Investigating Page Turning Methods for Sheet Music during Piano Play

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ABSTRACT

Musical pieces composed for the piano are registered on paper sheets. Since the space for sheets on the piano is limited, pianists have to turn pages while playing the piano to get access to the registered without having to stop playing. In this work, we present two methods to support page turning during piano play: 1) turning by touch and 2) turning by pedal in combination with two types of note layouts in (1) DIN A4 and (2) an adaptive display size. We compared these page turning methods to the baseline of using paper pages with 10 participants in a controlled lab experiment. Our results show that the pedal-adaptive turning method leads to the lowest interruption time while playing and pedal-based methods have a high usability and low cognitive load.

CCS CONCEPTS

• **Human-centered computing → Empirical studies in HCI**.

KEYWORDS

musical instruments, support setup, piano

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1 INTRODUCTION

Playing a musical instrument can have many positive effects on people's lives, such as self-actualization [14], or the reduction of depression [7, 26]. Musical pieces are most commonly written down as sheet music on DIN A4 paper sheets. Those sheets are typically placed on the music stands above the piano keyboard as support during piano play. Most musical pieces take up several pages of paper. Since the size of the music stand is limited, pianists have to turn places during piano play. Another possibility is the usage of a digital display to display the sheet music. Depending on the software, pianists either have to scroll or turn pages of the viewing software by hand.

During live performances, most musicians play by heart. However, especially during practice, page-turning is crucial and can impact piano play in the following ways. Because one hand has to stop playing, the play might be slowed down, interrupted, or pages might even fall down on the keyboard. Several commercial programs offer automatic page scrolling at a pre-defined speed. Other algorithms turn pages based on audio analysis denoted as automatic score following [1, 22]. While this reduces the burden from pianists, it also limits their control over the displayed sheet music [29]. For instance, during practice, a pianist might want to repeat specific parts of a musical piece or adapt their playing speed. Consequently, pianists require methods to actively adjust the displayed sheet music to their play.

In this paper, we investigate two page-turning techniques during piano play. All techniques keep the pianists in control while also reducing the burden on them. The first investigated technique is turning by touch and mimics page-turning by hand. The second technique utilizes a foot pedal to reduce the burden from the hands. We investigated the two page-turning techniques in a lab study with ten participants who play the piano. Each technique was evaluated with two different layouts – one digital depiction of a DIN A4 sheet and an adaptive layout. Manual page-turning served as a baseline. We found that turning pages digitally is faster and more convenient than using a printed paper, and pedal-based techniques are faster to operate than a touch screen.

2 RELATED WORK

In this section, we provide related work about piano play assistance. We summarize publications that investigated *piano play* and those that investigated *other musical instruments.*

Research most closely related to ours investigated other page-turning methods. Within this scope, systems for turning paper

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pages have been realized and investigated [32]. Such solutions are recommended for pianists with physical impairments who have difficulties in turning the paper sheets [32]. For digital sheet music, several different methods have been investigated. Those can be grouped into solutions that do not require a specific action of the pianist, such as automatic score following by audio analysis [1, 22], scrolling at a pre-defined speed [3], or gaze detection [29]. This, however, can only be used if the pianist plays the song from beginning to end without any detours or repetitions. The second set of solutions requires an action by the pianist, such as voice commands [10].

Another stream of research investigated support by alternative visualizations for sheet music. A widely known method is given by visualizing notes as vertical bars on a screen. The bars float towards the keys of a piano depiction. Their length represents the length of a tone. Synthesia is a commonly used commercial software for this visualization [28]. The bar visualization was more intuitive than sheet music, especially for beginners [25]. A better connection to the physical piano keys can be provided by projecting the bars on a surface mounted on top of a piano [23, 25, 34] or using augmented reality [9, 17]. However, the bar presentation is no substitute for sheet music since it conveys less information, e.g., no dynamics or pedal information. Other visualization options based on projection are: highlighting the connection between the tone denoted by sheet music and the pressed piano key [30] and projecting the hands of another person shifted by one octave [33]. Further research investigated the movements of pianists while playing. For this, several movement types have been investigated, such as joint movements [12], or pedal movements [16].

Several setups for supporting the players of other instruments have been previously presented and investigated. One large stream specialized on learning musical instruments. MusicJacket, for example, aims to teach body posture and the bowing techniques for violins via vibrotactile feedback [31]. Feedback about finger positions on the violin can be given by resistive [11, 21] or motion sensors [8]. Similar solutions have been proposed for guitars [18, 27] with a teaching support using augmented reality that captures or depicts finger targets [6, 15, 15, 20, 24] or a 3D-model of the hand [20].

3 PAGE TURNING METHODS

For turning the pages of printed sheet music, pianists have to move one hand from the keyboard, which can interrupt the play. In this paper, we investigate two methods to support page turning using: 1) touch and 2) foot pedal.

3.1 Turning Methods

Turning by ***touch*** aims to keep a similar motion like the turning of printed sheet music. To turn the page by swiping the screen, the pianist has to use one hand, which triggers the page turn. Compared to printed sheet music, the required motion is likely to be executed faster. A swipe gesture was used instead of a tap gesture because users are more likely to be familiar with it, e.g. from using their smartphone. Turning by ***pedal*** shifts the page-turning task from the pianist's hand to the left foot. Depending on the song, the right foot is already used for pressing the sustain pedal[1]. As a result, an interruption during play can be ruled out.

3.2 Layouts

In our study, we investigated two methods: 1) *A4 layout* and 2) *adaptive layout* (see Figure 1). The A4 layout displays a DIN A4 music sheet identical to printed DIN A4 sheet music with between 5-7 staves per page. The adaptive layout adapts to the view to different screen sizes. Each sheet is annotated with the positions of its staves, and a pagination algorithm sets bounds to position the staves onto multiple pages, similarly to word wrapping in a text editor. For our study, the layout algorithm scaled the staves such that three of them were displayed per page to ensure good readability for different players while keeping identical conditions for all players in the study. The annotation of staves was done automatically in a custom editor, which internally used a pre-trained machine learning model called *Measure Detector*[2] that recognizes the bounds of individual measures within the score. This could also be done by hand in a reasonable amount of time. The layout was horizontal to enable a number of notes that is similar to the A4 layout.

4 EVALUATION

To evaluate the page-turning methods, we conducted a controlled lab experiment with ten participants.

4.1 Participants

We recruited ten participants; four of them identified as female and six as male. They were between 13 and 52 years old (∅=22.90, *SD* = 10.62) and reported having a piano playing experience between one and thirteen years (Median=10). One participant was a professional piano player.

4.2 Study Design

The study was designed to be in a within-subject design and consisted of five experimental conditions. The experimental conditions were based on the combination of two independent variables with two levels each: type of page-turning (pedal/touch) and sheet layout (A4 format/adaptive), and one baseline using physical paper sheets:

(1) Baseline: Loose paper sheets in DIN A4 size. The participants had to turn the sheets manually in a way they are most comfortable with, keeping one single page open for reading at a time.
(2) Pedal-A4: DIN A4-sized sheet display with pedal page-turning.
(3) Pedal-Adaptive: Adaptive layout with pedal page-turning.
(4) Touch-A4: DIN A4-sized sheet display with touch page-turning.
(5) Touch-Adaptive: Adaptive layout with touch page-turning.

The A4 sheet layout displays the notes in a DIN-A4 format. The aim of the adaptive approach is to display the sheets of music in a way that utilizes the screen space better than a fixed A4 format. To increase reproducibility, three staves were displayed per page in the most space-efficient way on a horizontally oriented screen in the conditions with the adaptive layout. The order of the conditions was

[1]Grand pianos also have pedals for the left foot which, however, are not used very often.
[2]https://github.com/OMR-Research/MeasureDetector accessed 05-July-2021

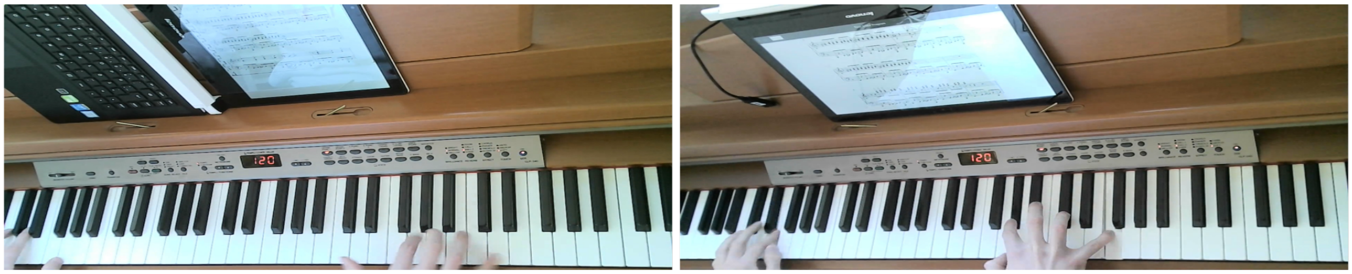

Figure 1: Two types of layouts evaluated in the study: (1) A4 sheet layout displays the notes in a DIN-A4 format (left) and (2) Adaptive layout adapts the view of different screen sizes with a goal to minimize a number of page turning (right).

counterbalanced using a Latin Square to statistically cancel out any learning effects over time. Each experimental condition took, on average, fifteen minutes, and the entire study lasted approximately ninety minutes per participant.

4.3 Collected Data

To compare page-turning methods for piano players, we measured the following dependent variables:

(1) *Interruption time [s]* is a delay caused by the page-turning action relative to the remainder of the play. It represents the negative effect perceivable by any potential listeners. It is calculated by comparing the play speed shortly before and at a page turn.
(2) *Subjective usability* of the page-turning methods using System Usability Score (SUS) [5].
(3) *Perceived cognitive load* of the page-turning methods using NASA Task Load Index (TLX) [13].
(4) *Perceived sheet size (Likert scale)*: for each turning method, every participant estimated the appropriateness of the sheet size (1 – too small, 3 – just right, 5 – too big).
(5) *Readability (Likert scale)*: for each turning method, every participant estimated the readability of each note sheet (1 – worse than paper, 3 – like paper, 5 – better than paper).

4.4 Study Task and Apparatus

The participants were asked to play a song of their choice on a digital piano. Before the study, the participants sent the song to the experimenters for pre-processing. The length of the song was limited to four pages, resulting in at least three page turns in roughly five minutes of total playing time. Another requirement for the song was an inability to play it by heart, but it was required to be able to play it as fluent as possible to avoid interruptions not caused by page turns.

The test setup (see Figure 1) consisted of a digital piano with 88 keys in standard size, two additional foot pedals (one to turn forwards and one to turn backwards) and a laptop with a multitouch screen (15 inches, 1920×1080 pixels). The screen was placed into landscape mode for conditions with adaptive layouts. For the A4 layouts, the screen was placed vertically such that the displayed PDF has a maximal size without distorting the aspect ratio or cropping on the borders. Additionally, we used a camera to record the hand movements of the players. The sizes of the digital sheets corresponded to those used by Bell et al. [3]: the staves were 5-6 mm in height in the A4 layouts and 7-10 mm in the adaptive layouts. The height of a single stave on the printed sheet was 6-7 mm.

4.5 Study Procedure

After obtaining informed consent, we conducted a brief interview with each participant to better understand their previous experience in playing the piano. Next, we introduced them to the experiment, and the participants familiarized themselves with the study setup, the camera recording and had a test run playing the digital piano. Every condition was followed by the SUS and TLX questionnaires and questions regarding the experience with the system. In the end, we collected subjective preferences and participants' feedback through a final questionnaire.

5 RESULTS

Overall, we found that turning pages using an adaptive layout combined with a pedal led to the shortest interruption time. Moreover, both page-turning methods with a pedal had the lowest perceived cognitive load and the highest SUS scores. The interruption time, SUS, and TLX scores were analyzed using a Friedman test. For the post-hoc analysis, we applied a pairwise Wilcoxon signed rank test corrected with the Bonferroni-Holm method.

5.1 Metrics

5.1.1 Interruption Time. Users had shorter interruption times using touch- and pedal-based methods for both types of layouts (see Fig. 2). The combination of pedal and an adaptive layout led to the shortest interruption time (< 1 second). We observed a statistically significant difference for the interruption time among turning methods ($\chi^2 = 15.92$, $p = 0.003$) with a moderate effect size ($W = 0.47$). The post-hoc analysis revealed statistically significant differences between the paper condition and both adaptive conditions (touch: $p = 0.049$; pedal: $p = 0.02$).

5.1.2 Subjective Usability and Perceived Task Load. The pedal-adaptive ($Mean = 80.8$, $SD = 12.2$), pedal-A4 ($Mean = 84.8$, $SD = 7.4$), and touch-A4 ($Mean = 84.8$, $SD = 15.2$) received the highest SUS scores above 80, where any SUS score greater than 80 is considered as excellent [2]. The touch-adaptive method ($Mean = 68.8$, $SD = 23.0$) performed comparably to the baseline

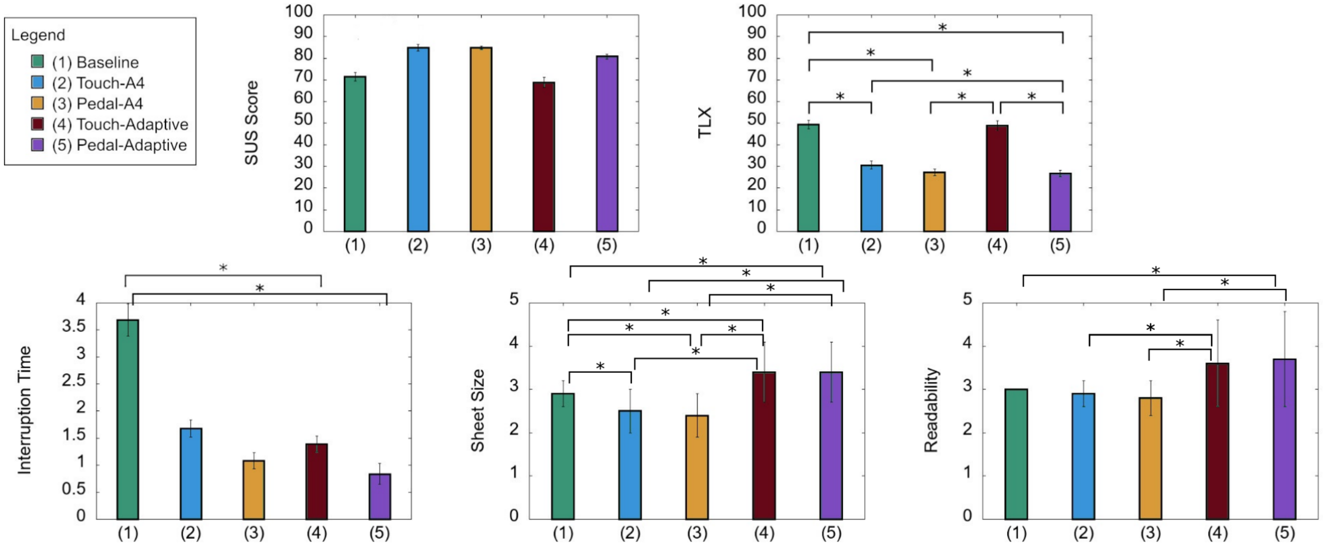

Figure 2: Bar charts of the user study results. The error bars regarding SUS, TLX, and interruption time indicate the standard error. The asterisk * indicates statistically significant differences.

using paper sheets (*Mean* = 71.5, *SD* = 19.8). Moreover, the subjective usability scores correlate with the TLX scores and is lower for pedal-adaptive (*Mean* = 26.7, *SD* = 15.2), pedal-A4 (*Mean* = 27.2, *SD* = 15.5), and touch-A4 (*Mean* = 30.6, *SD* = 18.6) than for touch-adaptive (*Mean* = 48.9, *SD* = 23.9) and the baseline with paper sheets (*Mean* = 49.4, *SD* = 20.4). This finding reflects an increased cognitive load for methods with low usability (see Fig. 2). We observed a statistically significant difference for the TLX values (TLX: χ^2 = 23.3, $p < 0.001$; SUS: χ^2 = 8.35, $p < 0.079$). The post-hoc analysis revealed statistically significant differences that are shown in Fig. 2.

5.1.3 Sheet Size and Readability. Overall, the A4 page formats was rated to be slightly too small (*Mean* = 2.45, *SD* = 0.5) and the adaptive page formats as slightly too large (*Mean* = 3.40, *SD* = 0.7). The paper format was rated with 2.90 (*SD* = 0.3) and is considered to be of an appropriate size. We observed a statistically significant difference for the readability among turning methods (χ^2 = 25.4, $p < 0.001$). See Fig 2 for the post-hoc analysis.

Overall, the readability of the A4 display (*Mean* = 2.85, *SD* = 0.4) was comparable to paper sheets. The adaptive sheets, on the other hand, were easier to read, with an average score of 3.65 (*SD* = 1.0). We observed a statistically significant difference for the readability among turning methods (χ^2 = 11.6, p = 0.021). The post-hoc analysis revealed statistically significant differences between the pedal adaptive and paper (p = 0.046), pedal A4 (p = 0.007) and touch A4 (p = 0.014), as well as between touch adaptive and touch A4 (p = 0.023) and pedal A4 (p = 0.011).

5.2 Subjective Preferences

5.2.1 Turning Methods. Turning the pages using pedal-based methods was generally preferred (N = 8) over the touch approach due to the advantage of keeping both hands on the piano keys. However, the pedal conditions had a slightly longer learning curve and were generally considered to be less intuitive than swiping by touch. Turning the page with a pedal also led to early page-turning or turning it twice. As mentioned by P3: *"the pedal was too easy to press accidentally, so that one could not rest the foot on it"*.

5.2.2 Sheet Layouts. Seven (out of ten) participants preferred the A4 format size, and the remaining three found the adaptive format more appropriate to use. Two participants stated that they wanted to minimize the number of page turns. This indicates that having smaller notes is an acceptable price to pay to have less page-turning effort. Another downside of the adaptive layout is that page turn positions are not as "well-placed" compared to printed sheets. This disadvantage can be countered by configuring the adaptive layout to a smaller sheet size. Two other participants were irritated by the layout due to the novelty of using it. The paper sheets were primarily disliked, and none of the participants has selected it as the most preferred presentation method. However, two participants ranked it their favourite option because it facilitates making notes directly on the sheet of paper, especially during practising hours.

In general, six (out of ten) participants reported that they could imagine using the software regularly. The remaining participants who answered "no" mentioned that they typically play without music sheets. A couple of participants expressed additional wishes and preferences. For example, P2 asked for an annotation feature, which is often necessary during practice, and P6 would prefer paper for songs with four pages or less.

6 DISCUSSION & LIMILATIONS

Our findings coincide with the findings from Bell et al. [3] regarding different sheet sizes. In particular, smaller sheet sizes are disliked but do not necessarily reduce readability. Enlarged sheet sizes were preferred over small ones, but the "normal" printed sheet size is still appreciated the most. However, Bell et al.'s study did not include the original paper as a baseline. In the study of McPherson [19], however, participants complained about small font size. Although they did not specify any exact sheet sizes, we can assume that the digital sheets were about or at least 85% the size of printed sheets, which roughly equals the size used in the A4 conditions in our study. McPherson did not specify which monitor was used, except that it was a "standard 17 monitor", which was displaying two pages instead of one. Given that the study was published in 1999, it can be assumed that they used a CRT monitor with comparatively low resolution. This issue must have been solved with the use of LCD displays, as the study by Bell et al. [3] does not mention this problem.

The page-turning methods and layouts evaluated in our study have their merits and use cases. Pedals can be comfortable to work with but might have to be carried around as additional components. Pedal page-turning can be further improved using a mechanism to reduce accidental and double pedal presses. An alternative solution would be to have the page-turning action trigger on a pedal release, as done by Blinov [4].

Standalone touchscreens have the benefit that they are portable as mobile devices. The touch gestures in our study were not always recognized on the first try and broke the flow of the player. The swipe gesture can be complemented by simple tapping as an alternative that may be faster and more reliable to execute.

Our evaluation was restricted to piano playing only, and the results from this study might not generalize for other instruments. Moreover, playing an instrument is something very individual and requires supporting solutions allowing personalization and configuration. Often, pages are either bound as a book or glued together by tape. In the first case, page-turning is considerably faster and thus less cumbersome than with loose sheets. In the second case, up to usually, four pages are shown at a time, which already fits a lot of smaller pieces without any page-turning.

7 CONCLUSION & OUTLOOK

In this work, we evaluated four page-turning methods for piano players against a baseline. We found that turning pages digitally is faster and more convenient than using printed paper. Moreover, pedal-based techniques are faster to operate than a touch screen, but they are not portable and might require learning. Considering the layouts, the adaptive layout required little overhead to set up and resulted in better screen space utilization. However, the layout with three (but large) staves required more page turns, which is not fully countered by the ease of using the pedal. Additionally, we found that piano players prefer larger sheets based on better readability but dislike turning pages more often.

In the future, we plan long-term evaluations with a larger sample size, which will allow users to configure the application in the best way for them. With this, one can evaluate more broad concepts and is not limited to comparing single configurations and individual preferences. Another aspect of future work can look into tracking the player's position without active user input by communicating the page turn in advance using eye-gaze tracking.

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