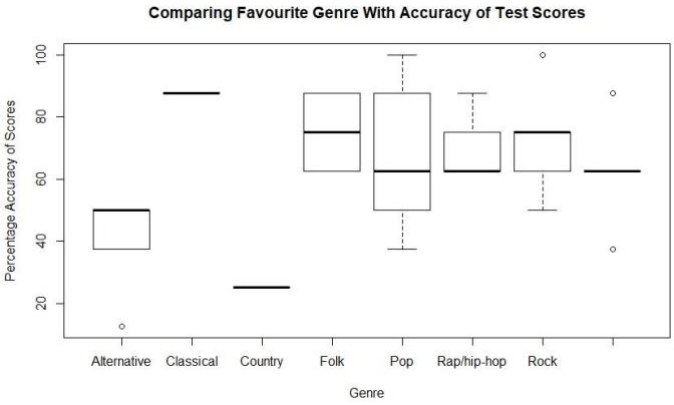

Figure 3. Comparing favourite genre with accuracy of test scores

4. DISCUSSION

From the examination of previous study, we have seen that those with limited musical training can correctly perceive cadences. This study has solidified this further, and proved that those with no musical training whatsoever can correctly complete cadential passages, and recognise these closing functions. We have also confirmed that PAC's are recognised more accurately than HC's, but that tonality has no significant sway on the accuracy of either cadence type. Neither group performed better than the other, suggesting that non-musicians can accurately recognise cadences regardless of the timbre they are sounded in. Most surprising, however, is that there is no correlation between accuracy of cadential recognition and LPW, therefore extensive music listening does not improve cadential recognition ability in non-musicians, disproving Bigand's (2003) conclusion.

Studies discussed in this report have examined how both musicians and non-musicians perceive cadences through rating how finished a phrase sounds (Bigand & Pineau, 1997; Sears et al., 2014; Sears et al., 2020), all revealing that non-musicians were capable of recognising cadences. This study, however, takes a unique angle. Participants here had to complete unfinished cadential passages in different tonalities and timbres, with different options to choose from, all familiar to the global key. This jigsaw puzzle-style experiment required participants to put cognitive harmonic expectancy into practice, and proved that non-musicians can do this with a good level of accuracy. Analyses also delved into a wider range of variables, of which other studies ignored.

Despite this, many limitations are visible in this study that must be addressed. Firstly, there are many variables left untouched in the analysis, such as age and gender, which would offer further insight into cadential recognition in non-musicians. Though comparisons between genders are limited in this field, age can affect harmonic priming, with adults often able to perceive more complex stimuli than children (Bigand, 2003). Despite a denser concentration of variables explored in this study, there are still more requiring attention.

Secondly, as the study took place during a global pandemic, it was impossible to physically monitor participants and be

certain that they had no musical training at all due to the online format and recruitment process. If this study was to be reproduced online, more questions regarding the participants' musical experience should be asked in order to ensure that all participants are on an equal playing field. Another limitation of this online study was that the groups were not split evenly due to the random allocation from Qualtrics. We may have seen different results with a greater participant sample split evenly between each group.

Thirdly, the audio excerpts used could be improved to ensure that all music played is of the highest, clearest quality, and using the same instruments for each excerpt. As YouTube clips were used as stimuli, there were notable differences in sound between excerpts of piano music as they each came from a different source. This may have affected results in the piano group, as this was most affected, though we cannot be sure unless the experiment is repeated with tracks recorded from the same instrument.

Finally, more genres of music could be explored beyond the realms of classical piano and choral music. Only one participant in the study recorded that they listened to Classical music the most out of the given genres, therefore classical piano and choral music may have been mostly unfamiliar to the majority of participants. Though these genres have been used in most other studies (Sears et al., 2014; Sears et al., 2018; Tillmann & Marmel, 2014; Tillmann et al., 1998) it would be insightful to compare cadential recognition in more familiar genres in order to compare results.

All these limitations are grounds for improvements to be considered in future studies in this field. The future directions for research are plentiful, and this study offers a unique starting point for these directions. More can be discovered regarding the cognitive process behind non-musicians' cadential recognition, and further research will help psychologists understand the main processes behind cadential recognition.

To summarise, this study has highlighted key variables that may affect the accuracy of cadential recognition in non-musicians. These variables have been previously unexplored in the field, and are here explored in a unique and interactive way through the solution of musical jigsaw puzzles. More is still to be discovered and learned, but the findings from this study bring us one step closer to understanding the vast phenomenon of cadential recognition in non-musicians.

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Tillmann, B., & Marmel, F. (2013). Musical Expectations Within Chord Sequences: Facilitation Due to Tonal Stability Without Closure Effects. *Psychomusicology: Music, Mind, and Brain, 23*(1), 1-5.

APPENDIX
Musical Examples

MAJOR PAC

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4*). J.S. Bach: Ach lieben Christen, seid getrost, BWV 256* [Video file]. Retrieved from https://www.youtube.com/watch?v=_z-yQ4aotJ4&list=OLAK5uy_noxaTRTjwYKtOi2e4-Nm1q6SJCjncJ8jA&index=5.

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4). *J.S. Bach: Ein feste Burg ist unser Gott, BWV 302* [Video file]. Retrieved from https://www.youtube.com/watch?v=M1nm62Ez3Rw.

Musicnetmaterials. (2014, April 22). *Mozart. Sonata para piano nº 6 Kv 284. III. Tema con variaciones* [Video file]. Retrieved from https://www.youtube.com/watch?v=B2Cj9X1LZfU.

Sheetmusic2print (2020, December 22). *Schumann : Sonata op. 118, no. 1 (1/4 : Lebhaft)* [Video file]. Retrieved from https://www.youtube.com/watch?v=ssf0_55Pkqc&t=18s.

MINOR PAC

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4). *J.S. Bach: Befiehl du deine Wege, BWV 270* [Video file]. Retrieved from https://www.youtube.com/watch?v=XGyIpwgYCdg&list=OLAK5uy_noxaTRTjwYKtOi2e4-Nm1q6SJCjncJ8jA&index=17.

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4*). J.S. Bach: Gott, der du selber bist das Licht, BWV 316* [Video file]. Retrieved from https://www.youtube.com/watch?v=bjwoZwWZP1o.

J. Triumvirate. (2018, January 21). *Beethoven - 11 Bagatelles, Op. 119 [Rudolf Serkin]* [Video file]. Retrieved from https://www.youtube.com/watch?v=Qjk2zYjwaJc.

ThePochaccos. (2014, November 16). *Bach-Kempff - Siciliano from Flute Sonata No 2 BWV 1031* [Video file]. Retrieved from https://www.youtube.com/watch?v=7yS-Ywu-xZU.

MAJOR HC

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4*). J.S. Bach: Als der gütige Gott, BWV 264* [Video file]. Retrieved from https://www.youtube.com/watch?v=drr_RC2LpQ0.

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4). *J.S. Bach: Christus, der ist mein Leben, BWV 281* [Video file]. Retrieved from https://www.youtube.com/watch?v=Inepx-GiQf0&list=OLAK5uy_noxaTRTjwYKtOi2e4-Nm1q6SJCjncJ8jA&index=27.

Musicnetmaterials. (2014, April 21). *Mozart Sonata nº 4 Kv 282 I Adagio* [Video file]. Retrieved from https://www.youtube.com/watch?v=8HaTNIMA-WM.

Zdravko Petrov. (2014, July 17). *Haydn - Sonata Hob XVI:37 in D dur - mov.1* [Video file]. Retrieved from https://www.youtube.com/watch?v=wRFal0787vk.

MINOR HC

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4). *J.S. Bach: Als vierzig Tag nach Ostern warn, BWV 266* [Video file]. Retrieved from https://www.youtube.com/watch?v=VIJEnko9e-s&list=OLAK5uy_noxaTRTjwYKtOi2e4-Nm1q6SJCjncJ8jA&index=13.

Augsburg Cathedral Boys' Choir - Topic. (2018, October 4). *J.S. Bach: Für Freuden lasst uns springen, BWV 313* [Video file]. Retrieved from https://www.youtube.com/watch?v=StHfsJ1BlBw.

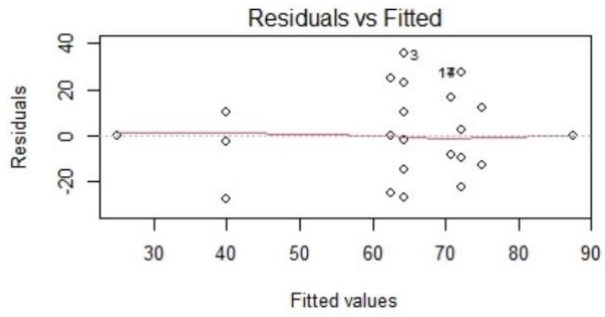
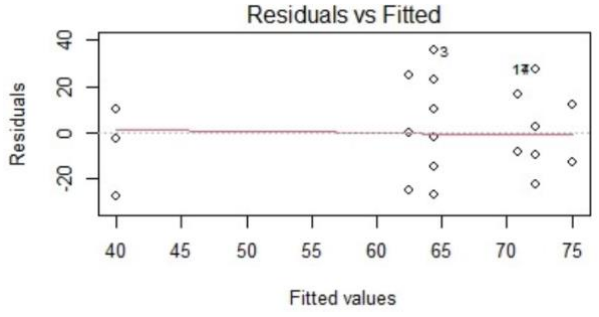
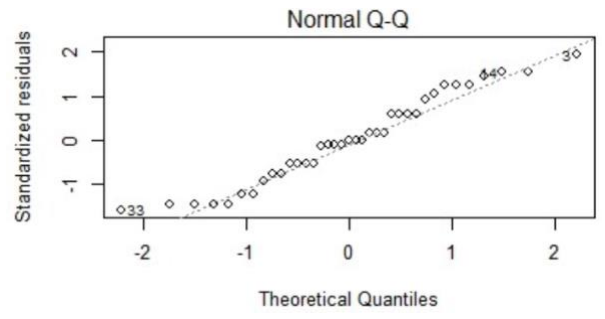
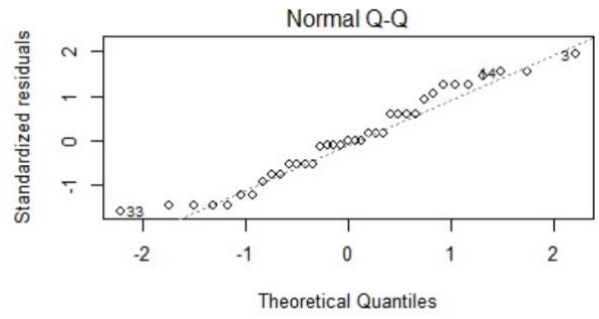
J. Triumvirate. (2018, January 21). *Beethoven - 11 Bagatelles, Op. 119 [Rudolf Serkin]* [Video file]. Retrieved from https://www.youtube.com/watch?v=Qjk2zYjwaJc.

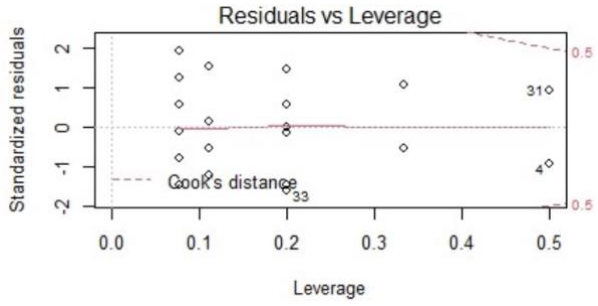
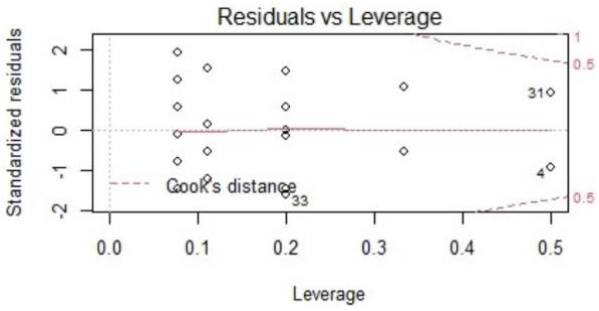
TheExarion. (2016, January 10). *Wolfgang Amadeus Mozart - K.397, Fantasia in D minor* [Video file]. Retrieved from https://www.youtube.com/watch?v=1BkZ8ci8_k4.

Practice Question

Rousseau. (2019, October 21*). Mozart - Twinkle Twinkle Little Star (12 variations on Ah vous dirai-je, Maman)* [Video file]. Retrieved from https://www.youtube.com/watch?v=hCKBl-TpRzc.

Table 1. Diagnostic Plots from ANOVA With and Without Points 23 and 32.

Original ANOVA Diagnostic Plot	**ANOVA Diagnostic Plot Omitting 23 & 32**
	
Outlying results visible, unequal distribution about the red line.	Equal spread of data about the red line - assumption that there is a linear relation holds true.
	

Data fits the normal QQ line fairly well, and holds that residuals are fairly distributed.	Data fits the normal QQ line fairly well, and holds that residuals are fairly distributed.
	
Points 23 and 32 outside of Cook's distance, omitted from this plot as they did not fit.	Points 23 and 32 omitted, all points within Cook's distance with no high leverage on data.