D2.5 – User Evaluations of Each Technology in Each Scenario

Project acronym	TELMI
Grant Agreement nr	688269
Project title	Technology Enhanced Learning of Musical Instrument Performance
Call identifier	H2020-ICT-2015
Topic	ICT-20-2015
Type of action	Research and Innovation Action
Start date of project (dur.)	1 February 2016 (36 months)
Report availability	Re-Restricted
Document due Date	31 October 2018 (extension granted)
Actual date of delivery	31 January 2019 (Draft submitted on 31 October 2018)
Leader	Royal College of Music
Reply to	Aaron Williamon, RCM (aaron.williamon@rcm.ac.uk)
Additional main contributors (author's name / partner acr.)	George Waddell, RCM; Ayman Moghnieh, SAICO
Document reference	TELMI-D-WP2-RCM-20181031-D2.5Evaluations_FINAL
Document status	FINAL

Executive Summary

This deliverable documents the processes and results of end-user evaluations conducted with the TELMI technologies. A series of scenarios were employed: open-ended lab-based use-sessions with the technologies in development to drive improvements and prioritise features; lab-based, controlled experiments to determine the efficacy of specific features, and structured field testing to determine usability.

Based on the continual feedback from the pilot and structured field tests, three user-centered platforms have been developed focusing on performance analysis, guided practice planning and review, and social learning. Laboratory-based experimental tests of the core performance analysis system demonstrated significant performance improvements (based on blinded expert evaluation) compared with no-technology control practice sessions after less than 10 minutes of use and strong qualitative responses in which all users expressed a desire to keep using the system, and strong likelihood to recommend its use to other musicians.

To understand this document the following deliverables have to be read.

Number	Title	Description
2.2	Definition of Exercises and Record of Expert Models of Success	Outlines the exercises used within the evaluation scenarios.
2.3	Definition of Student Goals and levels of evaluation	Outlines the success metrics used within the evaluations.

Table of contents

1. Introduction

Tasks 2.6 – 2.8 of the TELMI Project outline a series of evaluations of the TELMI technologies with the end users to determine their efficacy, usability, and by extension, the degree to which they may demonstrate market viability.

Over the course of central phase of the TELMI project (M12-33), WP2 (led by the Royal College of Music) has prioritised driving the development of each technology to points at which the features can be used with relative independence by the end-user, thus allowing the final evaluations to take place in scenarios with acceptable ecological validity. This has been achieved by employing a series of pilot evaluations with end-users, using both quantitative and qualitative approaches, then providing detailed feedback to the respective project partners responsible for each platform to improve and enhance the platforms. Through this work, the suite of TELMI technologies have evolved into a series of independently functional, though interrelated, end-user entities. This comprises:

1. ViolinRT (AKA SkyNote), including its audio and bowing features.
2. The TELMI Planner, including integration with ViolinRT (see Deliverable 5.2).
3. The TELMI Studio (i.e. social platform), initially integrated within the Royal College of Music learning management system (see Deliverable 5.3).

The nature of each of these technologies from the perspective of the end-user is summarised in Section 2 below. As these technologies differed in their developmental stages at the various points of evaluations (e.g. requiring further feedback on user design or feature prioritization), as they differed in the use case (e.g. to be used by an individual student versus use by a group of learners with their teacher), and as they differed in the operational needs (e.g. possible for download and independent use on an individual's laptop versus requiring access to bespoke equipment and technical expertise in a dedicated space), a single approach to evaluation was not deemed suitable. Furthermore, due to the large number of performance features and intended learning outcomes across the various technologies, it was determined that, wherever possible, controlled studies would focus on individual features so that their specific efficacy could be determined in the context of the wider platform. As a result of these needs, three approaches to evaluation were designed:

1. Piloting sessions to collect user feedback and drive development of the applications towards platforms suitable in their perceived utility and ease of use, thus ready for final efficacy evaluations.

2. Lab-based controlled experiments to test the efficacy of specific features within a single practice session.
3. Structured field deployments to determine usability in more naturalistic settings.

Details of each of these approaches are outlined in Section 3 below, with qualitative feedback from the Type 1 Piloting sessions integrated into Section 2 where the drove the development and nature of the prototypes ready for Type 2 and 3 evaluation procedures. including a summary of which technologies have been subject to which deployments based on their particular needs.

Section 4 focusses on the results of two final experimental evaluations of the core TELMI technology, ViolinRT (AKA SkyNote). Each comprised 11 high-level violinists taking part in a multi-stage, pre-post design in which practice without the technology was compared with practice with the technology.

2. End-user technologies for evaluation

This section briefly summaries the prototype technologies from the perspective of the end user, which were subject to end-user evaluations. The development of these technologies was driven by pilot-stage evaluation sessions with end-users carried out across months 18-30 of the project, whose qualitative feedback drove the final design and functionalities of the systems. Specific feedback from end-users leading to these designs is also summarised here.

2.1. ViolinRT

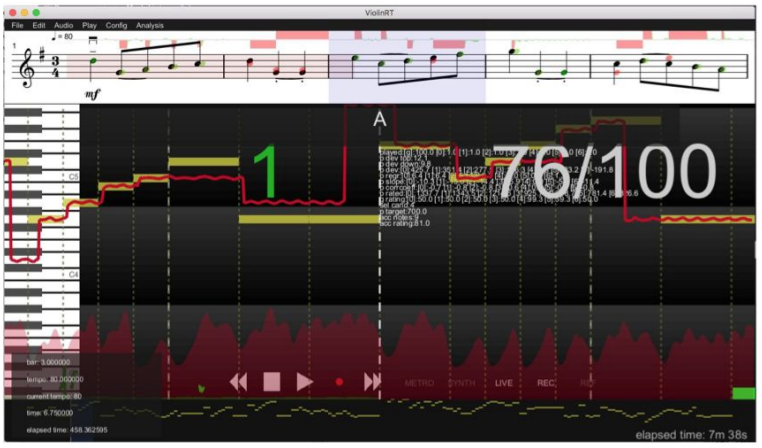
ViolinRT (rebranded as SkyNote when functionality for other instruments was added) comprises the central end-user platform for audio and motion-capture feedback. It consists of three components, differing by their deployment and use cases.

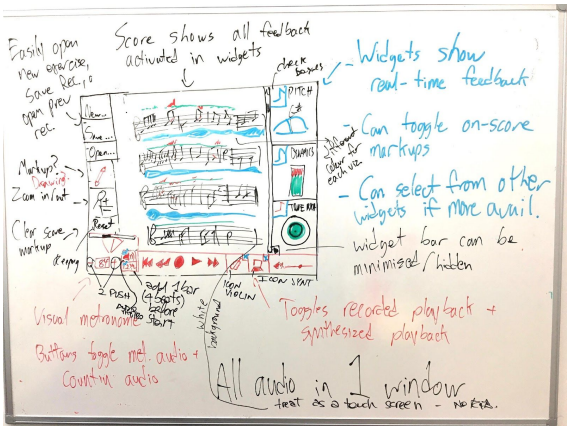
2.1.1. Audio features

The central ViolinRT functionality provides real-time and summarised feedback of audio-based features, initially targeting intonation, rhythm, dynamics, and tone quality. Across months 12-24, the RCM led discussions with violin students and teachers while using the early and developing prototypes of the ViolinRT platform, particularly concerning the user interface and how they would employ the system within their own learning. From this feedback, several key needs arose:

- The system could not be navigated by a user alone, significantly limiting the ability to test the efficacy of the system in an ecologically valid learning scenario. Thus, the system should be easily navigated and employed by a lone student, with clear signposting of features and avoiding the use of menu-trees for selecting features.
- The system should prioritise feedback displayed on the notated score.
- The user should be able to select and repeat particular portions of the score for playback, rather than having to repeat the entire section at once.
- Musicians should be able to customize the visualizations, both of the score and which audio features are displayed in real time. There was variance between those that wishes to see several features at once versus those that felt overwhelmed and wished to highlight specific features.
- The system should be available on both PC and Mac platforms, due to the ubiquity of Mac use among students.

To achieve these, the RCM created a mockup of a potential user interface. Figure 1 shows the early prototype demonstrated to violinists (see Deliverable 3.3), conversion to a digital mockup, and the final implementation being trialed by a violinist. Feedback relating to intonation, dynamics, and tone quality





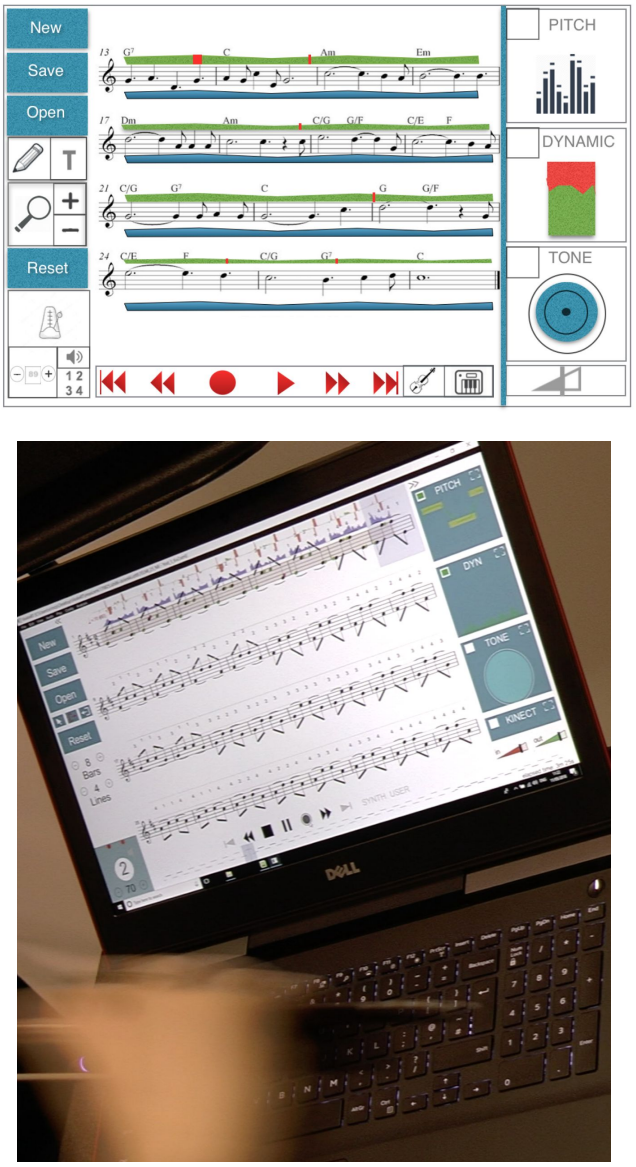


Figure 1: Top: Early prototype of ViolinRT; **Middle:** RCM mockups based on early system piloting; **Bottom:** final prototype for evaluation.

can be overlaid on one of the exercises taken from the TELMI catalogue (see Deliverable 2.2). The system is available on both Mac and PC platforms as a single installer, and as issues of intonation and dynamics are not specific to the violin, the system is compatible across monophonic instruments (called “SkyNote” in these settings).

2.1.2. Bowing features

As with the audio features, user pilot sessions focusing on the bowing features highlighted a need for user functionality and the ability to contextualize bowing feedback within the context of the score in addition to the bowing visualizations already developed in the second prototype (see Deliverable 3.3). Again, the RCM created a mock-up of how a score-based approach to bowing feedback could be implemented based on the user feedback and using the design approach of the audio features, allowing for a homogenous experience for the end-user (see Figure 2a left). Central to this approach was the focus on the custom bowing factor exercises developed by Madeleine Mitchell (RCM) for the TELMI project (see Deliverable 2.2), though as the initial notations were in graphic form the RCM converted these to traditional notation (see Figure 2 right). Pilot evaluations with this new visualization approach led to further feedback from violinists, which was communicated to UPF for further development. Examples of this feedback, and the actions taken, are presented in Table 1.

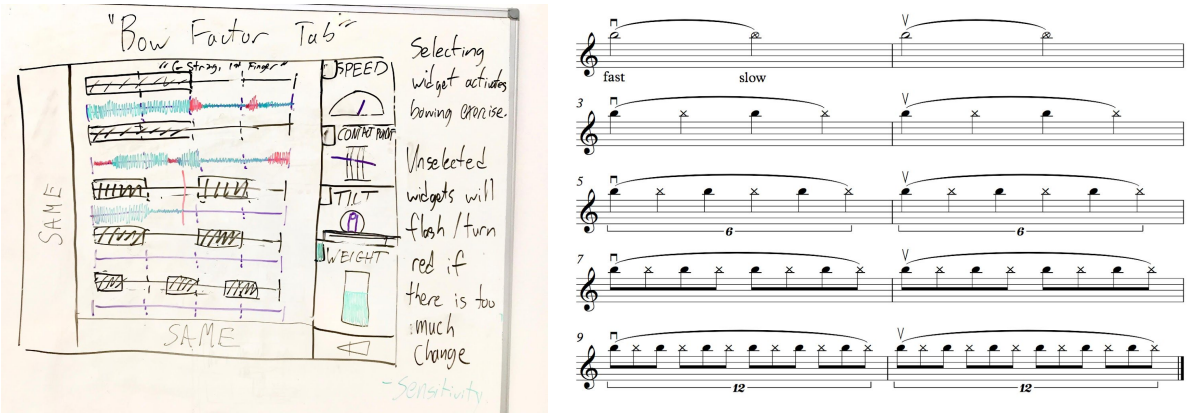


Figure 2a: Top right: RCM mockup of bowing features based on early system prototyping; **Top left:** Conversion of the bowing exercises to standard notation.

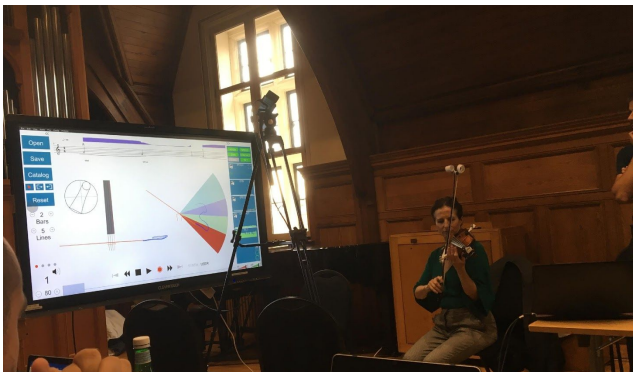


Figure 2b: Final prototype for evaluation, highlighting score-based feedback (left) and bowing visualizations (right).

Table 1: Examples of qualitative user feedback emanating from the pilot evaluations, and actions taken in their improvement.

Issues raised in pilot evaluations with enhanced, score-based visualisation	**Actions taken**
Overall Accuracy & Performance ● The bowing visualizations are not interpreted as entirely 'smooth', limiting a user's ability to use the feedback in real time. ● Speed is not perceived as fully accurate when alternating between slow and fast speeds within a single bow. Spikes are often shown as quite erratic spikes of speed in the slow sections.	Instrument marker configuration, Kinect calibration, and internal algorithms improved for accuracy.

Bow markers ● Violinists would prefer removable clips to adhesives when considering a use case where their own instrument is marked. ● Placement of the markers limits performance in the upper positions on the neck as it obscured a marker	Clip-based approach taken for marker attachment, and marker position revised to facilitate performance (see Figure 3).
Visualisations ● Invert the tilt feedback or give options to allow inversion (including option for contact point).	Visualisation options added.

The bowing features of ViolinRT are distinct from the audio features in several key aspects. Where the audio features can be operated on a lone laptop (Mac or PC) using the internal microphone, the bowing features require the use of the Microsoft Kinect (and thus a laptop operating the Windows 10 operating system) as well as violin and bow with markers (see Figure 3). It also requires the separate download and operation of the Kinect server and calibration functions. As a result, where the audio features can be functionally deployed in live settings in that an end user can download, install, and operate the system on their own device, the bowing features are currently limited to the RCM performance lab (see Deliverable 2.4 for a description), thus evaluations are limited to controlled, lab-based user experiments.

Figure 3: Violin and bow with revised marker placement used in the lab-based evaluations of the ViolinRT bowing features.

2.2. TELMI Planner / SkyNote

The TELMI Planner provides a practice management tool designed to guide students through the principles of self-regulated learning by guiding the planning, execution, and review of each practice session (as defined in Deliverable 2.1). The platform's full features are described in Deliverable 5.2 and 5.4, and usability was refined following a 1-week pilot implementation with 4 RCM students in a semi-structured field test. Due to the need for users to engage with the technology in their own practice over a period longer than a single session, development prioritized installers for both Mac and Windows as well as a self-contained tutorial instructing its use (see Figure 4).

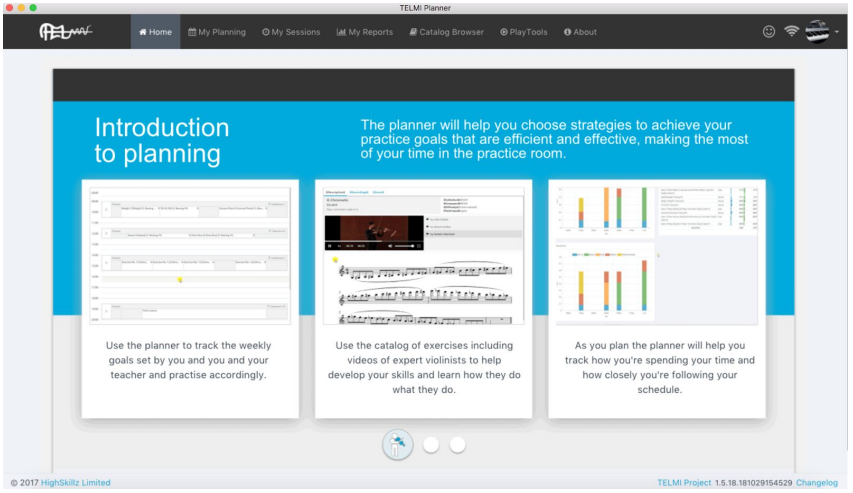


Figure 4: Tutorial features within the TELMI Planner allowing for structured live field deployment and evaluation.

The TELMI planner includes the audio features of ViolinRT (i.e. SkyNote), which can be launched from within the planner in the context of planned practice activities.

2.3. TELMI Studio

The TELMI Studio (aka MasterStudio) represents the social features of TELMI, allowing learners to come together to share performance practice in the model of a live studio class. The technology is fully described in Deliverables 5.3 and 5.5. HIGHSKILLZ and the RCM (including the RCM Digital team) have collaborated to provide initial implementation within the Royal College of Music's Learning Management System (LMS; Canvas by Instructure), where RCM faculty and students can use their

existing logins to access the platform remotely for trial sessions (see Figure 5). This allows for structured field testing using existing networks of instructors and their students. Key feedback from demonstration sessions with musicians and teachers have emphasized the need to expand the system to accept the upload of video recordings and evaluation, to upload musical scores, and to increase options for summarizing feedback and communication over one or more session. There is also a key demand for a stand-alone system that does not require integration within an existing LMS and can target the large, private market of music instruction. These features are being considered in future efforts to commercialize the platform.

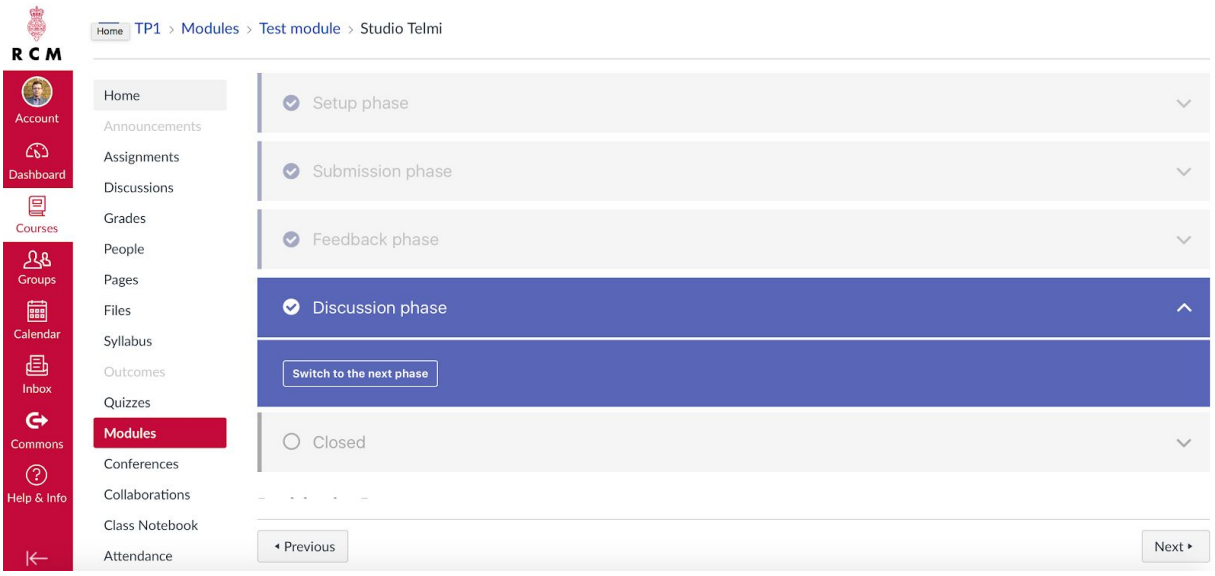


Figure 5: The TELMI Studio integrated within the Royal College of Music LMS.

2.4. EyesWeb

A user-centric version of the EyesWeb motion analysis features was proposed following pilot evaluations with RCM violinists and 2 RCM instructors in Alexander Technique. From this feedback, the RCM proposed a mock-up of a potential end-user interface for musicians to highlight and record specific features and limbs (see Figure 6), emphasizing the need to isolate the central spine-neck-head connection and the limbs (and their symmetry) and to see these from key angles (front, side, above). This would be combined with a simple interface to record and play back sessions, and to export videos for students and teachers/Alexander Technique instructors to share.

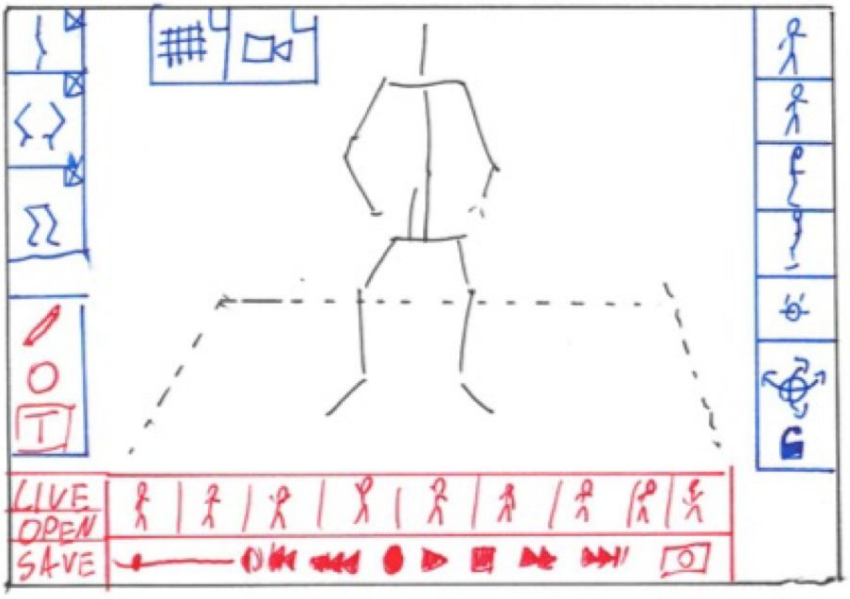


Figure 6: RCM mock-up of EyesWeb end-user interface based on user feedback from pilot evaluations of the motion capture features.

3. Evaluation formats

The differing nature of the technologies to be evaluated in terms of their implementation, features, and user-readiness necessitated a flexible approach to designing evaluation formats. Ethical approval for each scenario was granted by the Conservatoires UK Research Ethics Committee. The three approaches taken are described below.

3.1. Piloting feedback

Initial evaluations of early and developing prototypes in Months 12-30 focused on having users engage with the system directly and collecting feedback through interview and discussion, which was consolidated and fed back to the relevant TELMI partner developing the prototype in terms of problem areas and proposed solutions. This was done in individual and group settings.

- For ViolinRT, this primarily occurred within the RCM performance lab (see Deliverable 2.4), and Section 2 above describes how this feedback was consolidated and fed into the development of the prototypes.
- For the TELMI Planner, an early prototype of the planner was deployed to RCM students for one week of use followed by a focus group discussion led by the RCM and HIGHSKILLZ in which they highlighted developmental issues that were improved in further implementations. Further communication with musicians highlighting key features led to continual improvements, focusing especially on integration of ViolinRT/SkyNote within the Planner's functionality.
- For the TELMI Studio, initial piloting sessions were arranged with musicians and teachers to ensure feasibility and usability of the platform and guide future development.

3.2. Lab Experiments

Controlled laboratory experiments were employed to test the core TELMI features focusing on the development of individual violin skills (as defined in Deliverable 4.1) as featured in ViolinRT. These were situated in the RCM performance lab with the equipment setup described in Deliverable 2.5.

The aim of the lab settings was to test the impact of a particular feature of ViolinRT in a 10-minute-maximum practice session focusing on a single, skill-specific exercise in comparison with a similar session without use of the technology. Audio and video data were collected of pre- and post-practice recordings as well as the practice session itself, and qualtiative feedback was also collected in these sessions to better understand engagement with the system and to drive further development.

The materials and procedure for these experiments was as follows.

3.2.1. Materials / data recording

The laptop with ViolinRT was placed on a music stand in reach of the musician, above which a second music stand was placed to hold a paper version of the notated score (to ensure that any difference in technology/no-technology use wasn't hindered by lack of ability to refer to a traditional hard copy). Video was recorded in a frontal view, and in a second view trained on the screen to observe how the user engaged with the system (see Figure 7). In cases using the bowing features, the floor was marked at the point where the violinist needed to stand relative to the Kinect, and a violin and bow provided with markers attached and having been pre-calibrated with the system.

Figure 7: Setup for the lab-based experiments, with ViolinRT loaded on a laptop above which a notated score was provided, and a second camera capturing video of the interaction. A camera and Kinect were mounted to the front of and above the performer.

In addition to information and consent forms (see Appendix A), four paper questionnaires were employed (as described in Deliverable 2.3 and included in Appendix B).

1. *Self-efficacy*: a measure of the participant's confidence in their ability to successfully perform the exercise in the pre- or post-practice recording (from Ritchie & Williamon, 2011).
2. *Pre-test*: a self-assessment of the participant's perceived success in recording an exercise before having time to practice, including specific technical features (e.g. intonation, dynamics) as well as room for improvement.

3. *Post-test*: a self-assessment of the participant's perceived success in recording an exercise after the practice stage, repeating the questions of the pre-test but including questions on the perceived efficacy of and the mental and physical exertion required within the practice session.
4. *Technology assessment*: after sessions in which a technology was used, a survey investigating the usefulness and ease of use of the system (adapted from Davis, 1989) and including open-ended questions on the strengths and weaknesses of the technology captured in writing or as a semi-structured interview with the researcher.

3.2.2. Procedure

Participants first provided informed consent (see Appendix A) and standard demographic information (age, programme and year, years of experience on their instrument, etc.). In scenarios where bowing features are being tested, they are at this point given time to familiarize themselves with the provided violin and bow, including markers. They are allowed to affix their own shoulder or chin rest if they wish. They are also given an opportunity to practice maintaining the correct position relative to the Kinect to allow for accurate data collection using the visualization provided.

Following this first stage, musicians are given a hard copy of the notated score of the first of two exercises that they will be asked to record. Table 2 shows an example of the scores (taken from the TELMI exercises presented in Deliverable 2.2) used in an audio scenario and in a bowing scenario. After being given a moment to scan the score (without playing), they completed a *self-efficacy* questionnaire regarding their confidence in sight-reading the work. They then recorded the performance, and in the case of the bowing exercises did so along with the ViolinRT software (with metronome) at the exercise's default tempo, though they did not receive any feedback from the software. Each session was audio and video recorded, and the recording from ViolinRT saved. Following the performance the participant completed the *pre-test* form. They were then asked to practise the exercise (without the use of any new technologies) with the goal of making a second recording with as much improvement as possible. They are told they have up to 10 minutes to practise but can let the researcher know if they'd like to stop earlier and make the second recording if they feel they've improved it as much as they can. A time period of 10 minutes was chosen as it was considered a reasonable amount of time a violinist might spend on a single technical exercise in a typical practice period. At this point (or after 10 minutes) they complete recording as before, completing the *self-efficacy* form before and the *post-test* form after.

Table 2: Exercises used in the laboratory tests

	TELMI Exercise (D. 2.2)	***Skill***

Audio	3-Octave Scale in G Major	Intonation (easy)
(intonation, dynamics)	Yost Change of Position Exercise	Intonation (difficult)
Video	Bow factor exercise: Tilt	Bow control
(bowing)	Bow factor exercise: Speed	Bow control

The second exercise loop is conducted in a similar fashion, though during the practice period the participant is free to use ViolinRT as they see fit. They are given a brief (<2-minute) summary of what the software can do and given the opportunity to ask any questions about its use. The order of the two pieces indicated in Table 2 are counterbalanced between participants in their use in the *no technology* or *with technology* categories. Following the completion of this session (including the same forms) the participant completed the *Technology assessment* survey, which was followed if needed by a brief interview with the researcher about the technology.

This procedure is summarised in in Figure 8.

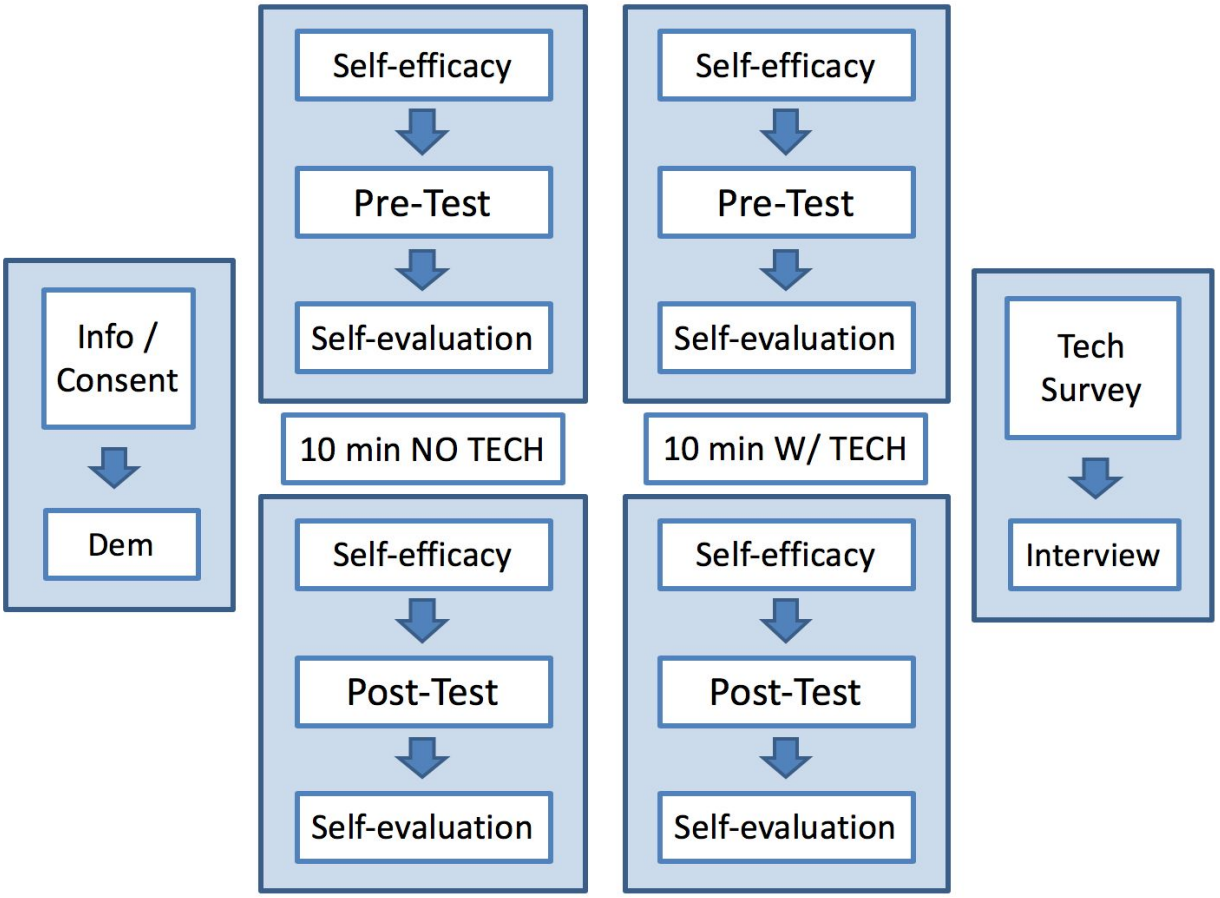


Figure 8: Protocol summary for the lab-based control experiments, in which TELMI exercises are tested in *with technology* and *no-technology* conditions.

3.3. Structured field tests

In cases of technologies where it could not be feasibly tested in a single, experimental setting due to the prolonged nature of the use case, structured field tests can be used. This is not currently feasible for the bowing features of ViolinRT due to its current reliance on the performance lab setup and motion capture equipment. However, the TELMI Planner (with SkyNote integration) and Studio have been pushed to a stable version so that live field testing can be pursued as commercialisation opportunities are followed.

4. Results of the final Lab-based evaluations

The following comprises results of the lab-based tests of ViolinRT following the protocol described in Section 3.2. Participants recorded performances of two exercises before and after a practice period of up to 10 minutes. During the second practice period they were given the ViolinRT platform featuring the automatic intonation and dynamic analysis to optionally use during their practice. Each session was followed by an interview during which the violinists were asked about the strongest and weakest features and suggested improvements, and whether/in what situations they would see themselves using the technologies in their practice and teaching.

4.1. ViolinRT Audio Features

The audio features were tested using a G major scale and a Yost string-change exercise, both of which focused on accurate intonation with a secondary focus on consistent dynamics and an even rhythm. Only the audio features (i.e. intonation and dynamics) were highlighted to the musicians in the demonstration of the technology.

4.1.1. Participants

Eleven (8 female, 3 male) conservatoire-level violinists participated in the test, with a mean age of 24.82 years (SD = 5.36, range 20-38). They had a mean 19.63 (SD = 4.98) years of playing experience on the violin, having actively taken violin lessons for a mean 17.36 years (SD = 3.78). The group comprised three undergraduate, seven masters, and one doctoral-level students. They reported completing a mean 17.64 (SD = 28.29) concerts (both solo and ensemble) in the previous 12 months, in some cases an approximation based on their memory. Ten of the 11 violinists reported actively teaching the violin, estimating they had taught a mean 37.30 (SD = 22.50) students (primarily at the beginner and intermediate level) across their teaching experience. Each followed the procedure described in Section 3.2 above.

4.1.2. Expert evaluation scores

Video recordings taken from each session were presented to a professional violinist for evaluation on a scale from 1-7. Videos were presented in grouped pairs by participant and exercise, consistently in the pre-post order. The expert was not informed whether the student had practised with or without the technology, thus any perceived improvement between the pre- and post- scores would not be biased by knowledge of the independent variable. The evaluator was free to review a video multiple times if they

chose, and the order in which they were presented video pairs with versus without technology was randomized.

A 2x2 factorial repeated-measures ANOVA was used to test the hypothesis that use of the technology would lead to a larger increase in expert rating in the post-test recording compared with the pre-test recording. Due to the relatively small sample size and presence of a hypothesized direction of effect (i.e. technology would increase, not decrease, practice improvement), a one-tailed calculation of significance was used. Pre- versus post-test was entered as one independent variable and with-technology versus without-technology was entered as the second independent variable, thus the interaction effect would demonstrate whether difference pre-/post-test was mediated by use of technology. A significant, very strong main effect of pre/post was found ($F_{(1,10)} = 47.62$, $p < .001$, $\eta^2 = .82$) in which the post-test performances were rated significantly higher than the pre-test performances across both groups. No significant main effect of with/no-technology was found. However, a significant interaction with a medium effect size was found ($F_{(1,10)} = 3.75$, $p < .05$, $\eta^2 = .27$), in which participants when not using ViolinRT saw a mean increase of 0.62 points on the seven-point scale (SD = 0.67) from their pre-test scores (M = 3.55, SD = 1.44) to their post-test scores (M = 4.18, SD = 1.47), and when using ViolinRT saw an increase of 1.18 points (SD = 0.60, i.e. nearly double; see Figure 9) from their pre-test scores (M = 3.46, SD = 0.82) to their post-test scores (M = 4.64, SD = 0.81).

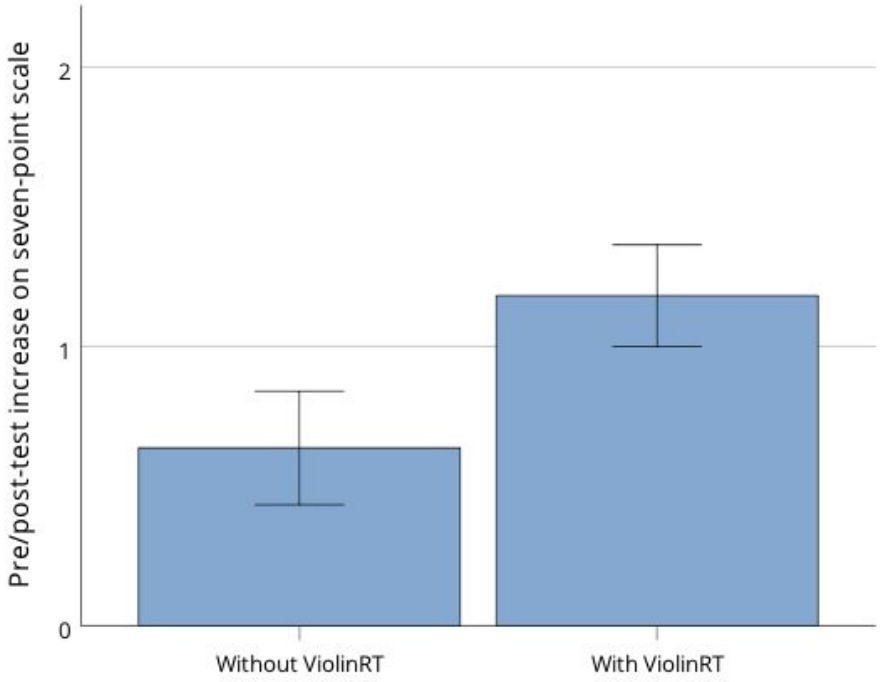


Figure 9: Significant increase (demonstrated by a 2x2 repeated-measures ANOVA interaction) in pre/post-test performance when using ViolinRT for up to 10 minutes versus not using ViolinRT in

intonation-focused exercises and using audio-focussed feedback. Error bars show +/- 1 SE to account for repeated-measures comparison.

4.1.3. Self-evaluation scores

Primary examination of the self-evaluation scores focused on the first, overall "performance quality" measure provided by the students in the pre- and post-test self-assessments completed immediately after the recordings. As with the expert evaluations, a 2x2 factorial repeated-measures ANOVA was used to examine pre/post versus technology/no-technology effects and their interaction. A direction of effect was not hypothesized, as it was considered that use of the technology might make students more aware of their shortcomings in performance and result in a lower degree of improvement, as well as the possibility of them recognizing greater improvement over the time. Thus, two-tailed tests of significance were considered.

A significant, strong main effect of pre/post was found ($F_{(1,10)} = 18.88$, $p < .001$, $\eta^2 = .64$) in which the post-test performances were self-rated significantly higher than the pre-test performances across both groups. A significant main effect of with/no-technology was also found ($F_{(1,10)} = 4.98$, $p < .05$, $\eta^2 = .33$), wherein both pre- and post-test scores were significantly lower in the with-technology group than the no-technology group (despite the fact that they had no exposure to the technology prior to either of the pre-test recordings). No significant interaction was found. Descriptively, participants when not using ViolinRT reported a mean increase of 1.09 points on the seven-point scale (SD = 1.14) from their pre-test scores (M = 3.91, SD = 1.51) to their post-test scores (M = 5.00, SD = 0.77), and when using ViolinRT saw an increase of 1.27 points (SD = 1.74) from their pre-test scores (M = 3.09, SD = 1.30) to their post-test scores (M = 4.36, SD = 1.21).

The lack of significant effect of the technology in the self-evaluations was mirrored in examining self-evaluations of the specific technical points (technique, musicality, intonation, rhythm, tone quality, dynamics, articulation). Bonferroni corrections were applied to control for the multiple comparisons, though significance levels would have remained above p = .05 without their application in any case.

4.1.4. Self-efficacy scores

Self-efficacy scores were summed from the nine items (following appropriate reverse-coding following Ritchie & Williamon, 2011) to form a total score between 9 (low self-efficacy) and 63 (high self-efficacy). Analysis was again conducted using the 2x2 factorial repeated-measures ANOVA. A significant, strong main effect of pre/post was found ($F_{(1,10)} = 18.24$, $p < .01$, $\eta^2 = .65$) in which self-efficacy reported prior to the post-test performances (no tech: M = 50.73, SD = 3.58; with tech: M = 46.73, SD = 5.31) was significantly higher than that prior to the pre-test performances (no tech: M = 45.64, SD = 6.31; with

tech: M = 43.82, SD = 7.51) across both groups. No significant main effect of with/no-technology was found, and no significant interaction was found.

4.1.5. Practice-related scores

Following the post-test recording, participants were asked to rate the perceived efficiency, improvement stemming from, room for improvement following, and mental and physical effort required in the practice session. Paired-sample t-tests were conducted comparing each score in the no-technology condition with that of the with-technology condition. No significant differences were found, suggesting both that participants did not find the technology to improve efficiency or reduce mental or physical strain, but also that either of these factors were not significantly negatively affected by engaging with the technology for the first time.

4.1.6. Time spent practicing

Participants were allowed to end the practice period at a time of their choosing (i.e. when they felt as ready as possible to complete the second recording with the most improvement), with an upper limit of 10 minutes. Length of practice time was recorded, thus allowing comparison of the time participants spent working on the exercise in the no-technology condition with that spent using the technology. Due to non-normality of the data (i.e Kolmogorov-Smirnov of $p < .05$) due to highly negative skew in the with-technology group, a non-parametric Related-Samples Wilcoxon Signed-Rank test was used to compare time spent practising in each condition. A significant difference with a medium effect size was found ($Z = 1.99$, $p < .05$, $r = .42$), in which participants practised for a mean 6.71 minutes (Mdn = 7.33, SD = 2.86) in the no-technology control condition and for a longer 8.67 minutes (Mdn = 10.00, SD = 2.30) when using ViolinRT, with the majority of violinists (n=8) using the full 10 minutes (see Figure 10). This could indicate the technology encouraging users to give more focus to the exercise, or taking more time to habituate to using the technology.

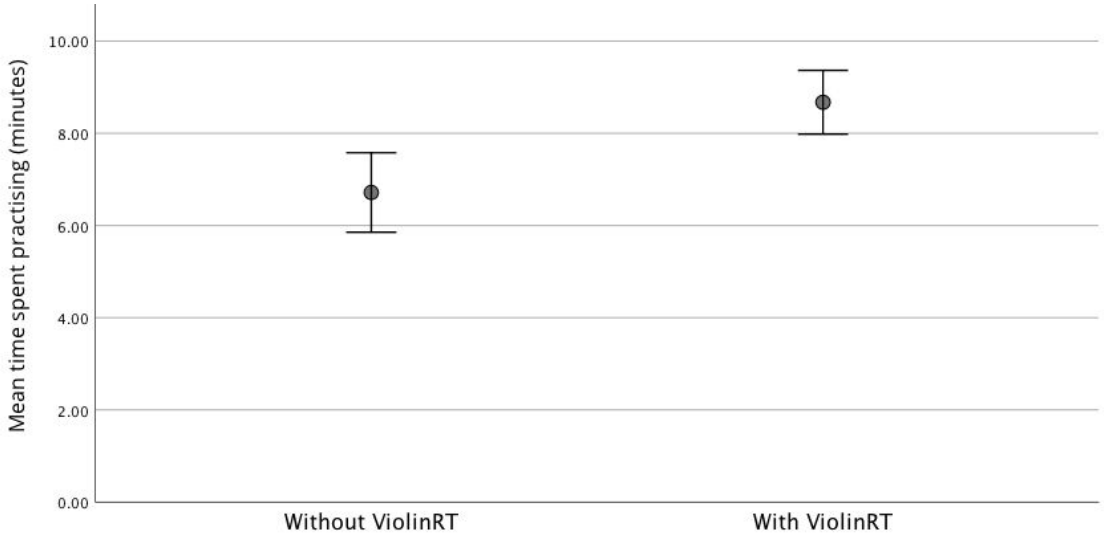


Figure 10: Significant increase (using a Related-Samples Wilcoxon Signed-Rank test) in time spent practicing the exercise without using ViolinRT versus with the technology in the intonation tests. Error bars show +/- 1 SE to account for repeated-measures comparison.

4.1.7. Technology Ratings

Following the final post-test session, participants competing a rating sheet of the systems ease of use (six items, mean calculated), usefulness (six items, means calculated), accuracy, and whether it was a tool they would use again and recommend to others. Scores were above the midpoint (see Table 3, and Figure 13 in section 4.2.7 for a comparison with responses to the bowing features).

Table 3: Technology ratings on a 1-7 scale

	Means	***Standard Deviations***
Ease of Use	4.15	1.42
Usefulness	4.35	1.01
Accuracy	4.64	1.63
Would use again	4.82	1.47
Would recommend	4.72	1.62

4.1.8. Qualitative results

Following the completion of the technology rating scales, participants were asked to either complete in writing and/or speak to the researcher regarding the questions relating their opinions on the strongest

and weakest points of the system, and potential room for improvement. Participants were also asked the fundamental question of whether they saw themselves using the technology were it available to them, and in what situations that might be. They were at this point encouraged to be as forthcoming as possible in their responses, and that as the goal of the interview was to further the technology's development their negative feedback would be valued as equally as any positive feedback.

Would they use it, and where?

In response to the fundamental question of whether could see themselves using the system in their practice, all eleven violinists affirmed in the positive that they would. However, there was variability in the use cases. The majority (n=7) stated that they could see themselves using it on a semi-regular basis in their practice, perhaps weekly, or biweekly, checking on fundamental aspects of particular exercises (akin to the ones highlighted in the test) as a test of their intonation and dynamic control in technically-focussed settings. They generally saw limited application for practicing repertoire, excerpt perhaps examining their consistency in particularly technical passages. In other words, the ViolinRT audio-based features were seen as a better served to address "fundamentals" or "technical features" as opposed to "musical" or "expressive" work. Beyond these seven, another three violinists imagined themselves applying the system in this way on a more regular daily basis. The remaining violinist (a masters-level student with significant teaching experience) could not see herself using the system in her own practice, but could see asking her young students using the system to ensure their intonation was not deteriorating between practice sessions. The majority of the students could not imagine applying the system in their RCM lessons, seeing the tool as something for their own (or their students') practice.

Strongest features

Students in general praised the score-based feedback and the ability to upload a variety of exercises. The ability to show varying levels of detail was also regarded highly; several students (n=2) preferred the advanced, piano-roll-style intonation feedback screen when interrogating particular passages, while the rest preferred the simplified version highlighting individual incorrect pitches on the score with more nuanced feedback unrolled above. The continuous measure of dynamic consistency was also seen as a useful tool by the majority, especially in being able to hide the feedback while playing to reduce visual clutter when focussing on intonation.

Limitations / suggestions for improvement

Two key limitations were raised by the violinists (both previously recognised by the research team, but proving very difficult to practically implement). First, that the system was highly sensitive to rhythmic inaccuracies, and that one could not isolate an examination of intonation from deviations from rhythm (i.e. moving to the following note slightly late would cause that note to be indicated as out of tune for a time). Most students (n=7) requested the possibility/option of some kind of "score following", in which

the system would recognize when a new note had been sounded and provide feedback as appropriate. Second, nearly all of the students (n=10) recognized that the system was employing a system of equal-temperament, wherein each note was assigned a particular pitch and, in the case of the enhanced intonation visualisation, compared directly with the corresponding note on a displayed piano roll. They expressed concern that, to be truly accurate, the system would need to take into consideration the relative tuning used by string instruments as mediated by the key and interval in question (see Deliverable 2.1), as well as be able to be calibrated to a different fundamental tuning (e.g. A=440 versus 442) as different musicians apply different tunings mediated by personal choice, instrument, repertoire, and genre performed. Other limitations raised by a minority of violinists were the system's ability to score only one pitch simultaneously (i.e. no multiple stops) and some difficulty in repeating individual sections to practice.

4.2. ViolinRT Bowing Features

The bowing features were tested using the custom Tilt and Speed bowing factor exercises, both of which focused on specific bowing factors highlighted within the ViolinRT system. All ViolinRT features (i.e. both bowing and audio, as above) were highlighted to the musicians in the demonstration of the technology.

4.2.1. Participants

Eleven (9 female, 2 male) conservatoire-level violinists participated in the test, with a mean age of 24.64 years (SD = 5.83, range 18-38). They had a mean 18.55 (SD = 6.56) years of playing experience on the violin, having actively taken violin lessons for a mean 16.27 years (SD = 5.20). The group comprised three undergraduate, seven masters, and one doctoral-level students. They reported completing a mean 20.55 (SD = 27.88) concerts (both solo and ensemble) in the previous 12 months, in some cases an approximation based on their memory. Nine of the 11 violinists reported actively teaching the violin, estimating they had taught a mean 31.67 (SD = 29.05) students (primarily at the beginner and intermediate level) across their teaching experience. Each followed the procedure described in Section 3.2 above.

4.2.2. Expert evaluation scores

Expert evaluations were conducted using the same protocol as in 4.2.1 above, with blinded pairings and analyzed using a 2x2 factorial repeated-measures ANOVA. A significant, very strong main effect of pre/post was found ($F_{(1,10)} = 37.73$, $p < .001$, $\eta^2 = .79$) in which the post-test performances were rated significantly higher than the pre-test performances across both groups. No significant main effect of with/no-technology was found. Also, no significant interaction was found resulting from the technology

use. Descriptively, participants when not using ViolinRT saw a mean increase of 0.81 points on the seven-point scale (SD = 0.60) from their pre-test scores (M = 2.72, SD = 0.91) to their post-test scores (M = 3.55, SD = 1.21), and when using ViolinRT saw an increase of 1.00 points (SD = 0.63; see Figure 11) from their pre-test scores (M = 2.36, SD = 0.92) to their post-test scores (M = 3.36, SD = 0.92).

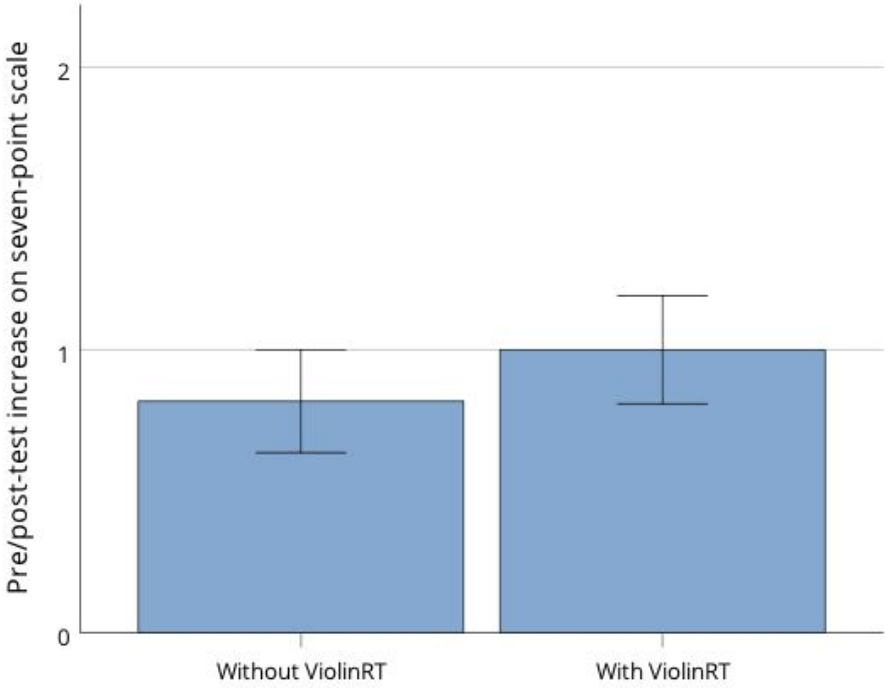


Figure 11: Non-significant increase in pre/post-test performance when using ViolinRT for up to 10 minutes versus not using ViolinRT in tests of bowing exercises. Error bars show +/- 1 SE to account for repeated-measures comparison.

Following the test, the expert commented that the participants struggled with the exercises (which were entirely novel to them) in the pre- and post-test (see the lower described scores above, all below the scale midpoint of 3.5, in comparison with the scores reported in the intonation-focused tests in 4.1.2 above), and suggested that 10 minutes of practice time may not have been sufficient for them to work with the material.

4.2.3. Self-evaluation scores

Analyses of self-evaluation scores followed the same procedure followed in 4.1.4 above, with the intonation tests. A significant, strong main effect of pre/post was found ($F_{(1,10)} = 25.55$, $p < .001$, $\eta^2 = .71$) in which the post-test performances were self-rated significantly higher than the pre-test performances across both groups. No significant main effect of with/no-technology was found, and no significant interaction was found. Descriptively, participants when not using ViolinRT reported a mean increase of

1.27 points on the seven-point scale (SD = 1.01) from their pre-test scores (M = 3.00, SD = 1.18) to their post-test scores (M = 4.27, SD = 0.78), and when using ViolinRT saw an increase of 1.05 points (SD = 0.91) from their pre-test scores (M = 3.41, SD = 1.07) to their post-test scores (M = 4.46, SD = 0.82).

As with the analyses of the intonation tests, the lack of significant effect of the technology in the self-evaluations was mirrored in examining self-evaluations of the specific technical points (technique, musicality, intonation, rhythm, tone quality, dynamics, articulation). Again, Bonferroni corrections were applied to control for the multiple comparisons, though significance levels would have remained above $p = .05$ without their application in any case.

4.2.4. Self-efficacy scores

As above (section 4.1.4) self-efficacy scores were summed and analysed using the 2x2 factorial repeated-measures ANOVA. No main effect of pre/post or with/no-technology was found, and no significant interaction was found.

4.2.5. Practice-related scores

Following the post-test recording, participants were asked to rate the perceived efficiency, improvement stemming from, room for improvement following, and mental and physical effort required in the practice session. Paired-sample t-tests were conducted comparing each score in the no-technology condition with that of the with-technology condition. As with the intonation tests, no significant differences were found, again suggesting a lack of perceived benefit or potential determent of using the technology on practice efficiency or mental strain in using the technology under the experimental conditions.

4.2.6. Time spent practising

Analysis of practice time followed the method described above in Section 4.1.6. Due to non-normality of the data (i.e Kolmogorov-Smirnov of $p < .05$), again due to highly negative skew in the with-technology group, a non-parametric Related-Samples Wilcoxon Signed-Rank test was used to compare time spent practising in each condition. A significant difference with a large effect size was found ($Z = 2.80$, $p < .01$, $r = .60$), in which participants practised for a mean 5.01 minutes (Mdn = 4.13, SD = 3.12) in the no-technology control condition and for a longer 7.83 minutes (Mdn = 9.00, SD = 2.71) when using ViolinRT (see Figure 12).

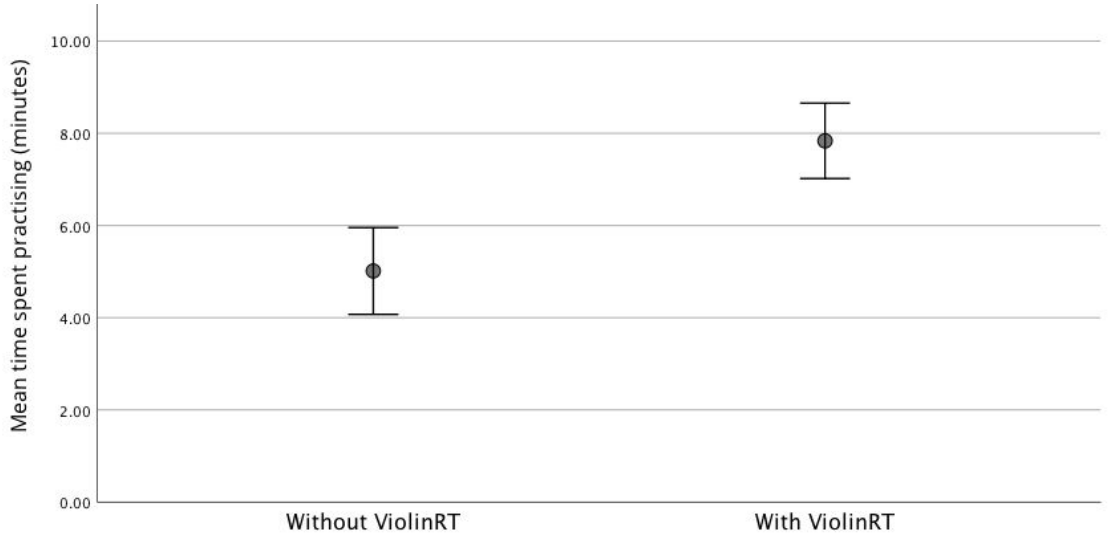


Figure 12: Significant increase (using a Related-Samples Wilcoxon Signed-Rank test) in time spent practicing the exercise without using ViolinRT versus with in the bowing tests. Error bars show +/- 1 SE to account for repeated-measures comparison.

4.2.7. Technology ratings

Following the final post-test session, participants competing a rating sheet of the systems ease of use (six items, mean calculated), usefulness (six items, means calculated), accuracy, and whether it was a tool they would use again and recommend to others. As for the intonation ratings, scores here were above the midpoint (see Table 4). Scores were descriptively higher than those received for the intonation features, though a series of independent-sample t-tests did not reveal significant differences between the two groups (see Figure 13).

Table 4: Technology ratings on a 1-7 scale for the bowing features

	Means	***Standard Deviations***
Ease of Use	5.05	1.08
Usefulness	4.79	1.58
Accuracy	5.00	1.84
Would use again	5.50	1.43

Would recommend	5.41	1.80

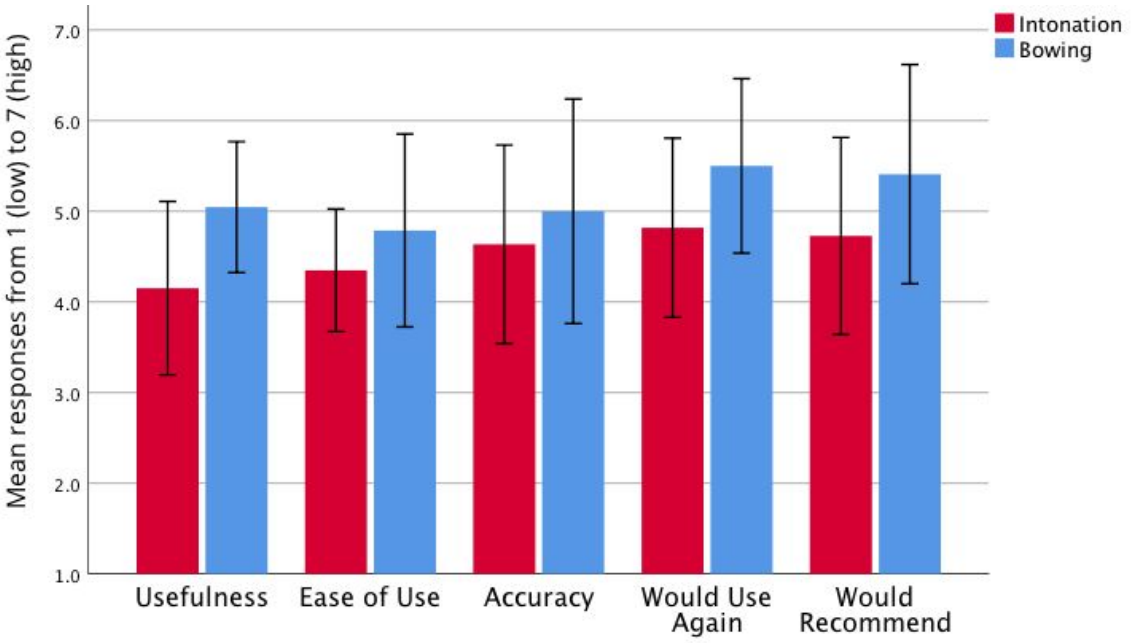


Figure 13: Mean technology rating scores for the intonation (red) and bowing (blue) features of ViolinRT. No significant differences were found between the two groups. Error bars show 95% CI.

4.2.8. Qualitative results

Following the completion of the technology rating scales, participants were as above asked to either complete in writing and/or speak to the researcher regarding the questions relating their opinions on the strongest and weakest points of the system, and potential room for improvement. In this session they now had the ability to consider the bowing features alongside the audio features, which had been shown to them as part of the session. Participants were asked the fundamental question of whether they saw themselves using the technology were it available to them, and in what situations that might be. As in the intonation sessions, they were at this point encouraged to be as forthcoming as possible in their responses, and that as the goal of the interview was to further the technology's development their negative feedback would be valued as equally as any positive feedback.

Would they use it, and where?

In response to the fundamental question of whether could see themselves using the system in their practice, all eleven violinists once again affirmed in the positive that they would. As with the intonation system, there was variability in the use cases. Considering the fact that the system in its current state would require visiting a space with the motion capture system in place and violin/bow markers available,

the majority (n=10) stated that they could see themselves using it on a semi-regular basis in their practice, perhaps biweekly, monthly, or termly, as a kind of “spot-check” of their bowing fundamentals with particular exercises or pieces of repertoire, or simply exploring the features in free-form playing. They felt that they would use the system more should the system setup and operation be simplified (see limitations, below). Again, one violinist (again a masters-level student with significant teaching experience) saw more likely use for her beginner-level students rather than in her own practice. In contrast to the audio-focused features, the majority of the students (n=8) could see themselves using the system with their teachers for these occasional bowing-examination settings, allowing for immediate feedback on their bowing patterns and exploring their technical fundamentals. For those with students, the majority felt that they would want to be with their beginner students in exploring the relatively complex feedback rather than leaving them to apply them on their own.

Strongest features

The most popular feature was the real-time bowing visualizations, particularly that showing the above and side view of the bow relative to the neck/strings. Violinists were immediately drawn to the relative angle of the bow to the strings (a feature not specifically highlighted in the side-widgets but has now been isolated and featured in subsequent development). Several expressed surprise that they were not as aware of their bow angle as they had previously thought. The visualization of the bow-frog traces was also praised, especially in revealing consistency of movement. Of the bow factor widgets, contact point was seen as particularly useful, then bow speed. Tilt was never mentioned as a key feature, either in the visualization or the widget, though still considered useful. The ability to switch between individual bowing feedback visualizations on the score was considered to be very useful, with comments that seeing all at once would be too much. The violinists liked that they could focus on a particular bowing factor in the recording, then switch to see what had happened with other factors they had not considered. Six violinists highlighted the TELMI bowing exercises themselves, finding them to be an interesting approach to isolating bowing features that they had not before considered. When the direct comparison was made, in no case were the audio-based features of intonation and dynamic analysis considered more useful than the bowing features; the latter consistently seen as being more useful (perhaps in contrast to the quantitative results, in which the audio features resulted in the significant improvement to practice outcomes) as well as more engaging and inspiring more excitement about potential applications for teaching and learning.

Limitations / suggestions for improvement

The primary limitation raised by all of the violinists was the physical limitations of using the system. Key among this was the necessity to stand in a relatively fixed position in order to provide the Kinect camera

adequate line of sight. This did not preclude use of the system and was helped by the alignment circles in the screen, though was considered a distraction. Related was the presence of the markers. Those on the violin were not seen as problematic (though limited movement to the upper neck positions not necessitated in the exercises), but the bow markers were noted for their additional weight and occasional contact with the strings at extreme angles. One violinist asked the purpose of the two antenna-like markers on the top of the bow. These were explained to be for accurate tilt and contact point data. The violinist suggested that, as they saw these features as less important than the bow movement, perhaps there could be an option to have simplified bow makers that show the crucial features, and those who want the enhanced bowing feedback could add the extra markers (this feature is now being implemented).

4.3. Automatic ViolinRT/SkyNote evaluations

Within SkyNote, a system to conduct automatic evaluations have been created by recording user performances within the SkyNote prototype and computing offline the performance rating algorithm developed during the project over the recorded data. In several cases the expert evaluations captured in the tests above (Sections 4.1 and 4.2) have been used to improve these models.

For intonation evaluation, the algorithm used is described in detail in *D4.2 Metrics for evaluation of skill performance and progress assessment* in section 3.3.2. The algorithm analyses the audio extracting the fundamental frequency curve and over this curve a set of features are computed, including linear regression, deviation, and correlation with the reference melody notes. The algorithm outputs a global score at piece level and local score at note level.

For bowing evaluation, a similar approach is used. Based on a reference ideal performance of each exercise to be evaluated, the algorithm compares the extracted bowing descriptors by SkyNote (tilt, position, speed, skewness, angle, contact point) with the reference values for each descriptor (as performed by a professional) at each note and provides a rating based on the accuracy of both the average values within a note and the deviation of these values during each note.

4.4. Live SkyNote feedback sessions

In addition to the laboratory-based examinations of SkyNote detailed above, SAICO has led several public, qualitative evaluation sessions in a contrasting market via Spanish-based conservatoires focusing on younger learners. Results have supported the feedback from RCM students, and transcript excerpts of the resulting discussions can be found in Appendix C.

5. Conclusions

Through interaction with and evaluation by music students, teachers, and administrators, the first TELMI prototypes from the project midpoint have been taken through a substantial chain of user-directed development leading to stable, reliable, and accurate final project prototypes.

The summative laboratory evaluations of ViolinRT/SkyNote and its respective audio-focussed and bowing-focussed features have demonstrated a significant improvement in practice outcomes in the audio features after only ten minutes of use of the system and minimal instruction. While a similar statistically significant outcome was not seen in the bowing features, these received higher accommodation in the qualitative results wherein users were enthused by their potential and demonstrated a unanimous desire to use the technology again in various forms in their learning and teaching, and would recommend the system to others.

Feedback from these final evaluations have already been fed into the current versions (to be highlighted at the project review), including improved marker sets, additional feedback features, and plans for transitioning to more user-friendly operational setups for potential commercialization.

6. References

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly*, 319-340.

Ritchie, L. & Williamon, A. (2011). Measuring distinct types of musical self-efficacy. *Psychology of Music*, *39*(3), 328-344.

7. Appendix A: Information and consent forms for the lab-based ViolinRT evaluations

TELMI Participant Information Sheet – 10/05/18

We are inviting you to take part in a study developing and testing new technologies for learning musical instruments. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information. Thank you for reading this.

What is the purpose of the project?

The aim of the research is to develop new technologies to help musicians and teachers learn the violin. At this stage in the project, we are testing prototypes of technologies that have been developed to see whether they help performance and practice and how they can be improved.

Why have I been chosen?

Violinists aged 18 and above are invited to take part.

Do I have to take part?

It is up to you to decide whether or not to take part. If you decide to do so, you will be given this information sheet to keep and be asked to sign a consent form. You will still be free to withdraw at any time without giving a reason.

What will happen if I take part?

You will be given the score for a standard violin exercise. We will record you playing an initial sight-read to the best of your ability, after which you will answer a few questions about how the performance went. You will then be given 10 minutes to practice, during which you may be given a piece of performance feedback technology that you can use to help you develop the exercise. After the allotted time is over, or when you let the researcher know you are finished practicing (whichever is earlier), we will record you performing the exercise again, and you will again answer several questions about how the performance and practice session went. The entire session will be recorded via audio, video, and motion capture. This process will be repeated for an additional exercise. We will then ask you what you thought of the technology and how it could be improved.

What are the possible risks/benefits of taking part?

There are no foreseeable risks to taking part. You will be paid for your time at the RCM Enhanced Student Rate.

Will my taking part in this project be kept confidential?

Yes. All recordings will be stored anonymously. While recordings without identifiable information (e.g. audio, motion capture animations) may be shown to the public or used by other violinists to learn the exercises, we will never show recordings that could be used to identify you (i.e. video) without your express permission.

What will happen to the results of the research project?

The data will be presented at national and international conferences as well as published in academic journals. All information about participants will remain anonymous. Collected data may be used for additional or subsequent research. If you are interested to learn more about the research results, you can always contact the research team.

Who has reviewed the project?

This project has been reviewed by an independent panel commissioned by the CUK Research Ethics Committee (CUK REC).

Contact for further information

George Waddell
Tel: 0207 591 4327 | Email:
george.waddell@rcm.ac.uk

Letizia Gionfrida
Tel: 0207 591 4732 | Email:
Letizia.gionfrida@rcm.ac.uk

Aaron Williamon
Tel: 0207 591 4348 | Email:
aaron.williamon@rcm.ac.uk

This Participant Information Sheet is for you. Thank you for taking part in this project!

TELMI
Participant Consent Form

TELMI
Technology Enhanced Learning of Musical Instrument Performance

Name of Lead Researcher: Aaron Williamon

Participant Identification:

1. I confirm that I have read and understand the information sheet dated 10/05/18 for the project in which I have been asked to take part and have had the opportunity to ask questions. ☐
2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason. ☐
3. I understand that my responses will be anonymised before analysis. I give permission for members of the research team to have access to my anonymised responses. I understand that all personal data about me will be kept confidential. ☐
4. I understand that the investigator(s) must adhere to the British Psychological Society's Code of Human Research Ethics. ☐
5. I agree to take part in the above research project. ☐

Name of participant	Date	Signature
Name of person taking consent *(if different from researcher)*	Date	Signature
Researcher	Date	Signature

8. Appendix B: Information forms for the lab-based ViolinRT evaluation

	Not at all sure 0%						*Completely sure* 100%
1. I am confident that I can give a successful performance.	1	2	3	4	5	6	7
2. I have set important goals to attain during this performance, but I cannot achieve them.	1	2	3	4	5	6	7
3. I am likely to avoid difficulties and challenges during the performance itself.	1	2	3	4	5	6	7
4. If I perceive the events or context surrounding this performance to be too stressful, I cannot even attempt to perform.	1	2	3	4	5	6	7
5. If something unexpected happens during the performance, I can handle it well.	1	2	3	4	5	6	7
6. I am likely to avoid this performance if the music looks or sounds too difficult for me.	1	2	3	4	5	6	7
7. I feel insecure about my playing for this performance.	1	2	3	4	5	6	7
8. I am likely to give up easily during the performance.	1	2	3	4	5	6	7
9. I am capable of dealing with problems that might come up during the performance.	1	2	3	4	5	6	7

Self-efficacy (Ritchie & Williamon, 2011)

PRE-TEST SELF-ASSESSMENT

Please rate your…	(from 1=low to 7=high)						
Performance quality	1	2	3	4	5	6	7
Technical competence	1	2	3	4	5	6	7
Musicality	1	2	3	4	5	6	7
Intonation / note accuracy	1	2	3	4	5	6	7
Rhythmic accuracy	1	2	3	4	5	6	7
Tone quality	1	2	3	4	5	6	7
Dynamic control	1	2	3	4	5	6	7
Quality of articulation	1	2	3	4	5	6	7
Room for improvement	1	2	3	4	5	6	7

POST-TEST SELF-ASSESSMENT

Please rate your…	(from 1=low to 7=high)						
Performance quality	1	2	3	4	5	6	7
Technical competence	1	2	3	4	5	6	7
Musicality	1	2	3	4	5	6	7
Intonation / note accuracy	1	2	3	4	5	6	7
Rhythmic accuracy	1	2	3	4	5	6	7
Tone quality	1	2	3	4	5	6	7
Dynamic control	1	2	3	4	5	6	7
Quality of articulation	1	2	3	4	5	6	7
Improvement from the pre-test	1	2	3	4	5	6	7
Efficiency of your practice	1	2	3	4	5	6	7
Room for improvement	1	2	3	4	5	6	7
Mental effort this practice required	1	2	3	4	5	6	7
Physical effort this practice required	1	2	3	4	5	6	7

TECHNOLOGY ASSESSMENT

To what degree did this feedback…	(from 1=low to 7=high)						
…help you learn more quickly?	1	2	3	4	5	6	7
…improve your performance?	1	2	3	4	5	6	7
…Increase your productivity?	1	2	3	4	5	6	7
…increase the effectiveness of your practice?	1	2	3	4	5	6	7
…make practicing easier?	1	2	3	4	5	6	7
To what degree was this feedback…	**(from 1=low to 7=high)**						
…useful?	1	2	3	4	5	6	7
…easy to learn to operate?	1	2	3	4	5	6	7
…something that did what you wanted it to do?	1	2	3	4	5	6	7
…clear and understandable?	1	2	3	4	5	6	7
…flexible?	1	2	3	4	5	6	7
…easy to become skilled at?	1	2	3	4	5	6	7
…easy to use?	1	2	3	4	5	6	7
…accurate?	1	2	3	4	5	6	7
…something you would use again?	1	2	3	4	5	6	7
…something you would recommend to others?	1	2	3	4	5	6	7
What were the most helpful features?							
What were the biggest weaknesses/limitations?							
How would you improve the feedback?							
Any other feedback on the technology?							

9. Appendix C: Transcribed feedback from Spanish evaluation sessions

The text below comprises excerpts of transcribed conversations (translated from the original Spanish) in feedback/evaluation sessions, led by SAICO, in which SkyNote was demonstrated to students, teachers, and administrators. Overall the feedback supports a general enthusiasm for and support of the technologies among mainstream users, distinct from the environment of the RCM in which the software was developed and evaluated. Concerns are raised of limitations of the technology, particularly around

Session 1 - Vic conservatoire

Participants
60+ students, aged 12-16.
6 music teachers.
1 representative of the conservatoire administration.

Format:
45 min presentation of TELMI and SkyNote
15 min discussion on the use of technology in learning
45 min hands-on sessions (students and teachers using SkyNote)

Feedback:

- Student 1 - Female age 15, 2nd year
    - I don't like to practice at home because I feel lost and lonely.
    - I feel that I cannot progress on my own.
    - I frequently watch videos on YouTube.
    - I like SkyNote because I can see how I am playing.
    - The structure of the exercises is very beneficial: I can see and listen to a demo from a teacher, then I can try to do it myself, and I can compare my performance with that of the teacher. I can repeat this process as much as I like, I am encouraged by the challenge.
    - I am not sure SkyNote will help me in the classroom, the teacher puts a lot of pressure and criticises a lot. I don't understand everything the teacher is trying to explain about my performance. SkyNote helps me to understand the teacher's viewpoint, but I am afraid that it will encourage the teacher to criticise more.

- Student 2 - Female age 16, 2nd year
    - At home I practice with with sister (21yo), we play and compete, take turns playing. We don't like the homework and practice material of the teacher, we prefer to practice freely. We listen to songs and try to emulate them, and compete to see who plays it better.
    - SkyNote helps us to see who scores better, and how each of us plays difficult music sections.

    - We like to play difficult sections, we like the challenge. The teacher insists on practices that are repetitive and boring. With SkyNote I can practice the sections I like for fun, and improve my skills. I feel much more free in learning what I like and learning in the way I like.

- Student 3 - Male age 15, 3rd year
    - I like to play music, especially freestyle. I am not a good composer, but I have a lot of fun experimenting with playing music. I learn through experimentation and sometimes sampling of popular songs. I enjoy transforming songs from a style to another, I listen to Rock and Metal music, then play them in my violin.
    - My parents registered me in the conservatoire to learn and improve my skills. The teacher helps me to improve, but I am really bored. I tried to quit two times, but my parents insisted I stay till I finish the program.
    - For me, SkyNote is like a virtual teacher. I can add to it the material I would like to practice. I can choose my own style, and I can define my own learning objectives.
    - I can still come to the conservatoire and meet regularly with my teacher for oversight and guidance, but I will be free to learn the way I want.

- Student 4 - Female age 14, 1st year
    - During this year, I had a lot of difficulties to learn the violin. My shoulders hurt after practice, and sometimes my wrists too. I am frustrated from my progress, I thought I could have progressed more.
    - I don't practice at home, I just repeat the exercises I learned in the classroom.
    - Recently, I started practicing with a classmate to encourage each others.
    - I like the way SkyNote visualizes my performance. I see where I am shaky. I can see my problems for the first time, now I know where I am making errors, and I can ask more specific questions to my teacher.
    - Also, I can compare my performance with that of my classmate and learn more from one another.
    - SkyNote gives me a little bit more confidence when I play and practice. I can also see what I'm doing right and feel like I am progressing.

- Teacher 1 - Female age 30-35, violin teacher
    - I have been actively looking for digital tools to help me engage the students in learning with little success. SkyNote is the first prototype I have seen that looks promising as a learning aid. It is to music learning what the choke boards are to classrooms.
    - Finally, we have a visual aid that helps me to demonstrate visually to the students how specific gestures and notes sequences can be played.
    - Also, it is fun to work with, we can save performances of a single student, and see how she or he progresses between them.

- Teacher 2 - Male age 35-40, violin teacher
    - I don't like music learning games and apps, I see that they are counterproductive. They interfere with the learning curriculum and sometimes falsely convince the students that they are progressing. If you are performing a game level repetitively, you are bound to master it. But this does not mean you are gaining music technical skills.
    - I consider SkyNote a learning framework with several visual tools, capable of helping the students and teachers to dissect and analyze specific parts of a music performance. I think that the ability to compare your performance with an optimal or expert performance allows you to discover a series of possible improvements, making practice much more interesting and engaging.

Session 2 - ESMUC TELMI Presentation

Participants
20+ students, aged 18-30.
4 music teachers.
1 representative of the conservatoire administration.
Director of pedagogical program.

Format:
30 min presentation of TELMI and SkyNote
1h:30 min hands-on sessions (students using SkyNote individually, and teachers using it to analyze the performance of their students)

Feedback:

- Student 1 - Male age 24, master class
    - I like to look at the SkyNote visualizations while playing and practicing, it helps me concentrate. I think projecting the interface on a wall is better than using a laptop, this way my eyesight does not conflict with my posture.
    - I imagine using this tool regularly, I think the scoring mechanism is a very nice feature, but maybe it should have difficulty levels for the same exercise.
    - The sound analysis component alone is a great feature, the visualizations are intuitive and very precise. I'm not sure that the posture analysis component is useful for me, I like to play and practice in different postures and I sometimes move while practicing so staying put in a single spot is difficult.

- Student 2 - Female age 26, master class
    - I am surprised by SkyNote, I was expecting something less elaborate. It looks like a complete laboratory that I can deploy at my own laptop.
    - The system is very sensitive, and detects any issue in my performance. Some issues are not really audible, especially those related to the timing of playing a note.
    - I cannot pause or stop or restart the exercise easily, and I am pressured to finish it. So I need to recover from errors, especially if I played a note at the wrong timing. This is an interesting feature.
    - I think I would definitely use SkyNote before exams and public performances, just to make sure that I am able to play the assigned music sections with ease. Looking at the quality of my performance in details will help me to become more confident when I repeat the performance in public or in the exam.

- Student 3 - Female age 26, master class
    - I often practice playing the violin at home as well as in the conservatory. I took a course about music technology, and I think that technology is relevant to music learning and music composition and in other applications in music.
    - I think that SkyNote is a powerful tool that allows me to understand how to evaluate my performance. It is a good examination tool that precisely analyzes many aspects of music playing.
    - In practice, I find it a bit too complex for everyday exercising, the interface could have a minimal setting because the features are a bit distracting. Also, the user can first play and then review the performance, so it allows you to concentrate exclusively on playing if you want to.

- Student 4 - Female age 21, master class
    - I like the idea behind using technology to help music learning and make it easier and more efficient, but I feel a bit controlled by the tool. It is constraining me to play and monitoring me constantly. I find this a bit stressful.

    - I wish there is a way to hide all the real-time analysis and focus on the notes, so I can relax and practice at my own pace. Later, I can review my performances to get a better understanding of how I am performing.
    - I understand that the tool is very relevant for exercising, exercises are repetitive and focus on specific features in the performance, repeating them in order to master them. But when you play a music composition, we should analyze the entire performance as a single piece and I don't think that the detailed analysis is relevant in this case.

- Student 5 - male age 25, master class
    - This is an awesome tool, I wish it had a competitive mode in which I can compete with my friends and keep score. I know that it is not a game, but putting a score on a performance instigates competition. Competition will definitely lead to more practice, and exercises become less boring, especially those that need you to repeat short specific sections.
    - Besides the analysis, SkyNote can also include indications on how to improve or correct specific errors. Currently, it looks like it relies exclusively on the teacher to do so, no recommendations are automatically generated based on the analysis.

- Teacher 1 - female age 30-35, violin teacher
    - I have always wanted to use technology in my classroom to help the students and engage them more. I am encouraged to work with SkyNote.
    - The most important feature I see is that visualization of the performance. It saves me the hassle of describing where and when errors or mistakes are made, so I can explain how they occurred and what to do to address them.
    - Also, by visualizing the performance for the entire class, other students can be more interested in the performance of their classmates. Now, when we do live practices, we take turns, and when a student is performing the exercise, the others seem distracted most of the time, or not concerned.
    - With SkyNote, the entire class can learn from the mistakes of a single student more efficiently

- Teacher 2 - female age 30-35, violin teacher
    - I like to use SkyNote in my class, but its use should be purposeful and in specific contexts. For instance, most of my students have difficulty mastering the right posture and bowing gestures. Part of the difficulties are due to the fact that the students cannot keep their eyes on their fingers. We frequently use mirrors, but the SkyNote visualization is much more efficient when projected on the wall. In this manner, the student can adjust constantly his or her own posture while keeping the head straight.
    - We have learned how to use digital tools for storing and visualizing music notes. So importing pre-existing notes and exercises into SkyNote is a great feature. I can also make videos, showing how the exercises should be performed, similarly to the pre-existing SkyNote exercises.

Session 3 - PRAT Music School Presentation

Participants
7 students, age 16-18.
7 music teachers.
Representative of the music school.

Format:
30 min presentation of TELMI and SkyNote
1h:30 min hands-on sessions (students and teachers using SkyNote individually)

Feedback:

- Teacher 1 - female age 30-35, violin teacher
    - We use apps on an iPad as learning aids, they are severely limited but fun to play with. They help me engage the younger students more effectively. They transform the classroom into a fun environment.
    - SkyNote is much more than an app, it looks like a very serious and elaborate platform. I think that it could be gamified, at least for the younger users. Also, Exercises can be designed in a fun way rather than on the basis of classic approaches.
    - I understand that professional learners do not like mixing games with studies, but this could be beneficial for the younger learners.
    - I would definitely ask for SkyNote to be deployed in the classroom, including the Kinect motion sensor. But also, I would like my students to have it on their own machines, and send me their analyzed performances

- Teacher 2 - female age 30-35, guitar teacher
    - I think this tool can be very useful for learning other instruments as well, not just the violin. It is fun and engaging. I understand that it is a prototype, but it is too precise and unforgiving, especially for beginners. Learning to play the violin is tough, but we can define difficulty levels, and at each level the precision/tolerance can be adjusted accordingly.
    - I think that SkyNote is a classroom tool more than an individual tool, especially for young learners, which may need a more simple and user-friendly version.
    - In all cases, the approach taken to analyze so many aspects of music performance gives me flexibility in teaching the students and customizing the learning process to each student. This is key for young students whom each progresses at a different pace, and each have different challenges to overcome.

- Student 1 - male age 18-21, violin teacher
    - I would like to have this tool on my laptop so I can practice more often on my own. I wish to share my performances with some friends and get their comments, so it would be nice to have a video recording feature. I also would like to see how I am progressing over time, if I am getting better.
    - Overall, I think it is a serious instrument, but I don't know which aspect to track or in which configuration it is best for me to practice. This can be recommended by the teacher.

EMVIC - Program coordinator and violin teacher - TELMI Presentation

We have struggled constantly to introduce technology in music learning, there are many barriers. For a start, there are no pedagogically validated technologies that we can pick off-the-shelf, and now we are starting to see encouraging proof-of-concepts and promising approaches like TELMI. These need long-term validation (years or experimentation and refinement) before adopting them on a mass scale.

We use digital tools on a limited basis, these are content managers and learning managers. We looked into learning design and lifelong-learning solutions at some point, found them too generic and too broad. We don't understand why there are no music-centric tools for learning, while there are similar tools for many other domains.

At some point in the near future, we will need to upgrade our IT infrastructure. This has been deemed of a secondary priority because we cannot justify it clearly because: 1) we cannot clearly envision its

impact and added value, 2) we are not sure how to integrate such tools in the pedagogical process effectively. Also, it is difficult to address all the different opinions about using such tools: some students and teachers are encouraged, but others are warry.

EMVIC - Director of pedagogical program - TELMI Presentation

We are falling behind in adopting new technologies in our institution. There is no clear necessity and therefore there is no decision to invest in IT in general. Some of the old folks here, whom hold administrative responsibilities, think that Digital stuff can be counter-productive. There don't see the relation between the digital culture and the activities organized by the institution. Lately, they seem more open to the idea, especially because of the younger generations that come to class with all sort of apps on their mobiles, some with interesting features. The teachers sometimes feel that they are competing against apps with less-serious approaches or without any fundamental pedagogical method.

The interesting aspect of TELMI is the development of tools grounded in science and technology, but also in pedagogy. This might be appealing to the teachers whom can think of it as having apps of their own to suggest to their students. However, here there is a need for a global transformation. The research conducted by TELMI is a start, but there are many things left to address. For instance, we use a document-based system to manage our music-learning repertoire, we have no digital libraries. We certainly do not have the internal skills yet to engage with remote learning or online classrooms. I can definitively say that many of the teachers are opposed to that, and feel that current technologies strongly restricts their ability to interact with their students. Etc. Therefore, we need a complete transformation and the TELMI tools could be the start.

I think that you can easily find enthusiasts among the teachers that can be the first to adopt SkyNote in their classroom. Usually, programs are dense, and teachers can seldom take the chance of engaging in extracurricular activities. But the fact that SkyNote is a performance analysis tool means that there is plenty of opportunities to use it during the class, and probably students and teachers will use it more frequently as they become accustomed to its features and start feeling its usefulness.

ESMUC - Director of Master program - TELMI Presentation

Learning music is less about the transfer of knowledge and more about the transfer of know-how and skills, supervised training is an essential activity, and in many classes make the bulk of the teacher-student interaction.

Current learning paradigms, especially those that support distant-learning or digital classrooms are severely disadvantaged in supporting supervised training. We still fundamentally rely on face-to-face sessions.

This is not very effective because the teacher usually selects students to practice by turn in front of the rest of the classroom, while others try to learn by watching. Teachers complement this activity with homework and occasional one-to-one sessions. From all these activities, students feel that one-to-one sessions are the most productive.

This is why the introduction of digital learning tools has been slow and difficult: most if not all do not respond to the needs and peculiarities of music learning.

I believe that the use of accurate detection and analysis algorithms is a new approach, SkyNote does not compare to any tool i know, even those that can analyze music to a certain extent. It looks like a

potential classroom tool and also a student tool. I believe that its real potential to revolutionize music learning lies in its ability to function for all instruments, which is still under development.

We would definitely be interested in testing and evaluating SkyNote, and participate in its design and development. We seldom have the chance to participate in the creation of technology, which will definitely be more successful if developed according to a participatory process.

PRAT MUSIC SCHOOL - Director of School - TELMI Presentation

We see our young students more interested in games and informal practice than in the classroom activities. The best way to motivate them is to organize short and informal competitions. As they thrive to learn and improve, the teacher tries to reinforce those that are slow to progress or suffer from particular difficulties.

We try to keep our teaching approach as organic and informal as possible. We ask students to contribute by identifying music pieces that they would like to learn. We try to make the learning as fun as possible.

SkyNote is an interesting system, it provokes students to compete for the best score, and therefore practice more and enjoy more the classroom, also the manner by which the teacher interact with students changes with this tool. Teachers and create digital guides like the ones in SkyNote, sharing videos and notes with the rest of the students, and engaging online as well as in the classroom. This is the potential I see for this system. I like that it is accurate, but sometimes accuracy is not the common denominator in the classroom, sometimes is it about moving about while playing. Sometimes using technology has unintended consequences, like unforseen restrictions on the manner by which a player plays an instrument.

PRAT MUSIC SCHOOL - Director of pedagogical program - TELMI Presentation

We are a small music school, we try to engage the local community, especially children to learn music. We are not a professional school, but we like to think that we are doing the best of our ability to develop the music talents of the community. Our budget is limited and we sometimes have difficulties to acquire instruments. Part of our income is from tuition fees and another part is from the municipality.

If we ought to invest in learning technology, then the impact of such investment on our business should be clear. Such technology should allow us to increase our reach in the community and improve the skills of our teachers and students. For this purpose, I see a potential in SkyNote as a tool that our music school can offer to its students to take home, practice on their own, and collaborate with other students. We can add the cost of the tool to the tuition fees or ask the municipality to subsidize it.

I also see the potential of using SkyNote in the classroom, but in our case, given the size of the class and the average age of students, it is worth to consider borrowing from competitive game for learning music, in which students are encouraged to compete and scores and performances are compared.