Perception of violin soundpost height differences

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PROCEEDINGS of ISMA 2019
International Symposium on Music Acoustics

13 - 17 September 2019 in Detmold, Germany

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Abstract

This experiment explores how changes in soundpost height affect the perceptual qualities of the violin and whether there is a threshold of change below which players and luthiers do not perceive differences. A violin installed with a height-adjustable carbon fibre soundpost was employed. The experiment was designed as a sequence of playing tests. An experimenter was present to change the soundpost height. Thirteen professional violinists and six luthiers participated. The experiment involved two phases. During the first phase, subjects played and described their feelings about the violin with different soundpost settings in order to find their optimal soundpost height. During the second phase, the experimenter randomly increased, decreased or did not change the soundpost height in ten trials within a range of approximately ±0.1 mm around their optimal height. For each trial, subjects were asked to play the violin, comparing it with the previous setting, and to decide whether they were the same or different. Initial results indicate that each subject's optimal soundpost height varies within an interquartile range of 0.3 mm and the smallest height variation that could be recognized above chance level is about 0.04 mm.

Keywords: Soundpost height, Violin, Perception

1 INTRODUCTION

The soundpost (SP) of a violin is an essential component of the instrument. According to luthiers, subtle changes to the soundpost dimensions or position can result in significant variations in the violin sound and playing qualities. The soundpost is typically made of the same wood as the top plate, and it is a cylinder of approximately 0.7 g, 6 mm diameter and a bit longer than 50 mm (1). It provides structural support between the top and back plates and also a means of adjustment in the assembled instruments. As stated by Savart in 1840 (2), the soundpost can help transmit the vibrations from the top plate to the back plate. Through properly interpreted experiments, he also proved that the first acoustical purpose of the soundpost is to introduce asymmetry to the violin.

Jansson et al. (3), Schelleng (4) and Bissinger (1) studied the function of the soundpost through comparison between the violin with soundpost and without soundpost. Jansson et al. (3) employed hologram interferometry to study the resonances of the violin body. They designed an artificial immovable soundpost for observing the interferograms of the plates. A nodal line or a nodal area appeared on the interferograms of the plates around the position of the soundpost when the soundpost was in place and the resonance frequencies increased with a soundpost compared to without a soundpost. The appearance of the modes changed more on the top plate than the back plate when the soundpost was installed. Double exposure holograms on the complete instrument while pressing strings against the fingerboard showed that the maximum deformation of the back plate is at the soundpost. Schelling (4) approximated the violin body as a closed cigar box and the soundpost as immovable to explain the effect of the soundpost in enhancing the sound radiation. Without the soundpost, the strongest radiating mode is not excited. Also, he explained that the appearance of a new body mode with the soundpost installed depends on the adjacent modes without soundpost that do not have a null at the soundpost position. He then abandoned the assumption of the immovable soundpost and found that the admittance of the contact point of the soundpost and back plate is the smallest compared to the top plate and the ribs, i.e., it is unnecessary to assume all motion of the back plate is ascribed to the soundpost. Bissinger (1) employed a modal analysis method to test an unvarnished violin. The peaks in the accelerance spectra did not show a substantial shift in frequency with soundpost or without soundpost, and the large peaks usually stayed large. About one-third of the peaks in the no-SP spectrum did not correlate easily to the SP spectrum, and the correlation reliability generally dropped with increasing mode frequency. Using the modal analysis data, he calculated the radiation efficiency of the violin. He observed a very considerable radiation efficiency enhancement of SP over no-SP in the region of 500-800 Hz, in which there are some very important peaks in the response or radiativity curves. Overall, the average radiation efficiency increased by 17% with the soundpost installed. Simulated response curves and Fourier spectra of bowed slide tones of this violin showed that removing the soundpost weakened the frequency response as well as the overall acoustical response from 0 to 2 kHz, and this effect is much more substantial in the frequency range of 400 to 800 Hz.

Saldner et al. (5) studied the action of the soundpost by employing a TV-holography technique to visualize the modal patterns of an unvarnished violin in real time and measuring bridge admittance of the violin. They compared the violin without soundpost, with soundpost in normal position and with soundpost 10 mm closer to the centerline. Through the bridge admittance measurements, they found that the magnitude of the B1- peak stays about the same with soundpost in normal position or 10 mm closer toward the centerline; the frequency of the B1- peak increases by 25 Hz (5%) when moving the soundpost closer to the centerline. The magnitude of the B1+ mode however increased considerably when shifting the soundpost closer to the centerline, with the frequency of the B1+ mode remaining about the same. In observing the holographic vibration distributions for the B1- mode, they found a similar frequency shift as in the bridge admittance measurements. Compared to without soundpost, they found that the main vibrations in the top plates are shifted to the opposite side to the soundpost. There are small vibrations or a nodal line at the soundpost position. The soundpost makes it possible for the symmetric vibration modes to be excited by the bridge.

Jansson (6) measured the bridge admittance to compare the violin with soundpost and without soundpost as well. He found that the magnitude of the “bridge hill” (BH) is the highest with soundpost in the bridge admittance measurement, while without the soundpost, the magnitude of a peak at approximately 550 Hz is the highest. He also explored the effect of the soundpost position on the violin timbre. The soundpost was moved closer toward the bridge or further away from the bridge, and closer to the centerline or towards the nearby f-hole by 5 mm. The BH was attenuated when the soundpost was moved closer to the bridge, and the timbre turned shaper; the BH was increased when the soundpost was moved away, and the timbre became softer. The magnitude of the B1+ peak increased with the soundpost moved towards the centerline, and the timbre turned darker; the magnitude of the B1+ peak decreased with the soundpost moved towards the nearby f-hole, and the timbre became lighter. However, no formal perceptual evaluation of the violin timbre variation was conducted.

Most of the previous research studying the role of the soundpost is from physics and acoustics aspects. How the soundpost affects the perceptual qualities of the violin, however, has not been properly investigated. As often described by luthiers or players, a very subtle change to the soundpost dimension or position can result in significant variations in the violin quality, especially when the changes are around the optimal soundpost condition. Therefore, the aim of this study was to investigate correlations between a change in height of the soundpost and variations of the quality of the violin, as evaluated by players.

We decided to focus on soundpost height variations, as it is difficult to specify repeated position changes with sufficient accuracy and speed during a playing experiment. A height-adjustable soundpost was employed for this experiment. Violinists and luthiers were invited to evaluate the violin with different soundpost heights through playing tests with controlled experimental conditions. The first question to be explored is how big of a change in the soundpost height could result in perceivable variations in the violin qualities by violinists and luthiers. In addition, the changes of interest should be around each subject’s optimal soundpost height. Detailed materials and method are described in Section 2. Section 3 presents the results and discussion. Conclusions are given in the final section.

2 MATERIALS AND METHOD

2.1 General design

This experiment explores how changes in soundpost height affect the perceptual qualities of the violin and whether there is a threshold of change below which players do not perceive differences. A violin installed with a height-adjustable carbon fibre soundpost was employed. The experiment was designed as a sequence of playing tests. An experimenter was present to change the soundpost height. Violinists and luthiers were invited to participate. The experiment involved two phases. During the first phase, subjects played and described their feelings about the violin with different soundpost settings in order to find their optimal soundpost height. During the second phase, the experimenter randomly increased, decreased or did not change the soundpost height in ten trials around their optimal height. For each trial, subjects were asked to play the violin, comparing it with the previous setting, and to decide whether they were the same or different.

Players were asked to use their own bows to play the violin and evaluate, as they typically use their own bows when testing violins in real life. Luthiers were given the option of either using their own bow if they play violin or to use a bow provided by us. This experiment took place in a room free of strong resonances and a relatively low reverberation time. The area of the experiment room was approximately 26.7 m^2.

2.2 Soundpost and violin

A height adjustable carbon fibre soundpost (Anima Nova) was employed for this study, as shown in Figure 1. According to the description by the manufacturer (Anima Nova), the soundpost has flexible ball-and-socket joints at its two ends, which allow the soundpost to adjust automatically to every contour of the violin whilst distributing the pressure evenly over the contact area. The upper cylinder shell possessing a scale on its bottom is sheathed with the lower cylinder through an internal thread, and one can increase or decrease the soundpost height by turning the upper cylinder shell anticlockwise or clockwise. A vertical line indicated on the surface of the lower cylinder acts as the pointer of the scale. A height change is specified by a number of graduations. The minimum graduation value is 0.02 millimeter and the scale employs an octal number system. By turning one complete revolution, the soundpost height varies 0.64 mm. There are 5 numbers ranging from 0 to 4 on the scale. Between adjacent numbers, there are 8 minimum graduations. Through the special tools provided by Anima Nova, one can change the soundpost height without taking it out of the violin body. Two adjacent numbers can always be seen simultaneously from the f-hole.

Figure 1. Anima Nova height-adjustable soundpost

The violin used in this experiment is a performance-level violin borrowed from Schulich School of Music, McGill University. We asked a local luthier to help replace the original wooden soundpost (around 53.77 mm high) with the Anima Nova height-adjustable soundpost. The height-adjustable soundpost was placed about 3.5-4 mm below the bridge and centered with the treble foot of the bridge according to the soundpost manufacturer's instruction. The soundpost was set initially at a relatively low height, approximately 53 mm.

2.3 Participants

Thirteen experienced violinists and six skilled luthiers participated in this experiment. Among the players, there were 8 females, 5 males; 7 native English speakers, 3 native Chinese speakers and 3 other native speakers. Their average age was 30 yrs (SD=9 yrs, range=21-54 yrs). They had at least 16 years of playing experience (mean=23 yrs, SD=7 yrs, range=16-40 yrs), and at least 8 years of training (mean=18 yrs, SD=4 yrs, range=8-26 yrs). They reported to play 23 hours per week on average (SD=10 hrs, range=6-37.5 hrs). Eleven players described themselves as professional violinists. One of the players was a doctoral candidate in music performance, 2 had master's degrees in music performance, 4 were master students in music performance, 3 had bachelor's degrees in music performance, 1 had a bachelor's degree in arts, and 2 were currently undergraduate students in music. They reported to play various types of music [classical (100%), contemporary (69%), jazz/pop (38.5%), baroque (23.1%), and folk (15%)]. 85% of them play in chamber music, symphonic orchestra or solo, respectively. One of the players play in Folk/Jazz band, pop band, chamber orchestra or work as a private music teacher, respectively. Among the luthiers, there were 4 males, 2 females; 3 native English speakers and 3 native French speakers. Their average age was 48.5 yrs (SD=11 yrs, range=36-61 yrs). They had at least 15 years of experience being a violin maker. Five luthiers played violin, among them there were 1 professional violinist, 2 advanced players and 2 beginners. All subjects were paid for their participation.

2.4 Detailed procedure

This experiment consisted of two phases and lasted about 1 hour. Subjects were scheduled individually. Two experimenters were present during the experiment. One experimenter, who made adjustments to the soundpost, sat behind a table, with a screen in front to prevent subjects from observing the adjustments. The other experimenter helped with facilitating the experiment and taking notes for the subjects. During the first phase, the soundpost was initially set at a relatively low height, around 53 mm. Subjects were then asked to play the violin with this initial setting and describe their feelings. Then the experimenter increased the soundpost height by 8 graduations, or about 0.16 mm and the subjects repeated the playing and describing process. Depending on the subjects' descriptions, the experimenter decided to increase or decrease the soundpost height by different graduations in order to find their most preferred setting, which required from 5 to 9 trials. Each soundpost height adjustment took about a minute to complete.

There was a 5-minute break between phase 1 and phase 2. During the second phase, the experimenter randomly increased, decreased or did not change the soundpost height in ten trials within a range of approximately ±0.1 mm around their optimal height. Subjects were asked to play the violin during each trial and compare it with the previous setting, to decide whether they were the same or different. At the beginning of phase 2, subjects were asked to play the violin with their optimal soundpost heights again. Then the experimenter increased, decreased, or did not change the soundpost height by different graduations over ten trials according to a plan determined in advance, which was unknown to subjects. The height variations are ΔH=0, 0, 2, -2, 3, -3, 4, -4, 5, -5 graduations (actual height of ΔH = 0, 0, 0.04, -0.04, 0.06, -0.06, 0.08, -0.08, 0.1, -0.1 mm). They were randomized differently for each subject, while keeping the variations approximately within ±0.1 mm around the subjects' optimal height. To minimize subject fatigue, there was a 5-minute break after five trials.

Thresholds were estimated using detection theory (7). As shown in Table 1, we have two stimulus classes. Height variations of ΔH=0 are class S1, and ΔH=2, -2, 3, -3, 4, -4, 5, -5 are different cases of the S2 class. A "Hit" is defined as a correct identification of an S2 class element (participants recognize a height change). A "False alarm" is defined as an incorrect identification of an S1 class element (they think the height changed when no variation of the soundpost height was made). Table 1 summarizes the four possible cases. The hit and false-alarm rates can be written as the following probabilities:

$$H = P(\text{“Different”} \mid S2) \tag{1}$$

$$F = P(\text{“Different”} \mid S1) \tag{2}$$

The perceptual sensitivity is estimated using the d' measure: d' is defined in terms of the inverse of the normal distribution function z:

$$d' = z(H) - z(F) \tag{3}$$

Thus, when H=F, d'=0 and the performance is at chance; when H>F, d'>0, which means that subjects are able to recognize a difference in height. The sensitivity of detection increases as d' increases. When H=0.99, F=0.01, d'=0.465: this is considered as an effective ceiling by many experimenters. By calculating d' for each ΔH, we can estimate the sensitivity in soundpost height variation.

Table 1. Different responses for different stimulus classes

Stimulus Class	Response	
	"Different"	"Same"
Different soundpost height (S2)	Hits	Misses
Same soundpost height (S1)	False alarms	Correct rejections

3 RESULTS AND DISCUSSION

3.1 Optimal soundpost heights

During the first phase of the experiment, we found an optimal soundpost height for each subject. The optimal soundpost heights were represented relative to the original soundpost height (around 53 mm). Figure 2 shows the relative optimal soundpost height of each subject sorted from smallest to largest. Figure 3 displays the boxplots of the relative optimal soundpost height for all subjects, players and makers separately. The interquartile ranges of the relative optimal soundpost height for these three groups are 0.3 mm, 0.32 mm and 0.26 mm, respectively. The interquartile range for makers is smaller than players, the median relative optimal soundpost height for makers (0.28 mm) is also lower than for players (0.36 mm). The mean relative optimal soundpost height and SD for all subjects are 0.34 mm and 0.156 mm. The corresponding mean and SD for players and makers are 0.36 mm, 0.163 mm and 0.3 mm, 0.143 mm, respectively. Players had a higher mean relative optimal soundpost height than makers. Figure 4 displays the mean relative optimal soundpost height for all subjects, players and makers separately. Error bars of two-sided 95% confidence interval of the means are also displayed. The confidence interval error bar of the means for makers is very high, which might be partially due to the small number of maker participants. We compared the relative optimal soundpost height for players and makers by performing the independent-samples Mann-Whitney U test. The results showed that the null hypothesis that the distribution of the relative soundpost height was the same across players and makers could not be rejected, $U=28$, $z=-0.969$, $p=0.368$.

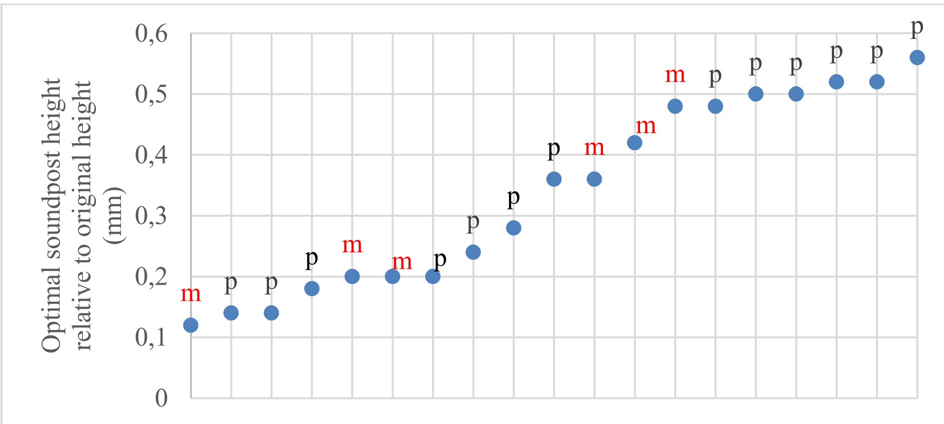


Figure 2. Optimal soundpost height relative to original height for each subject (m: makers; p: players)

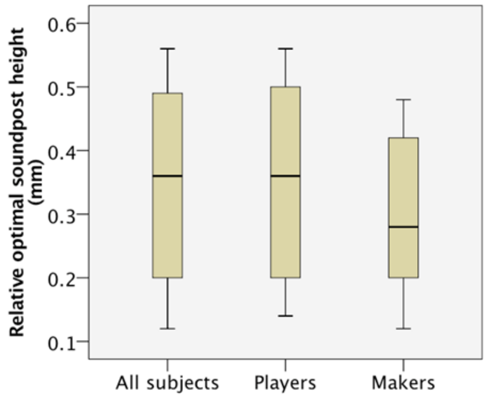


Figure 3. Boxplot of the optimal soundpost height relative to original height for all subjects, players and makers

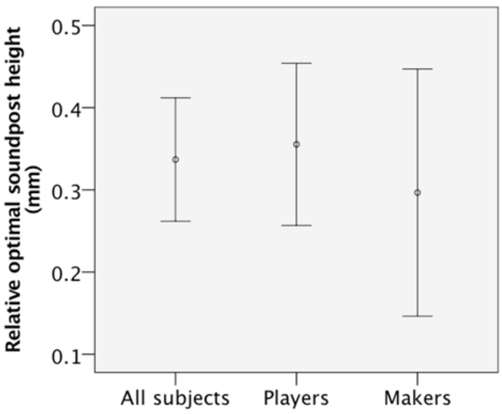
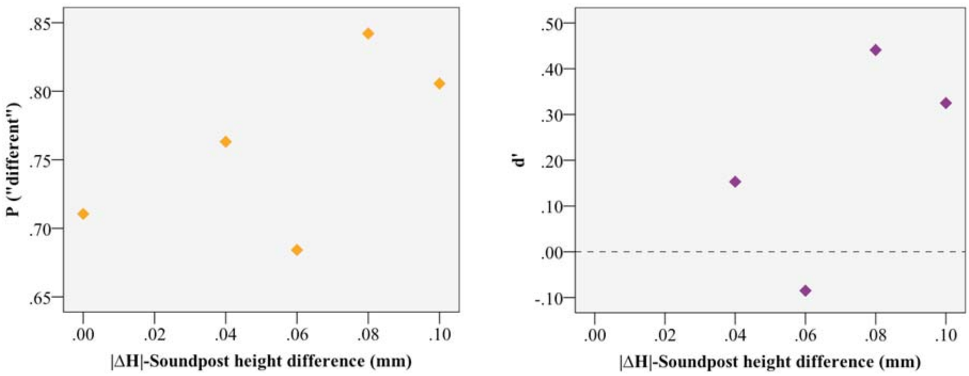


Figure 4. Mean optimal soundpost height relative to original height for all subjects, players and makers (error-bar = 95% confidence interval of the mean)

3.2 Perceptual threshold of soundpost height differences

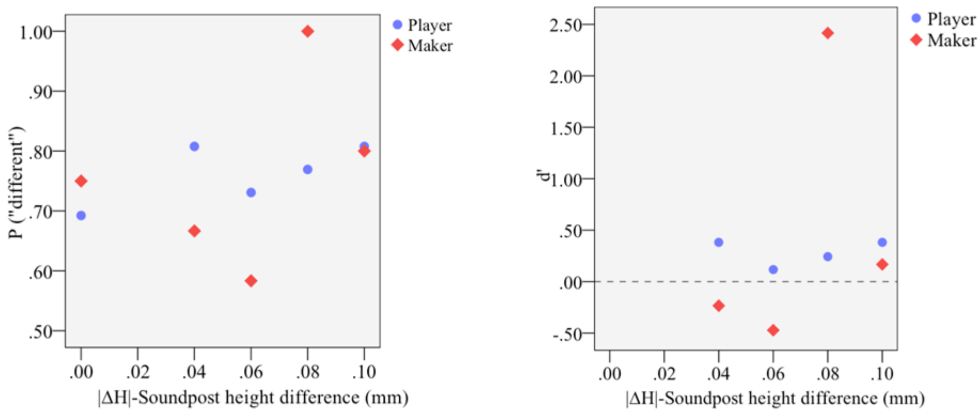
As described in the detailed procedure, we can estimate the threshold of the soundpost height differences by calculating a sensitivity measure d' for each ΔH. During phase 2 of this experiment, positive ΔH and negative ΔH were counterbalanced by randomizing the presentation of positive ΔH and corresponding negative ΔH for subjects. In addition, in order to increase the number of test trials (sample size) and estimate the threshold more precisely, we calculated d' for each $|\Delta H|$ instead of each ΔH. Figure 5(a) shows the probabilities that subject considered the two soundpost heights with a height difference of $|\Delta H|$ as "different". We can see that the false alarm rate, which corresponds to P ("different") for ΔH=0 mm is very high: 0.71. It is even higher than the hit rate for $|\Delta H|$ =0.06 mm: 0.68. The highest hit rate is for $|\Delta H|$ =0.08 mm: P ("different") =0.84. The d' for each $|\Delta H|$ is shown in figure 5(b). d' for $|\Delta H|$ =0.04, 0.08, 0.1 mm are bigger than 0, implying that subjects could recognize soundpost height changes of 0.04, 0.08 and 0.1 mm at greater than chance level. It is however surprising that d' is negative for $|\Delta H|$ =0.06 mm as, in this range of $|\Delta H|$, an increase of the sensitivity would have been expected with an increase of $|\Delta H|$.



(a) (b)

Figure 5. (a) Probabilities subjects considered the two soundpost heights with a height difference of |ΔH| as "different"; (b) perceptual sensitivity d' for each |ΔH|

In figure 6, we compare the results for players and makers. Dividing the population into two groups can be problematic because it reduces the amount of data in each group (which was already low), especially in the group of makers. The following results may only be indicative. Figure 6(a) displays the probabilities that players and makers considered the two soundpost heights with a height difference of |ΔH| as "different". We can see that the false alarm rate for makers (0.75) is higher than for players (0.69). The hit rates for makers vary more with |ΔH| than for players. The hit rates for |ΔH| =0.04 mm and 0.06 mm are much lower for makers than players, while the hit rate for |ΔH| =0.08 mm is much higher for makers (1) than players (0.77). The corresponding d' for each |ΔH| of makers and players are shown in figure 6(b). All d' for |ΔH| ≥0.04 mm is greater than 0 for players, while only d' for |ΔH| =0.08 mm and 0.1 mm are greater than 0 for makers.



(a) (b)

Figure 6. (a) Probabilities players or makers considered the two soundpost heights with a height difference of |ΔH| as "different"; (b) perceptual sensitivity d' of each |ΔH| for players and makers, respectively

4 CONCLUSIONS

In this experiment, we explored violinists' and luthiers' perception of violin soundpost height differences through a playing test. By employing a height-adjustable soundpost, we were able to find the optimal soundpost height for each subject and investigate the perceptual sensitivity to soundpost height differences around each subject's optimal soundpost height.

The results showed that the optimal soundpost height for each subject varies within an interquartile range of

0.3 mm. The variation interquartile range is higher for players (0.32 mm) than for makers (0.26 mm). The mean relative optimal soundpost height is also higher for players (0.36 mm) than for makers (0.3 mm). Statistical analysis showed that the differences of the relative optimal soundpost height for players and makers were not significant. The perceptual threshold of the soundpost height differences around each subject's optimal soundpost height was estimated through calculating a perceptual sensitivity measure of d'. The results for all subjects showed that subjects could recognize height changes of 0.04 mm, 0.08 mm and 0.1 mm at better than chance levels, but couldn't recognize the height change of 0.06 mm. Further investigation showed that the biggest fluctuation came from the makers' results. Players could recognize height changes of 0.04 mm and greater at above chance levels, but makers could only recognize the height changes of 0.08 mm and greater.

Overall, the subjects performed at only a little bit greater than chance level in recognizing the differences we presented. And the false alarm rate was very high, i.e., subjects tended to say "different" even though there was no change at all in the soundpost height. That might partly be due to the sequential nature of the trials (they could not compare the different settings at the same time) and thus they might forget what the previous setting was like (though it only took a minute or less to make the soundpost changes). As well, there was a significant amount of variation in their organization approach to violin evaluation. Some subjects used a very consistent set of playing materials for each trial, while others used either very limited or changing materials between trials. Makers were in general significantly less skilled than players and thus may not have been able to "explore" the full range and capabilities of the violin. Additionally, the variation of soundpost height was quite small (within ±0.1 mm), which made the task very difficult and could have contributed to player fatigue, so perhaps the true perceptual threshold is beyond that range. Finally, there was some imprecision in soundpost adjustments, with an absolute average error of 0.007 mm. All these factors could have had an effect on our results.

ACKNOWLEDGEMENTS

We acknowledge support and funding from the Centre for Interdisciplinary Research in Music Media and Technology, the Natural Sciences and Engineering Research Council of Canada, Hector and Ada Ma China Scholarship Council and the China Scholarship Council. We would like to thank the inventor of the Anima Nova height-adjustable soundpost, Pal Molnar, for generously loaning the soundpost to us, as well as for instructions on the installation and use of the soundpost. We thank the Schulich School of Music for loaning the violin for the experiment. We are also grateful to Tom Wilder for helping with the installation of the soundpost to the violin.

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