Playing Style Affects Steel-String Acoustic Guitar Timbre

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Introduction

We investigate how steel-string guitar timbre is affected by playing style and manufacturer model. Timbre has been commonly studied using dissimilarity tests (see e.g. Grey, 1977; McAdams et al., 1995, Barthet et al., 2010), yielding "timbre spaces" using multidimensional scaling (MDS). Prior guitar timbre research has focused for example on classical guitar (Traube, 2004), influence of guitar pick position (Traube & Depalle, 2003), physical modelling of guitars (Välimäki, 1995), and the understanding of the perceptual effects of guitar neck construction (Paté et al., 2012) and back wood material (Carcagno et al., 2018). To our knowledge, this is the first study assessing the influence of playing style on guitar timbre.

Guitar Timbre Dissimilarity Test

We conducted a guitar timbre dissimilarity test using recordings of 10 different steel-string acoustic guitars[1] varying in price from the Thomann[2] website. For each guitar, recordings of three different playing styles were used: picking (mainly individual notes played with a combination of fingers and pick), strumming (mainly chords played with a pick), and fingerstyle (strings plucked with fingers rather than a pick).

The recordings were all produced using the same equipment (Schoeps Stereo-Set MK 4 microphones and Apogee Ensemble Thunderbolt preamp and audio interface) and AAC versions were processed to keep the same loudness (-23 LUFS) and stereo width across stimuli. We developed a custom test interface using BeaqleJS, a Javascript audio evaluation framework (Kraft & Zölzer, 2014). The study was completed by 27 participants (8 female, 19 male, mean age: 27), each with at least five years of guitar/musical experience. For each playing style, participants were asked to rate the pairwise timbre dissimilarity for 45 different unordered guitar pairs on a scale ranging from 0 (identical) to 1 (very dissimilar). The study received ethics approval from the Queen Mary Ethics of Research Committee (QMERC20.565.DSEECS22.071) and participants received a £10 Amazon voucher. The order of the pairs and the order within pairs were randomised across participants.

Results and Discussion

Intra-class correlations

We computed the intra-class correlation (ICC) on participant ratings, a common inter-rater reliability statistic (Hallgren, 2012). Using a two-way ICC model (Vallat, 2018), we obtained ICCs of 0.92 ($p < .001$), 0.89 ($p < .001$) and 0.86 ($p < .001$) for picking, strumming, and fingerstyle, respectively. These high ICC values indicate a strong agreement between participants (Cicchetti, 1994) for each playing style.

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[1] Cort Earth 100 NS, DAngelico Premier Bowery LS, Recording King RDS-11-FE3-TBR, Takamine GD90CEZC-NAT, Fender Redondo Special MAH, Epiphone Hummingbird, Furch Blue Gc-CM, Seagull S6 Original Burnt Umber Presys, LAG THV20DCE Tramontane HyVibe, Seagull Artist Mosaic CH CW Bourbon B

[2] https://www.thomann.de/

0.01796

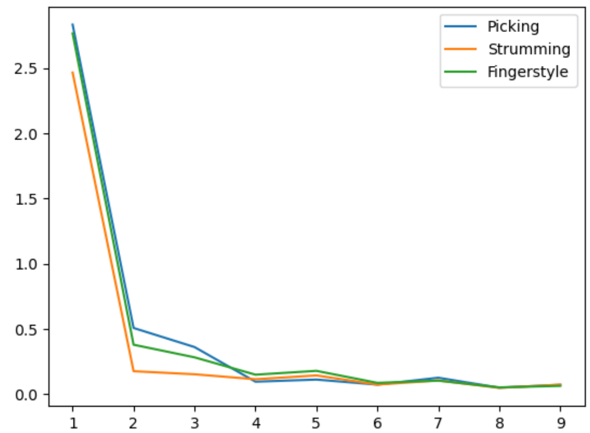
Table 1: LME model results for fixed effects (estimate, standard error and p-value) and random effect (participant and guitar/pair variance and standard deviation).

		Coef	Std. Error	Std. Dev.	Pr(>|t|)
Inter-guitar average dissimilarity model	*Intercept (picking)*	*0.56053*	*0.01914*	-	*> 2e-16*
	Strumming	*-0.03325*	*0.02191*	-	*0.13957*
	Fingerstyle	*-0.06862*	*0.01529*	-	*0.00012*
	Participant variance (picking)	*0.003577*	-	*0.05981*	-
	Participant variance (strumming)	*0.007919*	-	*0.08899*	-
	Participant variance (fingerstyle)	*0.004442*	-	*0.06665*	-
	Guitar variance (picking)	*0.002173*	-	*0.04661*	-
	Guitar variance (strumming)	*0.001538*	-	*0.03922*	-
	Guitar variance (fingerstyle)	*0.000365*	-	*0.01909*	-
Raw dissimilarity model	*Intercept (picking)*	*0.43947*	*0.02214*	-	*> 2e-16*
	Strumming	*0.03325*	*0.02220*	-	*0.140824*
	Fingerstyle	*0.06862*	*0.01712*	-	*0.000241*
	Participant variance (picking)	*0.003236*	-	*0.05689*	-
	Participant variance (strumming)	*0.007197*	-	*0.08484*	-
	Participant variance (fingerstyle)	*0.003750*	-	*0.06124*	-
	Pair variance (picking)	*0.015314*	-	*0.12375*	-
	Pair variance (strumming)	*0.007501*	-	*0.08661*	-
	Pair variance (fingerstyle)	*0.004261*	-	*0.06528*	-

Linear Mixed Effect Model

We used a linear mixed effect (LME) model to investigate the effect of the playing style on guitar timbre dissimilarity. Two models were tested, with both using random intercepts and random slopes in modelling the random effects.. The first model used as our dependent variable the inter-guitar average dissimilarity $\bar{D}_i^{(k)} = (N-1)^{-1} \sum_{j=1, j\neq i}^{N-1} d_{i,j}^{(k)}$ where *i* and *j* refer to guitars, *k* to participants, *N* is the total number of guitars, and $d_{i,j}$ is the measured dissimilarity rating ($i \neq j$). The playing style was treated as a fixed effect and the participants and guitar as random effects given that different participants may perceive timbre differently and guitars may have different overall timbre profiles. The LME model achieved a conditional R^2 of 0.63. The effect of playing style on guitar timbre dissimilarity was found to be highly significant. Pairwise comparison tests indicate highly significant differences between fingerstyle and picking ($t = 4.4, p < .001$). The second model used the raw dissimilarity ratings for each pair of guitars. The playing style was again treated as a fixed effect and the participants and guitar pair as random effects. Again, the effect of playing style on guitar timbre dissimilarity was found to be highly significant. Pairwise comparison tests indicate highly significant differences in both fingerstyle and picking ($z = -4, p < .001$) and fingerstyle and strumming ($z = -2.6, p = .023$). The results from both models can be found in Table 1. The findings reveal that two guitars which can be judged on average as similar

Figure 1: Stress for different MDS dimensions of each playing style.



when played on one playing style (fingerstyle) can be judged on average dissimilar in a different playing style (picking and strumming) and vice versa.

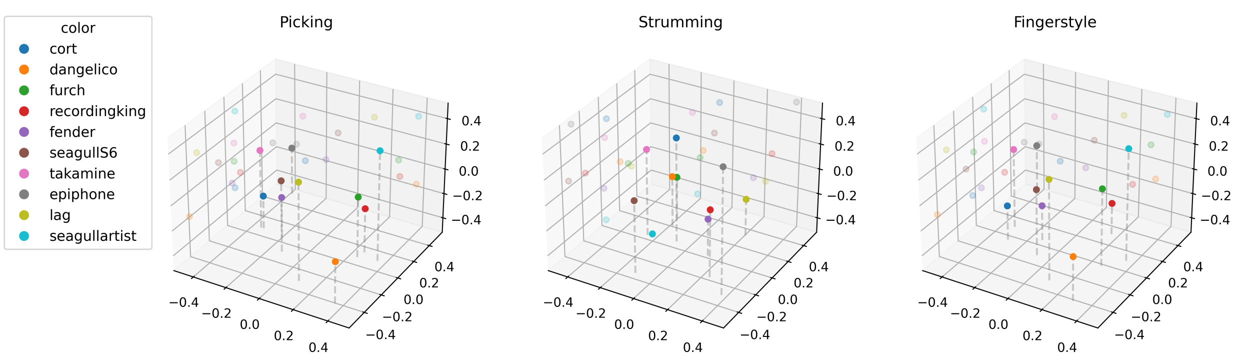
Multidimensional Scaling

Given the high ICCs, the dissimilarity ratings were averaged across participants for each playing style. Non-metric multidimensional scaling (MDS) was then performed on the average dissimilarity matrix for each style yielding 4-dimensional configurations (see stress values in Figure 1 and visualisation of the first three MDS dimensions in Figure 2). 46 timbre descriptors were calculated for each stimuli (audio sampled at $f_s = 44.1$ kHz) using the Timbre Toolbox (Peeters et al., 2011) and their average was used as summary statistic (parameters in Table 2). We applied a feature pruning technique based on Principal Component Analysis as in (Eerola et al., 2012), which yielded 12 important timbre descriptors. Table 3 reports the Spearman correlation coefficients of these descriptors with the MDS dimensions. Both picking and strumming have dimensions that are highly correlated with harmonic/noise energy content (harmonic energy and noise energy), something not seen for fingerstyle. Fingerstyle has a dimension that is highly correlated with the spectral and spectro-temporal features (spectral centroid, spectral slope and spectro-temporal variation). These descriptors tend to be less correlated with the picking and strumming dimensions. Interestingly, fingerstyle is the only style with a dimension significantly correlated to the odd to even harmonic ratio which may be related to the position of the plucks along the string (Traube & Depalle, 2003). The use of fingers tends to dampen the higher harmonics of the sound (Traube, 2004). It is possible that when a pick is used a different acoustic signature of the guitar emerges compared to when it is played with fingers, which produce less rich higher-order harmonic content in string vibrations; the significant harmony and noise energy correlations for some of the picking and strumming dimensions

Table 2: Signal representation parameters for timbre descriptors.

Representation	Hop Size (samples)	Window Size (samples)
Temporal Energy Envelope (TEE)	*128*	*1023*
Short-term Fourier transform (STFT)	*256*	*1023*
Equivalent Rectangular Bandwidth (ERB)	*256*	-
Sinusoidal harmonic partials (Harmonic)	*1103*	*4410*

Figure 2: First three MDS dimensions for each playing style.



corroborate this hypothesis. The three MDS dimensions seen in Figure 2 do seem to show picking and fingerstyle as having similar relative distances between guitars, though not all of the timbral differences are accounted for by these 3D plots given the 4D MDS configurations. These results suggest that steel-string acoustic guitar may have multiple timbral identities resulting from a combination between the physics of the instrument (mostly stable for a given instrument) and how it is played (variable, depending on the performer's style).

*Table 3: Spearman correlations for MDS dimensions of each playing style with the pruned timbre descriptors (representation noted in parentheses; significant correlations in bold: * p<.05, ** p<.01, *** p<.001).*

Playing style	**Picking**				**Strumming**				**Fingerstyle**			
Dimension	1	2	3	4	1	2	3	4	1	2	3	4
Spectro-temporal variation (ERB)	-0.24	0.22	-0.04	-0.52	0.47	0.35	0.2	0.48	0.24	0.35	0.14	-0.47
Frame Energy (Harmonic)	0.24	-0.03	0.53	0.16	0.08	-0.32	0.02	-0.39	-0.12	0.47	0.08	**0.67***
Harmonic Energy (Harmonic)	**-0.89*****	0.16	-0.12	0.3	0.41	-0.49	**0.73***	-0.04	-0.42	-0.24	0.04	0.16
Noisiness (Harmonic)	**0.92*****	-0.42	0.1	-0.16	-0.39	0.56	**-0.72***	0.03	0.54	0.13	0.25	-0.25
Odd to even harmonic ratio (Harmonic)	-0.18	-0.48	-0.39	0.19	0.36	-0.48	0.59	0.53	-0.36	0.35	0.02	**0.64***
Spectral Centroid (Harmonic)	**0.65***	-0.49	0.15	-0.04	-0.41	0.47	**-0.71***	-0.21	**0.82****	-0.32	0.33	-0.53
Spectral Kurtosis (Harmonic)	**-0.67***	-0.09	-0.02	0.04	-0.01	-0.12	0.62	0.01	-0.52	0.47	-0.02	0.62
Spectral Slope (Harmonic)	0.62	**-0.67***	0.27	0.04	-0.45	0.1	-0.5	-0.32	**0.79****	-0.53	0.47	-0.3
Spectro-temporal variation (Harmonic)	0.32	-0.3	-0.2	**-0.73***	**0.75***	-0.25	0.44	0.12	**0.88*****	-0.38	0.27	-0.5
Spectral Decrease (STFT)	-0.01	-0.31	0.31	0.36	-0.45	-0.38	-0.16	-0.39	-0.35	-0.24	-0.05	0.6
Spectro-temporal variation (STFT)	0.05	-0.24	-0.04	-0.62	0.14	0.37	-0.3	0.47	0.47	0.05	0.1	**-0.78****
Effective Duration (TEE)	0.1	0.27	**-0.73***	0.08	0.54	0.04	0.07	-0.18	0.26	0.1	0.24	0.49

Conclusion

We conducted a timbre listening study which revealed a dependence of a steel-string acoustic guitar's timbral profile on the playing style. Future work will involve an analysis of semantic timbral descriptions of steel-string acoustic guitars and preference data in order to better understand what aspects of steel-string acoustic guitar timbre are preferred by listeners. We suggest that timbre research should explore the influence of playing style as similar observations could be obtained for other instruments. We hope that these results will help further works into guitar timbre and guitar AI modelling.

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