GuitarFins: Skillful Input Triggering with a Guitar Pick

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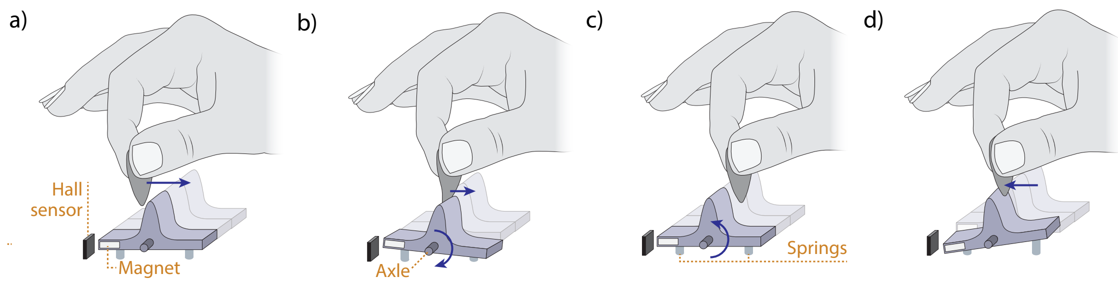

Figure 1: GuitarFins are input components that can be triggered with a guitar pick. a) The pick approaches a fin element. b) When pushed by the pick, the fin rotates and a hall sensor senses the motion of the fin-integrated magnet. c) When continuing the motion until the fin is released, springs rotate it back to its neutral state. d) The fin can be pushed from both sides.

Abstract

Having a guitar strapped on inevitably restricts physical movement when it comes to using digital interfaces (e.g., via mouse and keyboard) or adjusting equipment settings in between. Furthermore, guitarists typically use a guitar pick, which is often an additional hindrance—the pick often needs to be tucked or put down whenever having to operate an interface, which incurs additional context switching costs. However, we believe that the guitar pick can be turned from a hindrance into an opportunity by utilizing the guitarists' dexterity with a pick for fast and convenient user input.

We introduce GuitarFins—physical input elements, with which the pick becomes the end-effector for physical user input. To test the performance and subjective experience of using guitar-embedded input while holding a pick, we conducted a user study with 16 guitarists for which we augmented two guitars—one with GuitarFins and one with buttons. We found a variety of nuanced differences in terms of performance and individual preferences.

UIST '26, Detroit, MI, USA

ACM ISBN 979-8-4007-2856-3/2026/11
https://doi.org/10.1145/3830398.3830477

CCS Concepts

• **Human-centered computing → Interaction devices**.

Keywords

Electric Guitar, Guitar Pick, Augmented Guitar, Musical Instrument

ACM Reference Format:
Markus Kaltenecker, Jan Kolberg, Dieter Schmalstieg, Michael Sedlmair, and Andreas Fender. 2026. GuitarFins: Skillful Input Triggering with a Guitar Pick. In *The 39th Annual ACM Symposium on User Interface Software and Technology (UIST '26), November 02–05, 2026, Detroit, MI, USA.* ACM, New York, NY, USA, 13 pages. https://doi.org/10.1145/3830398.3830477

1 Introduction

Guitar playing is commonly interleaved with operating equipment, e.g., when adjusting effect settings, or software applications, such as interactive guitar tablature interfaces [40]. Using such digital interfaces during guitar play sessions often involves costly context switching [32], because traditional input methods are not designed to be used while holding a guitar. Furthermore, in some situations the input devices for interface control (e.g., mouse, keyboard, or touch screen) can be far away from the guitarist when playing, or generally inconvenient to use, as the strapped-on guitar impedes physical access [31]. Previous research has explored different ways of controlling specific interface operations (e.g., backing track playback) more conveniently while holding a guitar. One approach is to use the guitar's audio signal for simple interface control [10], but this entails dealing with ambiguities, e.g., deciding when to trigger commands via the audio stream and when to ignore it (during guitar play). Other previous solutions involve unobtrusive custom hardware to be used on or around the guitar [1]. However, an often overlooked aspect when designing hardware for user input to be used during guitar play is the fact that guitarists typically use a guitar pick (especially with the electric guitar). Hence, switching between playing the guitar and doing other tasks, such as controlling software for recording and playback, requires tucking the guitar pick or putting it down. This complication is sometimes mitigated with configurable foot pedals that allow to occasionally switch between effect settings with the foot. However, the input precision and activation frequency of pedals are far below those of buttons and mouse input, and triggering many interface operations can become tedious over time [1, pg. 8], e.g., when navigating between many banks (groups of settings and effects).

We seek to explore the opportunities to utilize guitarists' dexterity with a guitar pick for user input in order to enable seamless switching between playing and using the pick for fast and fine-grained digital operations. As the first instance in this new type of user input premise, we implemented GuitarFins. Instead of triggering an operation with a button, a GuitarFin input component is triggered by picking it like a guitar string. Figure 1 depicts an array of such fins and the envisioned interaction. Figure 1.a shows how a picking hand approaches one of the fins. When in contact (Figure 1.b), the fin rotates around the pivot. The sudden change in sensor readings (using magnetic sensing) indicates a trigger event, which can be mapped to a UI operation such as jumping forward one bar in a tablature interface or starting a recording. When continuing the motion until the fin is released (Figure 1.c), springs rotate the fin back to its neutral state. The fin can be hit from the opposite direction as well (Figure 1.d), allowing for alternate picking (a guitar technique for very fast, yet precisely timed hits with a pick) or allowing to assign different functions to up and down strokes. We implemented a prototype of GuitarFins and integrated it into an electric guitar (Figure 2). GuitarFins can be mapped to key presses to control specific functionalities of desktop applications, such as navigating through guitar tablatures, without context switching and while still holding the pick.

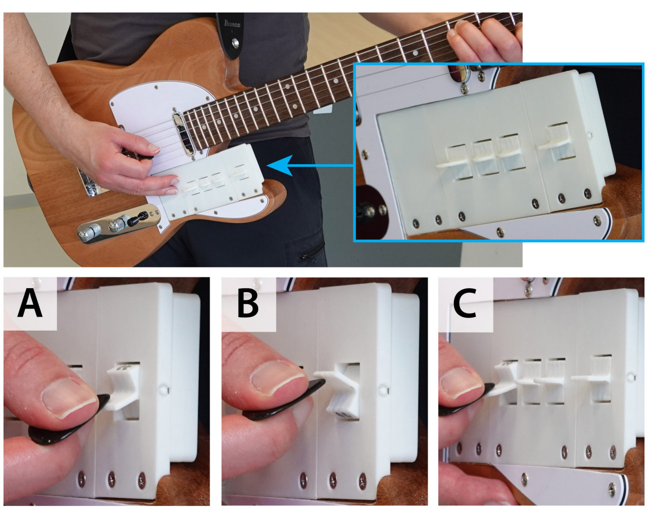

Figure 2: Our GuitarFins prototype. A fin can be triggered via down strokes (A) or up strokes (B). Different functions can be mapped to different fins and stroke directions (C).

Based on our prototype as well as an alternative prototype with guitar-embedded buttons, we conducted a user study in which we compared guitar pick-based and button-based input triggering. Our comparison includes low-level performance metrics (e.g., triggering speed) as well as high-level qualitative feedback when using the input methods in specific applications. Our study revealed that there are nuanced strengths and weaknesses of the two input methods. For instance, buttons are more familiar and less error-prone when used in a selection task, while GuitarFins are faster when triggering input repeatedly on the same component and, for some participants, are more enjoyable to use. Our investigation informs future designs of pick-based input, including other forms of input that utilize the guitar pick as an end-effector. Our contribution is two-fold:

- We present the GuitarFins concept and prototype, with which the guitar pick becomes the end-effector for a skillful, fast, and convenient alternative to physical button presses.
- We investigate the low-level performance as well as high-level subjective experiences with guitar-embedded input in a user study, comparing GuitarFins and buttons. Our study provides insights about the implications of holding a guitar pick during user input as well as how the two guitar-embedded input methods can be combined to best utilize their strengths.

2 Related Work

Additional input on the guitar can roughly be divided into serving two purposes, namely, effect control (primarily equipment) and application control (e.g., software interfaces for guitar practice). Regarding the latter, previous work aimed to tackle the problem of using digital applications while holding a guitar. In the context of musical instrument usage, Martinez Avila et al. refer to this problem space as *encumbered interaction* [1, 30–32], a term we adopt in this paper. In this section, we survey encumbered interaction use cases—in particular within guitar playing—as well as previous works on guitar augmentation.

2.1 Using Digital Interfaces While Playing

In this day and age, guitar playing—whether alone or with others—is often supported by digital tools. Many utilities that were previously analog are increasingly becoming digital and hence more flexible and programmable. These utilities include foot pedals, effect adjustments, and digital metronomes, among others. Furthermore, desktop and mobile applications can support guitar playing and practice in different ways. In this subsection, we mainly discuss software (including commercial systems) in order to introduce use cases that can be relevant for guitar-embedded input, i.e., controlling such software while being encumbered.

Tablature Interfaces. Digital tablature interfaces such as Guitar Pro [40] or *Songsterr* [23] are often used during practice due to their beginner-friendly notation and their many helpful features. Especially song navigation and playback operations make those tools highly useful for playing along. However, the number of features that must be accessed while holding the guitar (choosing a song, starting/stopping, choosing/muting tracks, etc.) can be hard to control when encumbered. Hence, researchers proposed different variants of *score following* [9] or *tablature following* [27] so that the playback can automatically adjust to the learner. In contrast, *GuitarPie* by Heyen et al. [10] focuses on directly operating a tablature interface by mapping the guitar's audio signal to a pie menu, linking menu elements to play/stop, stepping forward/backward, switching instrument tracks, and so on. However, the main problem with audio-only approaches is that there are potential ambiguities when distinguishing between playing and digital input.

Background Track and Video Playback. Another common task during guitar practice is to control the playback of videos or background tracks [31, pg. 4], [32, pg. 6]. *Soloist* by Wang et al. [56] is a tool that extracts melodies from video tutorials (e.g., YouTube) and segments the video into demonstration parts, explanation parts, and more. While their functionalities streamline the learner's digital support for the playback-practice loop, the encumbrance of the user remains, as the application is mostly controlled via mouse and keyboard (though querying segments via audio is also possible). Tutorial systems such as *Rocksmith* [52] and *Yousician* [25] feature interactive song playback and visualizations, while also tracking the correctness of the played notes during playback.

Remote Jamming. Remote jamming has become increasingly relevant in recent years [16, 19, 21]. Jamkazam [13] is a video teleconferencing application specialized for jamming, prioritizing low-latency audio transmission. Schlagowski et al. [46] use Augmented Reality and 3D reconstruction to make the remote jamming experience feel closer to in-person jamming. While there are no established designs for remote jamming applications, their functionalities can be a mix of video conferencing operations (e.g., muting, switching cameras) and operations of playback/recording applications (e.g., start recording), all of which can be inconvenient to control when encumbered.

2.2 Instrument Augmentations

Many previous research projects added input and output capabilities to the guitar or the pick in various ways, either physically [34] or via visual augmentations, i.e., via Augmented Reality [5, 24, 39]. This subsection discusses previous works that physically augment the input (and sometimes output) of guitars.

Augmenting the Guitar and Integrating Components. Conventionally, electric guitars contain knobs and switches to control basic audio parameters (most prominently, volume). Some guitars feature an additional *kill switch* [6, red button], which allows one to momentarily cut off the guitar's audio, i.e., triggering it fast creates a tremolo-like effect. Beyond basic audio control, the guitar and amplifier manufacturer *Vox* was experimenting (already in the 1960s) with additional input components in the form of an array of buttons and knobs as part of their *Guitar Organ* [55]. Instead of enabling user input for applications, the main purpose of a Guitar Organ is to provide fine-grained control of the guitar's sound (also giving it the features of an organ). However, all input components are conventional buttons and knobs. Similarly, *smart guitars* integrate buttons as well as the strings themselves into one digital audio and user input/output system [45, 51]. One variant of the keyboard module of an *Enya Cyber-G* [41] contains a strumbar-like element, but it is not designed to be operated with a guitar pick. It is instead used as the primary trigger for playing the instrument (similar to strumbars found in *Guitar Hero* game controllers). Such smart guitars can typically also be connected to smartphone apps [49]. The *Guitar Wing* product [22] is a physical extension for the guitar body with buttons and touch input. The *Fretlight* system [47] augments the guitar with LED beacons inside the fretboard to visually indicate which strings to press at which frets (primarily for teaching purposes). Similarly, Marky et al. [28] use LED beacons on the fretboard, while also adding capacitive sensing for additional input (to sense which string was pressed at which fret). MacConnell et al. [26] use potentiometer strips and embedded audio processing to enable touch-controllable audio effects. Benito Temprano et al. [2] use magnetoresistance sensing below the strings to estimate how much the guitarist bends a string (a technique for smoothly changing the pitch of a ringing note). Instead of directly augmenting the body of the guitar, *StretchyStrap* by Martinez Avila et al. [1] enables simple input by pulling custom handles that are attached to the guitar strap. Besides electric guitars, researchers and manufacturers also integrated digital inputs in acoustic guitars [17, 35, 57]. For example, Martelloni et al. [29] add percussion sound capabilities to an acoustic guitar.

Overall, guitars have been physically augmented for a long time, either with standard buttons and knobs or with more specialized hardware designs. However, building physical input components that are operated with a guitar pick and comparing those with conventional guitar-embedded input has not been explored so far.

Augmenting the Guitar Pick or the Picking Hand. Another type of physical augmentation is to add sensing capabilities to the guitar pick, sometimes in combination with wearables for the picking hand. The motion that a pick undergoes and the pressure that is exerted on it contain information that can be utilized for classification, interaction, implicit input, and more.

MagPick by Morreale et al. [38] utilizes the already-existing magnetic field of the guitar pickups (a core component of an electric guitar that converts the string oscillations to the analog audio output) to sense the guitar pick's motion, enabling additional effect control via movements above the strings. *MIDI Pick* by Vanegas et al. [53] features a pressure sensor to trigger input, e.g., for effect controls via the guitar pick. *PLXTRM* by Vets et al. [54] adds movement sensing and string contact detection capabilities to a guitar pick, primarily for additional effect control during performance. In addition, they mention use cases in music education (e.g., tracking strokes during alternate picking).

Beyond effect control, sensing on the guitar pick has been used as an unobtrusive alternative to classical biofeedback for musicians [15, 36]. *PressurePick* by Fender et al. [7] features a pressure sensor on a guitar pick to use it for estimating fatigue during practice by measuring the regularity of pressure patterns on the pick.

In addition to adding sensors to the pick, some researchers also built custom wearables for the picking hand. For instance, Kamo et al. [14] and Matsushita et al. [33] use wrist-worn inertial sensors to detect and evaluate the guitarist's playing technique. Yoshida et al. [58] attached a pressure sensor to a pick, which is connected to a ring-wearable with an inertial sensor around the index finger of the picking hand. Based on the sensor values, they propose use cases such as dynamically controlling visuals while performing.

Overall, physically augmenting the guitar pick can be viewed as complementary to our focus on hardware components on the guitar body. Specifically, within this work, we set the goal of supporting any guitar pick, including ordinary lightweight ones, neither preventing nor requiring additional electronics or wearable devices.

Musician-Instrument Relationship. Previous works explored the impact of guitar augmentations (or instrument augmentations in general) on the relationship between the musician and the instrument. The musician-instrument relationship is generally described as symbiotic, with the instrument becoming integrated into the body schema of the musician through extensive practice [43]. The instrument thus becomes transparent and acts as an extension of the body, the musician no longer requires to consciously think about how to interact with the musical environment through the instrument. Central to the musician-instrument relationship is the concept of instrumental genesis [43, 48], the interplay of two processes through which musician and instrument shape each other. Through the process of instrumentalization, a musician adapts the instrument to their own needs. Conversely, through the process of instrumentation, the affordances and constraints of the instrument shape how the musician uses and thinks about the instrument. These processes are highly subjective and depend on the physical capabilities, acquired skills, and even cultural background of the musician [20, 48]. Overall, such musician-instrument relationship concepts are relevant when interpreting and contextualizing feedback from guitarists in domain-specific evaluations like ours.

2.3 Synopsis of Related Work

Guitars have been augmented physically and visually, both in terms of input and output, targeting various use cases such as effect control, video playback, and more. However, to our knowledge, no previous approach actually utilizes the guitar pick as an end-effector for operating input components on the guitar—leveraging the dexterity of guitarists with a pick. Our work marks the first step towards turning the guitar pick from a complication to an opportunity by (1) implementing the GuitarFins input component, which is triggered with a guitar pick, and (2) by investigating how guitarists use physical input on a guitar while holding a pick.

3 The GuitarFins Prototype

We implemented GuitarFins as physical modules that we integrated into the corpus of an electric guitar. In this section, we describe the hardware and software of our prototype.

3.1 Hardware

We implemented a GuitarFins prototype with a one-plus-three fin layout, meaning that we built one module with a single fin, and one with three. Figure 3 shows the hardware of our prototype.

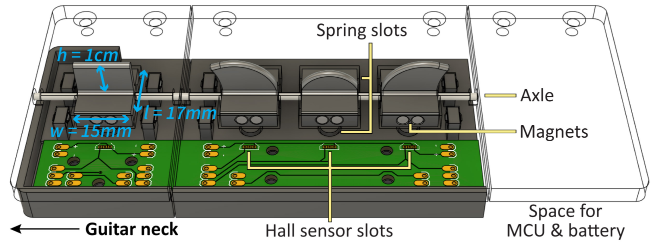

Figure 3: The hardware components of our GuitarFins prototype. This instance consists of a single-fin module and a triple-fin module. The microcontroller (MCU) together with the battery is located below the right-most plate.

Guitar Integration. We integrated our prototype into an assembled *Harley Benton* guitar kit. Specifically, we milled out a rectangular area below the neck and inserted screw holes at 20 mm steps. We cut out the same rectangle from the pickguard (also see zoomed-in callout in Figure 2). The other physical components are mostly 3D prints and are divided into modules. A module consists of a base element (holding the electronics), a plate, and a number of fins. A plate has two screw holes with their distance being multiples of the 20 mm steps. Each fin contains two holes on each side to insert magnets. The fins are supported by two springs each (connected to the base) so that they are pushed back to their neutral state after releasing them. We use a small ABS rod as an axle for fins to rotate around. We chose the size of the holes in the fins accordingly, aiming to keep the physical resistance low when rotating, while keeping oscillations after releasing a fin to a minimum. The length of the fins (l = 17 mm, see Figure 3) is designed to allow for enough rotation so that the pick can be pushed past a fin easily, without making them too unstable for the springs to push them back. On the triple-fin module, the fins are rounded, the middle fin is shorter, and the outer two fins slightly extend outward (see triple-fin module in Figure 3) to make them easier to trigger without looking.

Electronics. We created custom printed circuit boards to mount hall sensors (*49E*) and to connect them to an *ESP32S3*. The hall sensors are close to the magnets on one side of each fin, approximately at the vertical position of the magnets when the fin is fully rotated towards the sensor. The fin rotation creates a monotonous signal (rotating towards the sensor yields high and rotating away yields low sensor values). The sensor values can be transmitted to a PC via USB or Wi-Fi to send key press events via software (next subsection). Alternatively, the ESP32 can run the same logic on-device and be connected as a bluetooth keyboard to send key press events directly.

3.2 Software

Our software (implemented in Python) receives the hall sensor streams via USB (serial) or Wi-Fi at 5 ms intervals (200 Hz), which we pre-process with simple temporal smoothing. When the signal value exceeds a trigger threshold, we send a trigger event to the application layer. If the value then falls below a release threshold, we send a release event. More concretely, we trigger when the value reaches 65% (where 100 % corresponds to the highest possible sensor value and 0 % to the resting state) and remain in the triggered state until the value drops below 35%. We apply the same approach to the other direction, i.e., values below the resting value. A fin trigger event can be mapped to a single key (allowing for alternate picking) or two different keys (one for up strokes and one for down strokes).

4 User Study

We conducted a user study to evaluate the performance and subjective experience of guitar-embedded input components. We specifically wanted to compare GuitarFins with ordinary button input and were interested in both the low-level performance of the components and the subjective high-level experience of using guitar-embedded input with concrete applications. Due to the inherent novelty of the input, we designed a mostly explorative study, but we were also interested in measuring specific performance metrics. After careful consideration regarding where quantitative methods and inferential statistics are appropriate [8] and where qualitative testing is likely better suited, we decided to use quantitative testing in very structured low-level performance tasks (mostly focusing on the physical aspects of using guitar-embedded input) and more open-ended qualitative testing for the user experience with concrete applications. For the quantitative part, we had prior expectations. Specifically, we expected that GuitarFins can be triggered faster than buttons and that they are possibly more enjoyable, while also being less fatiguing to use. Conversely, we expected the more familiar button input to be easier to use when it comes to operating *multiple* elements. The user study was approved by the ethics committee of the University of Stuttgart.

4.1 Study Design

Our study consisted of a quantitative and a qualitative part. The quantitative part uses a within-subject study design with two blocks, denoted as B:*BlockName*. The first block was a triggering task, called **B:Triggering**, and the second block was a discrete 1D selection task, called **B:Selection**. Each block contained two conditions denoted as C:*ConditionName*, i.e., both blocks were completed with both devices. The two conditions were **C:Fins** and **C:Buttons**. The conditions (i.e., devices) were counterbalanced within each block. Blocks were not counterbalanced, as we are not comparing any data between blocks or between tasks. The tasks of the quantitative part are aimed at measuring the low-level physical performance of the two inputs. B:Triggering is representative of tasks that require frequent fast triggering, such as creating a tremolo effect (similar to pressing a kill switch very fast) or emulating double bass drumming, while retaining full control. B:Selection is representative of tasks like navigating to a specific bar in a tablature or selecting items from a menu.

In the qualitative part, participants tried out different applications, followed by a semi-structured interview. We chose types of applications that are commonly used in a guitar practice context (also see use cases from previous works in subsection 2.1). We specifically focus on typical digital interfaces used in individual practice scenarios, namely, Tablature, Metronome, and Video Player.

4.2 Participants

We recruited 16 participants in total (12 male, 4 female). The participants were 21 to 39 years old (mean: 29.9). They had 2 to 25 years of active guitar playing experience (mean: 9.5). In terms of guitar playing expertise, 5 rated themselves as "Novice", 6 as "Intermediate", and 5 as "Advanced". A table containing the detailed previous experiences of the individual participants in terms of guitar playing and pick usage can be found in the *supplemental materials*.

4.3 Apparatus

Figure 4 right shows our apparatus and study setup. Participants were seated in front of a screen (during tasks and when filling out questionnaires via mouse and keyboard). We prepared two guitars (*Harley Benton* guitar kits), one with GuitarFins (Figure 4 Fins) and one with ordinary buttons (Figure 4 Buttons). Both devices feature four elements with three elements close together and a single separate element (Figure 4 left). The placement of both is equal (lower part of the guitar corpus, same as in Figure 2).

GuitarFins Device. For the C:Fins condition (Figure 4 Fins), we used our implementation as described in subsection 3.1. The prototype version for the user study was connected via USB in order to avoid unstable signals. Furthermore, instead of printed circuit boards, we used larger stripboards with hall sensors on both sides, in case individual sensors fail or get misaligned (in the end, using backup sensors was not required throughout the study period). Otherwise, in terms of shape, function, etc. the study prototype was equivalent to the one described in section 3.

Buttons Device. For the C:Buttons condition, we initially built a version with simple button components commonly used for hardware prototyping. However, pilot testing revealed that such buttons have a resistance that is too high for our purpose, which can especially be inhibiting in cases that require pressing them quickly. Hence, we were concerned that our results would not reveal differences between the interactions but rather make buttons appear less suitable simply due to the resistance of our chosen components. We eventually settled on disassembling a game controller (*Logitech F310*) and integrating the salvaged A, B, X, Y buttons into our prototype. Informal tests quickly revealed that these buttons were much more convenient to operate, especially for longer tasks, leading to a fairer comparison.

Figure 4: Left: The two devices of our study corresponding to the two conditions C:Fins and C:Buttons. Right: The study setup. Participants were seated in front of a screen (during tasks with a guitar and when filling out questionnaires). They could choose from various guitar picks (0.38 mm to 2.0 mm).

Participants were instructed to hold a pick when using the buttons (as we wanted to evaluate situations in between guitar playing rather than standalone interactions without a pick), but they could choose with which finger to press them.

Study Software. We used the threshold-based triggering as described in subsection 3.2. Buttons and fins used the same serial communication and triggering logic. To provide minimal feedback when triggering, our software plays a brief beeping sound with each activation. The same sound was used for both devices and in all tasks. In the quantitative part, our software records and processes trigger events to streamline trial management and measurements. Whenever the experimenter activated a "ready" state for a trial, our software waited for the first valid input to start measuring. This logic was also communicated to participants.

4.4 Tasks and Procedure

The procedure for each session was structured as follows (also see Figure 5). After the participant arrived, the experimenter explained the purpose of the study. The participant read and signed a consent form, while being able to ask questions about the study. Afterward, the experimenter introduced the setup, and the participant was given the opportunity to get familiar with the two guitars (one with GuitarFins and one with buttons). This included warming up, playing with a guitar pick, and trying out the input methods.

Quantitative Part. When the participant was ready, the quantitative part of the study commenced, which consisted of the two aforementioned blocks B:Triggering and B:Selection. Each block had two counterbalanced conditions (C:Fins and C:Buttons) and started with a training phase, in which the participant tried the task in both conditions. To collect subjective quantitative data, the participant provided questionnaire responses after each condition.

In the first block (B:Triggering), the participant was asked to trigger the component at a very fast, but still convenient rate for

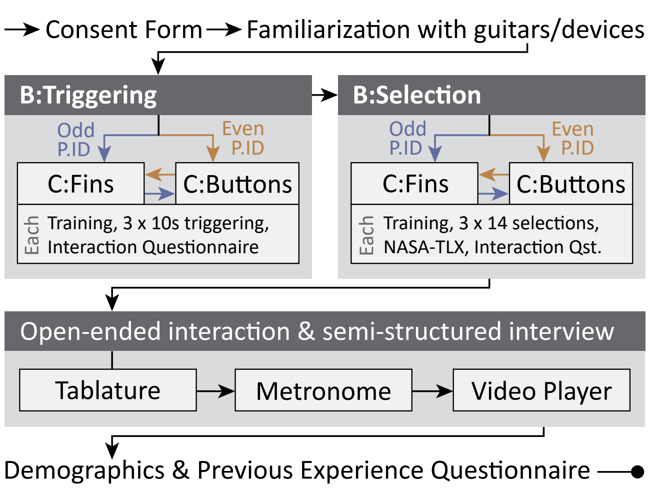

Figure 5: Study procedure with the two quantitative blocks and the open-ended interaction for qualitative feedback. Each quantitative block started with a training phase. The two conditions of each block were counterbalanced.

Table 1: Our custom 7-point Likert scale *Interaction* Questionnaire. For each, the possible answers range from "Strongly Disagree" over "Neutral" to "Strongly Agree".

Q1:Enjoyable	*This interaction with the input device was enjoyable*
Q2:Fatiguing	*This interaction with the input device was fatiguing/exhausting*
Q3:Hindrance	*The guitar pick was a hindrance during interaction*
Q4:Practice	*I would use this interaction with the input device during practice*
Q5:OnStage	*I would use this interaction with the input device on stage*

a duration of 10 seconds, i.e., without over-exerting. This was an open-loop task, as the participant focused only on triggering the input repeatedly without controlling anything. Each of the two conditions in this block (C:Fins versus C:Buttons) consisted of three repetitions (3 × 10 seconds). After the three repetitions, the participant completed the *Interaction* Questionnaire (Table 1).

In the second block (B:Selection), the task was to select a highlighted rectangle from a horizontal list of rectangles (see Figure 4 right). In both conditions, the device had three linearly arranged inputs: *Move Left*, *Select*, and *Move Right*. The participant was instructed to select quickly, but still with a pace that allowed them to avoid mistakes. Each condition was executed three times with different pseudo-random target sequences (same sequences for all participants). In all three repetitions, the participant had to sequentially select 14 targets. There were 16 slots in total, and the targets were never in the first or last slot. After the three repetitions, the participant completed the *Interaction* Questionnaire. Because this task included a closed feedback loop (controlling and reacting to the on-screen visuals), the participant also completed a *Raw NASA-TLX* (simply "*NASA-TLX*" hereafter) after each of the two conditions.

Qualitative Part. After about 40 minutes, the study transitioned to a purely qualitative part. First, the participant tried out three applications, during which they were encouraged to express their thoughts (think-aloud protocol).

- **Tablature**: We used *Songsterr* [23] and mapped navigation and playback control to the fins. The triple-fin module was used to move the playhead *Left*, *Down*/*Up*, and *Right*. This mapping means that up and down strokes on the middle fin were mapped to two different directions. The single-fin module triggered *Play* or *Pause* with a down stroke, and *Back to Start* with an up stroke.
- **Metronome**: We used an online metronome website[1] to let the participant configure a digital metronome. They could strum the single fin to dictate a beat and apply fine adjustments with the other fins. The small fin activated or deactivated the metronome.
- **Video Player**: We opened a public guitar tutorial video on *YouTube* to let the participant try video navigation (*Play*/*Pause*, *Forward*/*Backward*, *Volume Up*/*Down*).

The participant was encouraged to play the guitar in between while trying out the applications, e.g., playing along in the tablature after

[1] https://www.musicca.com/metronome. Last access: 21st of July 2026.

triggering *Play*, setting a beat to then strum along with the digital metronome, and following the exercises of the video tutorial.

The applications were mainly used with our GuitarFins prototype, as the pick-based activations are more novel. However, the participant could always switch to buttons when they wanted to try specific interactions for comparison. The main interaction of the tablature and the video player was similar to the selection task. However, especially for the metronome, the experimenter encouraged the participant to also try the buttons, as rhythmic interaction was not part of the quantitative measurements.

After trying out all applications, the session transitioned into a semi-structured interview. The experimenter asked the participant about aspects that they had not mentioned yet and encouraged them to elaborate on specific statements they had already made. The applications remained active throughout the interview, so that the participant could still try or demonstrate specific interactions while discussing and answering questions.

End of Study Session. At the end of the study session, the participant completed the *Demographics and Previous Experience* Questionnaire. The questions about demographics are partially inspired by Hughes et al. [12]. In total, a session took 90 min or slightly longer, depending on the discussions in the qualitative part. The participant was paid 22.50 EUR and could take the pick(s) that they used during the session with them.

4.5 Measurements

In addition to collecting the previously mentioned subjective ratings (*Interaction* Questionnaire, *Raw NASA-TLX*, *Demographics and Previous Experience* Questionnaire), we measured several objective metrics in the quantitative part. In B:Triggering, we counted the number of strokes in C:Fins or the button presses in C:Buttons, respectively, denoted as **TrCount**. For the final count value of a participant, we took the average of the three trials. In B:Selection, we summed up the task completion times of the three selection sequences (i.e., completion time of 42 selections total without the pauses in between trials), denoted as **SelTCL**. We also counted the total amount of movements, denoted as **SelMvmnts**, as well as the amount of missed selections (triggering selection while not on the target rectangle), denoted as **SelMissed**.

5 Results and Discussion

5.1 Quantitative Results

We used inferential statistics on the quantitative measurements. In this section, we only discuss results that are significant. An overview of all test results can be found in the *Appendix*.

Results of Measurements. Figure 6 shows plots of the measurements of both quantitative blocks. We use paired t-tests to compare C:Fins and C:Buttons where the differences between paired samples are normally distributed (tested with Shapiro-Wilk and visual inspection) and Wilcoxon signed-rank tests, where they are not.

In the B:Triggering block, fins were triggered more often within 10 s (mean = 82.77) than buttons (mean = 68.19). The p-value of the Shapiro-Wilk test is only slightly above .05. We visually inspected the distribution and eventually decided to use a Wilcoxon signed-rank test, as we considered it safer to not assume a normal distribution. The difference is significant (p = .002, W = 12.0). Only 2 out of the 16 participants were slightly slower with fins than with buttons, while the other 14 out of 16 were faster with fins.

In the B:Selection block, buttons outperformed fins according to the three measured metrics. Specifically, the total task completion time SelTCL (3 × 14 = 42 selections in total) was higher with fins (mean = 77.26 s) than with buttons (mean = 56.0 s). This difference was significant (p < .001, t = 10.309, CI = [16.86, 25.66], d = 2.78). The total number of movements SelMvmnts was higher with fins (mean = 258.19) than with buttons (mean = 238.88). This difference was significant (p < .001, t = 6.564, CI = [13.04, 25.58], d = 1.96). The total number of wrong selections SelMissed was higher with fins (mean = 5.31) than with buttons (mean = 1.25). This difference was significant (p = .003, W = 7.5).

Results of Subjective Ratings. The 7-Point Likert-scale responses of the *Interaction* Questionnaire for C:Fins and C:Buttons of separated by block can be seen in Figure 7. We interpreted subjective ratings as ordinal values and compared the conditions within each block using Wilcoxon signed-rank tests.

The *NASA-TLX* score (only in B:Selection) was higher with the fins (mean = 52.063) than with buttons (mean = 34.375). The difference is significant (p = .001, W = 5.5), which means that using fins was perceived as having a higher workload than buttons in the selection task.

In both blocks, almost all responses of the *Interaction* Questionnaire were statistically insignificant. We only found a significant difference in the subjective ratings for the question Q3:Hindrance in B:Selection, indicating that with fins, the pick is significantly less of a hindrance (p = .007, W = 8.0). However, this significance is not surprising, as the fins are designed to be operated with a pick.

In general, there was a large spread of subjective ratings when participants were exposed to the input elements for the first time, using them in the somewhat abstract tasks of the quantitative part. This leads to limited empirical evidence for the quantitative subjective aspects (compared to the objective results discussed above), while also being indicative of a large spectrum of backgrounds and personal preferences, which we report in the next subsection.

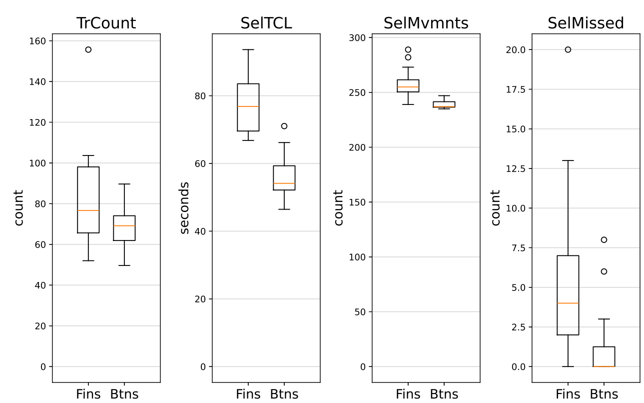

Figure 6: Boxplots of the measurements of both blocks, with both conditions each. All metrics were significantly different between the two conditions.

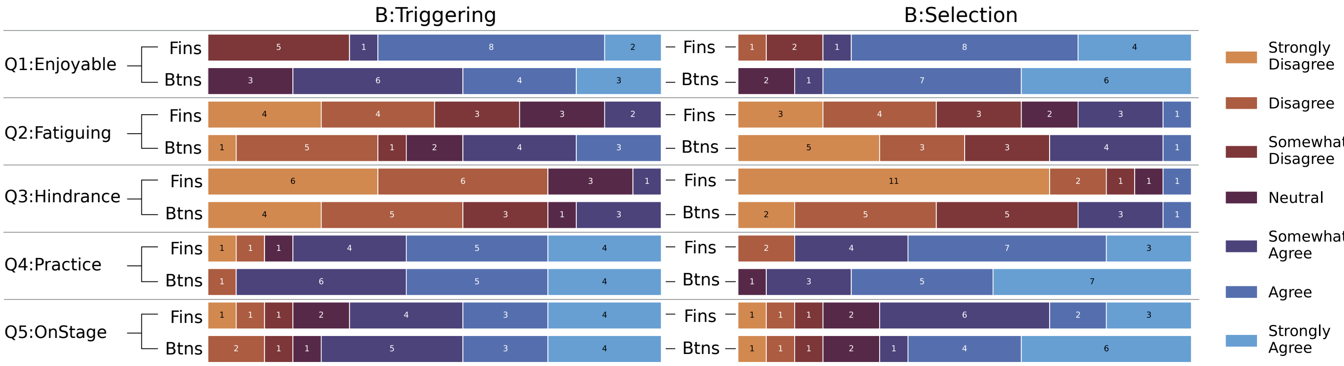

Figure 7: User ratings obtained in the *Interaction* Questionnaire for both blocks and conditions. The difference in ratings for Q3:Hindrance in the Selection block was significant.

5.2 Qualitative Feedback

In addition to the quantitative ratings, we collected qualitative feedback about both devices in conjunction with the tested applications. Below is a description and discussion of the high-level takeaways, plus a selection of specific statements from participants. An extended description of the qualitative feedback can be found in the *supplemental materials*. Where necessary, the participant quotes that are part of the qualitative feedback report below were translated into English, paraphrased, and/or shortened.

Applications. While many participants struggled with the selection task in the quantitative block, the tablature interface (*Tabs* hereafter) generally felt intuitive to them, though it can "*take time to get used to*" (P10). For instance, P4 and P9 stated that the selection task was better with the buttons, but the *Tabs* worked really well with fins (possibly due to training and the *Play*/*Pause* fin being separate from the triple-fin module). In connection to the *Tabs* and the *Video Player*, many participants stated that it was particularly useful not having to constantly switch to mouse and keyboard, which is a general strength of guitar-embedded input. The *Metronome* was considered useful, but generally participants did not note major differences between fins and buttons. Both, strumming a beat (as a guitarist) or tapping a beat with the fingers (a natural way of indicating rhythm) worked well. A common feature request across all applications was to make fin-key mappings customizable. We changed the key mapping on-the-fly upon request, but there is currently no UI for user-defined mappings.

Placement. The most prominent issue mentioned was that the fins were sometimes in the way when strumming. Several participants suggested putting the input above the neck, while simultaneously observing that this position might be less ergonomic, so it should be used for commands or operations that are not used as often. The participants unanimously would find a position behind the bridge impractical, as it is hard to reach and the arm would be in the way.

We designed the fins to be approximately at the height of the strings, but the fin height is in fact one of the many design variables that can be explored in the future. The most promising solution is to have the fins recessed into the guitar's body, so that the pick remains above them when strumming the strings.

Aesthetics of Interaction. We asked participants how they imagined the type of input and the corresponding interaction looks to observers (e.g., audience). They had quite diverging opinions. P4, mentioned that using a pick for input might look strange and that buttons are more subtle. Others stated that the fins were "*cool*" (P2,P6,P11,P15), "*more fitting to a guitar*" (P5), and that the buttons[2] in comparison could appear like a "*toy*" (P14). P9 hyperbolically stated that "*one looks silly when pressing [guitar-embedded] buttons all the time*" (comparing it to a game controller), while "*fins appear more serious*". Similarly, P2 stated that they "*would not press buttons during a metal concert*", while "*using fins looks less like gaming*" and that the fins "*might be appealing in modern music concerts*".

Most Critical Participants. Some participants had critical remarks about fins or guitar-embedded input in general, especially in the beginning. In some cases, their opinions changed throughout the study. For example, P5 commented when being given the guitar with fins for the first time "*I cannot imagine this on stage*". Over time, however, P5 warmed up to the idea of the interaction, and eventually contributed ideas for future on-stage use cases throughout the qualitative part. P4, P7, and P16 remained quite critical towards using fins with the pick, meaning that they generally preferred buttons. However, P4 got the impression during video navigation that using the fingers on the fins might work better than on buttons. For P7, the problem of hitting the fins accidentally was especially severe, as P7 "already accidentally hit the pickup selector switch sometimes" (a pre-existing component on the guitar). P12 was most critical overall and categorically rejected the idea of having extra input on the guitar, stating "*I would never buy a guitar with buttons on it*" (likely also referring to fins). When asked to elaborate and to explain, what type of input was acceptable, P12 stated that "*a [kill switch button] is ok, but anything else not*". This participant identified as a "*purist*" and elaborated that "*[for them] the guitar should basically look like it's from the 60s*". This feedback makes it clear that guitar augmentations and the associated non-established interactions are not necessarily acceptable for everyone, which we discuss further in subsection 5.4.

[2] We instructed participants to imagine *button input in general*, and *not* how the buttons on our prototype look specifically. Whenever in doubt, we asked them whether they meant buttons in general or the ones in our prototype when they referred to them.

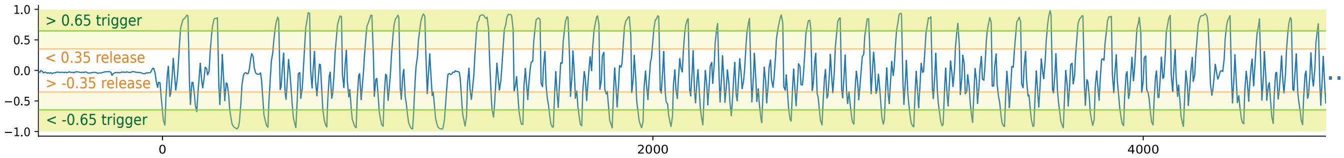

Figure 8: Excerpt of the normalized and smoothed hall sensor signal of P3 in the third trial of the C:Fins condition in B:Triggering. On the y-axis, -1 and 1 correspond to the min/max sensed voltages, and 0 to the voltage when resting. The trial started with a few missed triggers before mostly stabilizing after 1.5 s and reaching around 16 strokes per second.

Learning Curve and Enjoyment. Multiple participants stated that the fins are "*fun*" (P5,P9,P15). For instance, P9 said "*buttons are more pragmatic, but fins are more fun, like a user interface that you enjoy, even though it might not be the most effective one*". However, many participants stated that the fins require training before they could reach the accuracy of buttons (i.e., regardless of triggering speed, which is already faster with fins). P14 was highly skeptical during the quantitative part. Specifically, when being given the guitar with fins for the selection task (their order was buttons first, then fins), P14 said "*oh no [...] this is going to be impossible*". After training during the selection task and throughout the qualitative part, P14 increasingly enjoyed using the fins and eventually preferred them over buttons, imagining even more enjoyment "*especially after continued training*". Similarly, P11, an advanced regularly performing guitarist, saw the learning curve as a strength, stating "*I want to learn this [...] I want to become really good with the fins.*"

5.3 After the Study: Signal Inspection

Curiously, P3 reached a TrCount of almost 160 in B:Triggering with fins, which is way above the average of all participants. Figure 8 shows an excerpt of their signal recording, with around 16 trigger events per second visible. While this picking speed is well within the human limits of alternate picking (especially in fast-paced musical genres such as metal), we wanted to inspect and verify this outlier, as we could not rule out that our device was sending false positive trigger events. We invited the participant again in a separate high-frequency 1000 fps video recording (*not* to record new study data), so that we could manually count the strokes afterward, average the count over a few seconds, to eventually verify that the reported values from the study are likely valid. Indeed, the participant hit the fin with around 16 strokes per second—even slightly exceeding what was counted during the study. The close-up slow motion recordings can be found in the *supplemental materials*. Such recordings also help understand undesired noise and oscillations. We fine-tuned the physical prototype to have as little resistance as possible, while also not oscillating too much, but there are still small oscillations after each trigger event (also noticeable in the slow motion recordings). While those normally do not reach the activation threshold when swinging to the other side (see Figure 8), we additionally added a time threshold of 40 ms, meaning that we treat extremely fast activations as oscillations or signal spikes and discard them.

5.4 Summary and Implications

The study confirmed that there is no one-size-fits-all solution for skillful guitar-embedded input in terms of both, performance and personal preference. While triggering the same fin was empirically faster, switching between fins was more challenging, especially with the relatively short amount of training.

For the selection task, the arrangement with three buttons matching the three unoccupied fingers can be highly effective in terms of performance, while still not necessarily being subjectively preferred in the long-run. Another aspect of the selection task was that participants had to look away from the device (to the screen), which means that the participants had to rely on proprioception. Tasks that would involve selecting without looking away (e.g., output via a co-located small screen next to fins or LED beacons) would likely have led to fewer errors, but would not have tested fins in a challenging use case. Furthermore, during the selection task, participants often overshot by one slot when using alternate picking, likely because alternate picking is often used with even numbers of strokes. Another observation is that small misalignments often caused many consecutive incorrect inputs. Specifically, when using alternate picking to move the active slot, while accidentally shifting the pick towards the middle fin without noticing, several selections were triggered before being able to react. Similarly, trying to select, while accidentally hitting *Left* or *Right* often caused brief periods of disorientation. Therefore, multi-fin designs should likely keep the selection fin (or a similar command) separate from the movement fins. This was also the mapping in our example applications. In actual applications such as *Songsterr*, though similar to selection, fins were generally reported to feel natural, likely because incorrect inputs could be easily corrected and the *Play*/*Pause* trigger was further away from the rest. Overall, this indicates that fin interaction design needs more exploration. How to arrange input elements optimally might differ considerably between buttons and fins.

As mentioned before, some study participants triggered the fins by accident while strumming. It is clear that by introducing new input components to a guitar, we add new affordances and constraints to the instrument, which, especially without training, require conscious thought to be dealt with. This can have an influence on the musician-instrument relationship as it impacts the transparency of the instrument at least temporarily. It would be interesting to see how this changes in the long-run (especially given more practice) and whether the familiar strumming gesture helps incorporate the fins quicker into the body schema of the musician compared to other input components like buttons, which require gestures that are less familiar to the right hand in a guitar playing context. Beyond the guitar, this also mirrors the findings of Morreale et al. [37] suggesting that adapting to changes in an instrument's structure (a violin in their case) is different for each individual. Similarly, the processes of instrumental genesis [43, 48] are highly subjective, which is reflected by the different preferences of participants in terms of shape, size, placement, or even type of the input components, as well as the desire of some participants to use their fingers to control the fins and the broad range of proposed use-cases. The availability of different input components with different affordances implemented as a modular approach can support the *instrumentation* process as well as the *instrumentalization* process of instrumental genesis (see section 2.2 for an explanation of genesis).

Due to the rich set of styles and backgrounds within the guitar playing domain, our qualitative analysis gained deeper insights than what subjective ratings could express in terms of understanding how different guitarists would use (and learn to use) input on the guitar (with a particular focus on binary triggers). For instance, in both conditions, there was a wide spread in terms of subjective enjoyability (see Q1:Enjoyable in Figure 7). This means that the opinions among the invited guitarists varied considerably, beyond what we expected as individual differences. Hence, it is clear that continuous conversations and inquiries within the domain are required to more sharply define a target audience, while respecting individual preferences, e.g., for more "purist" guitar styles.

6 Limitations and Future Work

This work focuses on GuitarFins as a new type of input component, specifically designed around usage with a guitar pick. We investigated the suitability of fins versus buttons in terms of triggering speed and a simple selection task. As the use of a guitar pick as an end-effector for physical input is underexplored, we deliberately kept the scope to the simplest input possible: binary triggering events. Our prototype and study mark a first step and investigation of this type of guitar-embedded input, leading to a plethora of opportunities and questions for future work in terms of design alternatives of GuitarFins, long-term deployments, and various types of pick-based input components beyond fins.

Complementary Input Methods. The tested input methods can be seen as complementary to each other and should be chosen based on their strengths for the desired type of interaction (e.g., three buttons to be used in tandem plus one fin for fast or rhythmic input). Beyond the tested tasks, the more complex parts of applications, such as setting up a recording session (basic settings, filenames, etc.) or searching for a video, are likely better with a mouse and keyboard, meaning that guitar-embedded input components will not fully replace those devices anytime soon, but rather complement them. More concretely, the strength of guitar-embedded input is in the convenient operation of simple, but frequent inputs that would otherwise interrupt the flow, such as moving a playhead or restarting a recording. Furthermore, physical input on the guitar can also be complementary with other modalities such as input methods based on the guitar's audio signal or gestures [3, 4, 11, 18, 42, 44].

Similarly, foot-based input can be combined with fins as well. We implemented one such use case by sending MIDI commands to a synthesizer floorboard (Figure 9). Concretely, fins can be used to select a bank fast and conveniently (usually done between songs), whereas foot-based input is used when switching patches *within* a bank while playing. Going further, allowing to also set the patch via fins on stage could even partially free guitarists from having to return to the foot pedal every time—especially in cases where they do not have to switch effects and play a note at the same time.

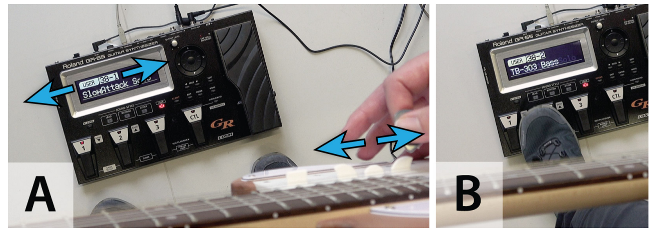

Figure 9: Combining GuitarFins with foot-based interaction. A) Our software sends MIDI commands to the floorboard to quickly and conveniently switch between banks via GuitarFins. B) Patches within the bank can then be switched as usual with the foot while playing.

Other Use Cases for Input Triggers. There are many use cases that go beyond the ones tested in our study, some of which were also mentioned by our participants (see *supplemental materials*). The most straightforward future use cases are about streamlining the communication with equipment or recording software (effect controls, amplifier settings, record / play / retake, etc.). In addition, those extra inputs could be part of a live performance. For example, they could emulate simple sounds of other instruments, e.g., to live-record a drum track for a connected looper to repeat in the background. Fins or buttons could control lights or visual effects on stage [50], where fins in particular, with their very fast alternate picking input capabilities, could generate strobe light effects that were previously fast pre-programmed on-off sequences.

Beyond streamlining or enhancing conventional use cases, fast guitar-embedded inputs could also be explored with more "playful" applications, such as using them as a game controller. Furthermore, exploring the ceiling of pick-operated input with more complex use cases, such as writing simple chat messages while still holding the guitar, is another long-term future research endeavor.

Fin Design Alternatives and Extensions. Our GuitarFins underwent many iterations to find the right shapes and physical resistance. Yet, the current prototype is still just one of many design alternatives and has potential for simple or more complex extensions. For example, we did not implement hold-to-repeat functionality, as we wanted to measure the input component's inherent performance property as a physical input component (including the subjective experience of triggering the component often). Hold-to-repeat is a software feature that depends on the configured delay and rate of triggering key presses, where preferences might vary between users. However, for actual deployments with personal configuration, long-presses would be enabled—especially for long-term usage. Relatedly, a straightforward software extension is to use the intensity of how much the fin is pushed by the pick, enabling non-binary input (e.g., scrolling with different velocities using continous analog control). As mentioned before, switching fins without looking is currently a limitation, as it requires training before it can be used fast and persistently, meaning that the spacing and function mapping need to be chosen carefully. Adding active haptic feedback, such as force feedback or vibrotactile 'clicks', could partially address this and further improve the feel and accuracy of activations.

The post-study recordings with P3 point to a potential limitation of the specific design of our prototype. P3's picking technique involves gripping the pick almost fully except for the tiny part at the tip, which our three-fin module design is not optimized for. This meant that during the selection, they had more than average misinputs (13) due to hitting neighboring fins with their fingers. Hence, the optimal size and distance of the fins might also depend on the picking technique. To mitigate the issue, the fins could be recessed further into the guitar's body, which, as mentioned before, could also address the issue of accidentally hitting the fins. This is also related to minification and better modularization. A commercial product aiming for acceptance by a broad range of guitarists and ensuring longevity should keep irreversible modifications to the instrument to a minimum. In the case of GuitarFins, this could mean a minification of the modules and a mounting solution that mounts them to the pickguard without requiring modifications to the body of the guitar. Alternative sensing components like piezo-resistive, capacitive, or pressure sensors might be suited for minification and different use-cases. In addition, making parts of the body detachable (similar to smart guitars) could combine many advantages. Such modularity would need to be part of the guitar manufacturing process, i.e., the guitar-embedded input would be fully integrated.

Future User Studies and Long-Term Deployments. In our study, we were interested in the low-level performance as well as the subjective experience of guitar-embedded input components by testing a specific instance. Future studies could investigate the performance and ergonomics implications of different placements on the guitar and whether there are any differences with regards to the impact on the musician-instrument relationship and the transparency of the instrument. Similarly, this study investigated a layout with an input component array that is *parallel* to the neck. Other arrangements, such as along the picking direction (arranged like guitar strings) or other angles, can be designed and tested in the future. Furthermore, in the quantitative part, we instructed participants to use the fins with the pick, though fins can also be used with the fingers, possibly even more conveniently than buttons due to a sideways finger motion instead of pressing into the guitar. It will be interesting to see what usage patterns emerge when used over a longer period (e.g., using fingers for inputs without moving the wrist, while using the pick for fast activations).

The quantitative part of our study tested a specific configuration and compared specific prototype instances (as usual with quantitative testing). Other buttons or other fin designs may lead to different results. Testing different designs and other types of triggers (e.g., single-pole double-throw toggle switches with a momentary center-off configuration) remains to be explored in multiple dedicated quantitative studies.

In addition, there are many aspects that yet need to be tested, such as rhythmic input performance, non-binary analog input, comparing up-stroke with down-stroke input triggering, and more. Furthermore, a core assumption of our use cases (and hence our scope) is that stationary input, such as a keyboard or tablet, is either not available (on stage), difficult to reach (e.g., during band practice) or inconvenient to reach (e.g., desk during practice). Currently, guitarists tend to set up their practice environment so that digital input is reachable (e.g., next to a desk [31]), although a better practicing space might be available away from the desk. It will be interesting to see whether guitarists change their practice and recording setup over time if guitar-embedded input is available. However, comparing pick-operated input with devices that feature multiple types of inputs will require a more holistic view on the concept, as it requires inputs that go beyond binary triggers (e.g., to emulate mice or directional inputs in general).

Other Pick-Operated Input Components. As described so far, our GuitarFins concept in itself already points to various future research challenges. Yet, GuitarFins comprise just one instance of using a pick (or plectrum for any string instrument) as an end-effector for skillful physical input. For example, other classical types of components, such as knobs or sliders, could be operated similarly with the pick instead of (or in addition to) the fingers when designed accordingly. We could enable microgestures with micrometer-precision motion sensors (as in optical mice) or joystick-like 2D input, executed with fine-grained pick motions. Another possibility could be isometric physical input components that sense directional pressure instead of motion, such as a small slit (just large enough for the pick to enter) with pressure sensors inside. Going further, instead of being integrated into the guitar or another string instrument, pick-operated components could also be part of separate input devices, e.g., residing on the desk as a peripheral device, or integrated in equipment, such as guitar amplifiers. The design of conventional input devices could also be adjusted so that it can be used with a pick as well, such as a specialized mouse that has a slit with sensors or another element for the pick—combining wrist movement with pick-based activations for mouse clicks. Overall, the premise of the user holding a guitar pick unlocks several challenges and opportunities for future HCI and instrument interaction research.

7 Conclusion

We presented GuitarFins, a new type of physical user input component that is operated with a guitar pick. Our concept is an instance of using domain-specific skills for effective, seamless, and enjoyable interaction. In a user study with 16 guitarists, we compared GuitarFins with buttons to test our prototype and, more generally, to generate insights into how guitarists use and think about input while holding a guitar pick. Participants were persistently faster when triggering a single fin, while buttons are useful when having to switch input elements often, especially when positioned in a way that they can be used with the three fingers that are free when holding a pick. The qualitative findings of our study suggest that many participants consider fins to be enjoyable to use—especially when imagining longer-term training. Overall, our prototype and study findings mark the first crucial step for understanding the implications of holding a guitar pick during input, as well as for designing devices around the use of a guitar pick as an end-effector for skillful user input.

Acknowledgments

We thank the participants of our evaluation for their time and expertise. This work was supported by the *Alexander von Humboldt Foundation* (funded by the *German Federal Ministry of Research, Technology and Space*), the *Cyber Valley Research Fund*, and by the *German Research Foundation DFG* (grants 495135767, 390831618).

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Appendix: Statistical Test Result Tables

Table 2: Statistical results of our measurements of both blocks. The columns include each metric's measured mean values and the Shapiro-Wilk tests (normality of differences), followed by either the paired t-test results or Wilcoxon signed-rank test results (whichever is applicable).

	Fins	Btns	Shapiro		t-test / Wilcoxon		
Measure	*mean*	*mean*	*W*	*p*	*t*	*W*	*p*
TrCount	82.8	68.2	.89	.05	–	12.0	.002
SelTCL	77.3 s	56.0 s	.98	.95	10.31	–	<.001
SelMvmnts	258.2	238.9	.94	.33	6.56	–	<.001
SelMissed	5.3	1.2	.79	.002	–	7.5	.003

Table 3: Results of Wilcoxon signed-rank tests of the B:Triggering block.

	Fins	Btns	Wilcoxon	
Measure	*median*	*median*	*W*	*p*
Enjoyable	6.0	5.0	42.5	.52
Fatiguing	2.5	4.0	30.0	.08
PickHindrance	2.0	2.0	30.0	.47
DuringPractice	6.0	6.0	18.0	.3
OnStage	5.0	5.0	24.0	.71

Table 4: Results of Wilcoxon signed-rank tests of the B:Selection block.

	Fins	Btns	Wilcoxon	
Measure	*median*	*median*	*W*	*p*
Enjoyable	6.0	6.0	16.0	.22
Fatiguing	3.0	2.5	21.5	.53
PickHindrance	1.0	3.0	8.0	.007
DuringPractice	6.0	6.0	13.5	.07
OnStage	5.0	6.0	19.0	.2