Integrating BPMN and Chord Wheel Visualization for Understanding Musical Harmony: A Human-Centered Eye-Tracking Study

JOSEF PAVLÍČEK[1,a], PETRA PAVLÍČKOVÁ[2,b] ,IRENA ŠTRAUSOVÁ[1,c]
[1]University of South Bohemia in České Budějovice, Faculty of Economics, Department of Applied Mathematics and Informatics, Branišovská 1645/31a
CZECH REPUBLIC

[2]Czech Technical University in Prague, Faculty of Information Technology, Department of Software Engineering,
Thákurova 9, 160 00 Praha 6
CZECH REPUBLIC

[a]ORCiD: 0000-0002-3959-5406
[b]ORCiD: 0000-0002-7456-2108
[c]ORCiD: 0009-0007-8999-0061

Abstract:- Modeling musical harmony as a sequential process offers an alternative perspective to traditional notation systems. This paper explores how Business Process Model and Notation (BPMN) can be applied to represent chord progressions, focusing on the systematic construction of triads, seventh chords, and their transformations. By combining BPMN with the interactive Chord Wheel Diagram, harmonic relationships can be expressed as procedural models that make tonal dependencies and chord development within a key easier to follow. To examine the usability of the proposed approach, we conducted a qualitative study involving user tasks supported by eye-tracking analysis. The results reveal patterns of visual attention and highlight points of increased cognitive effort during chord construction. The findings suggest that process-based visualization can support intuitive understanding of harmonic logic and may serve as a bridge between computational modeling, music education, and interactive learning tools.

Key-Words: - BPMN process modeling, chord wheel visualization, harmonic analysis, eye-tracking, music education, human-centered design, cognitive load, qualitative study, interactive learning tools, computational music representation.

Received: March 11, 2025. Revised: December 13, 2025. Accepted: March 11, 2026. Published: June 5, 2026.

1 Introduction

The idea of describing harmony as a process has deep historical and theoretical roots. Early discoveries of the mathematical basis of musical intervals [1] and the development of notational systems [2] represent initial attempts to formalize music as a structured language. Traditional music theory resources [3], [4], [5] emphasize notation and symbolic systems as the primary pedagogical tools. However, these classical approaches often impose a cognitive burden on learners with a limited theoretical background, [6].

Informatics-based models, by contrast, propose more visual and process-driven methods. Prior work has demonstrated that BPMN diagrams can capture chord progression in C major, highlighting how exclusive and parallel gateways represent harmonic branching, dissonance, and chord transformations, [7]. Similarly, the Chord Wheel Diagram has been introduced as an interactive visualization tool integrating BPMN into a web-based application for guitar pedagogy. The implementation is available online as the application https://www.aakordy.cz, where users can explore chord construction and tonal relationships interactively. Their qualitative user studies confirmed that learners perceive process diagrams as more comprehensible than classical notation, echoing Nielsen's insights on usability and cognitive load, [8].

Computational musicology has proposed multiple alternatives to standard notation. Geometric models of tonal space [9], Euler's theoretical extensions of harmonic representation [10], and visualization platforms such as midiVERTO [11] illustrate the potential of geometric and real-time approaches. In addition, probabilistic models of chord progressions [12] and grammatical frameworks for the analysis of harmonic rules [13] have been introduced. Together with approaches focused on jazz chord prediction [14], these studies confirm that harmony can be represented as a set of formalized and computationally processable rules rather than solely as symbolic notation.

At the methodological level, the development of BPMN itself has been analyzed in computer science research, including its historical origins [15], state-of-the-art surveys [16], and BPMN extensions for knowledge representation [17]. Previous studies also contributed significantly to BPMN usability evaluation [18] and quality metrics [19], underlining the robustness of BPMN for educational and analytical contexts. Applied to music, this methodology allows the mapping of harmonic logic as a procedural flow that learners can follow interactively, bridging the gap between notation and cognitive models of tonal systems [6], [20].

2 Problem Formulation

Music harmony is traditionally explained through symbolic notation and chord labels. While effective for professional musicians, these methods often create a high cognitive load for learners without formal training. Representing harmonic relations as a process offers a new perspective: harmony can be seen as a sequential development, where chords evolve step by step within a given tonality.

Our research explores how Business Process Model and Notation (BPMN) can be adapted to represent the logic of chord construction in Figure 1 and 2. Instead of treating harmony as a static symbol, BPMN diagrams capture the branching, parallel, and sequential relations between notes. This approach allows chords—triads, sevenths, and their variants—to be described procedurally in Figures 2 and 3.

A second dimension is provided by the Chord Wheel Diagram, an interactive web-based tool visualizing tonal centers and their associated chords. By linking BPMN with the chord wheel, we can formalize the structure of harmony while offering users an intuitive, visual way to construct chords. The key research question is whether such process-based visualization improves comprehension and reduces ambiguity compared to conventional notation.

2.1 BPMN as a Framework for Music Relations

BPMN uses activities, gateways, and flows to describe processes. Applied to harmony, each degree of a scale can be represented as a process element, while gateways express alternatives such as major/minor thirds or dominant vs. diminished sevenths. This formalization allows for a consistent description of how chords emerge from the base triad and progress into more complex forms.

2.1.1 Mathematical Model of a Process Diagram for Chord Construction

Let pitch classes be integers modulo 12:

- $P = Z12 = \{0,\ldots,11\}$. (1)

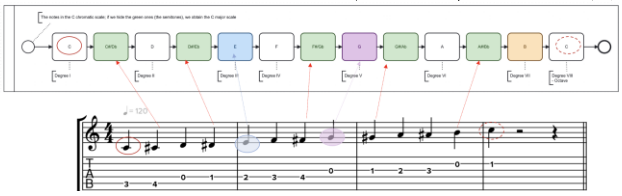

Fig. 1: Model of the chromatic scale with highlighted tones of the C major key
Source: created by the authors

A key (tonality) is a subset $K \subseteq P$ (e.g., $K\_Cmaj = \{0,2,4,5,7,9,11\}$). A degree map chooses a root $r \in K$ (Degree I–VII):

- $r = root(K,d)$, $d \in \{1,\ldots,7\}$. (2)

We model a BPMN process diagram as a finite directed acyclic graph (DAG):

- $B = (V,E,\tau)$. (3)

where V are nodes, $E \subseteq V\times V$ are sequence flows, and $\tau{:}V\rightarrow\{start,task,XOR,AND,end\}$ is a node-type function. In this context, a BPMN process diagram without loops can be interpreted as a directed acyclic graph (DAG). Each task node represents an elementary operation that incrementally extends a chord state, while gateway nodes encode controlled branching decisions, such as the selection between major and minor intervals or the inclusion of optional chord extensions. Executing the BPMN diagram, therefore, corresponds to evaluating the DAG from the start node to the end node, producing a well-defined harmonic structure. Figures 2 and 3 illustrate concrete DAG instances for triad and seventh chord construction, where the graphical BPMN notation directly reflects the formal structure defined in Equation (3).

A chord state is a finite set of pitch classes containing the root:

- $S \subseteq P$, $r \in S$. (4)

Each task node represents an operation that transforms one chord state into another by adding or modifying pitch classes.

- $2^P \rightarrow 2^P$.

The core operation adds intervals:

- $add(x,\Delta)(S) = S \cup \{(x+\Delta) \bmod 12\}$. (5)

Intervals (in semitones):

- $\Delta\_M3 = 4$, $\Delta\_m3 = 3$, $\Delta\_P5 = 7$, $\Delta\_dim5 = 6$, $\Delta\_P5+ = 8$, $\Delta\_M7 = 11$, $\Delta\_m7 = 10$. (6)

Here, the symbols M and m denote the size of the interval (major or minor) relative to the root, not the overall quality of the resulting chord. For example, a dominant seventh chord consists of a major triad combined with a minor seventh interval.

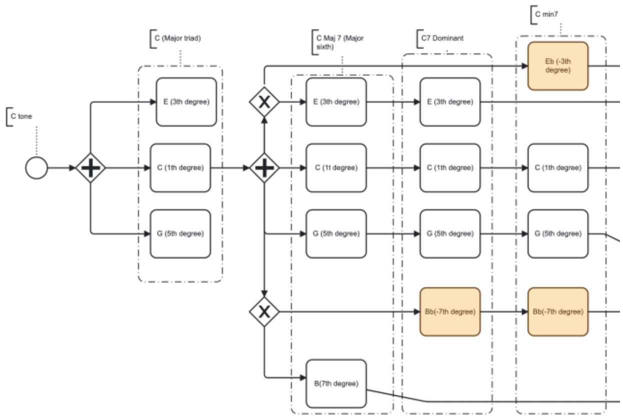

Fig. 2: Diagram of fifth and seventh chord construction in the key of C major. The minor third degrees are visually highlighted
Source: created by the authors

Gateway semantics:

- AND: $\Phi\wedge(S) = \bigcup \Phi\_bi(S)$. (7)
- XOR: $\Phi\oplus(S) = \Phi\_bj(S)$ such that $g(bj,S)=true$. (8)

The diagram denotes:

- $[\![B]\!]: 2^P \rightarrow 2^P$. (9)

Tonality constraint:

- $Diatonic(S,K) \Leftrightarrow S \subseteq K$. (10)

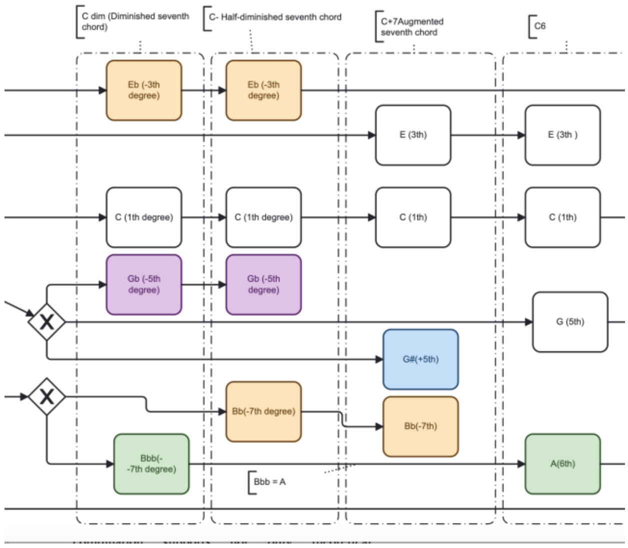

Fig. 3: Diagram of fifth and seventh chords with the extension to the diminished fifth. The minor third, the lowered fifth, and the seventh degrees are visually highlighted
Source: created by the authors

2.1.2 Example of BPMN DAG Execution for Seventh Chord Construction

To illustrate the practical use of the mathematical model introduced above, we consider the task of constructing a dominant seventh chord within a given tonality. The example corresponds to the construction of a G7 chord in the key of C major and is visually represented by the BPMN process diagram shown in Figures 2 and 3.

Let the pitch class set be $P = Z12$ and the key be $K\_Cmaj = \{0, 2, 4, 5, 7, 9, 11\}$. Selecting the dominant degree of the scale determines the root $r = 7$ (G). The initial chord state is defined as $S0 = \{7\}$.

Following the BPMN process from the start node, the first task node applies the operation $add(r, \Delta\_M3)$, yielding.

$S1 = \{7, (7 + 4) \bmod 12\} = \{7, 11\}$, which corresponds to the addition of the major third (G–B).

The next task node applies $add(r, \Delta\_P5)$, resulting in $S2 = \{7, 11, (7 + 7) \bmod 12\} = \{7, 11, 2\}$. This step completes the construction of the major triad (G–B–D).

At the subsequent XOR gateway, the branch corresponding to the minor seventh is selected, and the operation $add(r, \Delta\_m7)$ is executed. The resulting chord state is

$S3 = \{7, 11, 2, (7 + 10) \bmod 12\} = \{7, 11, 2, 5\}$.

The final state S3 represents the dominant seventh chord $G7 = \{G, B, D, F\}$. This example demonstrates how the BPMN process diagram can be interpreted as a sequence of formal operations that incrementally construct a harmonic structure in accordance with the defined model.

2.1.3 Composition of BPMN DAGs for Chord Progressions

The previous example illustrated the construction of a single chord. In practical harmonic work, however, musicians usually operate with sequences of chords that form progressions over time. Within the proposed framework, such progressions can be naturally described as compositions of BPMN DAGs, where the chord state produced by one process provides the harmonic context for the following step.

A typical example is the ii–V–I progression in the key of C major. In this case, the progression can be expressed as a sequence of three BPMN process executions with roots D, G, and C. Each process relies on the same set of formal operations introduced in Section 2.1.1, while differing in the chosen root and in the gateway decisions that determine chord quality or extensions. The progression, therefore, emerges from the repeated execution of structurally similar DAGs, rather than from a single static representation.

This way of modeling harmony differs from geometric approaches such as the Tonnetz or the Spiral Array. While these models capture relationships of harmonic proximity, they do not explicitly represent decision points, optional chord extensions, or the procedural steps involved in chord construction. In the BPMN-based approach, harmonic reasoning is made explicit as a sequence of operations that can be followed and revisited, which is particularly helpful for learners.

From a pedagogical point of view, this compositional property supports a step-by-step exploration of harmony. Users can observe how individual chord constructions are connected and gradually assembled into larger musical structures. The same principle can also be applied to more complex progressions or basic modulations by adjusting the selected tonality and gateway conditions, without changing the underlying formal model itself.

2.2 Interactive Visualization Layer

While the mathematical model defines the formal structure of chord construction, its practical use relies on an appropriate visual representation. To support exploration and interpretation of the underlying process logic, the proposed approach introduces an interactive visualization layer that maps the BPMN model to user-facing graphical elements.

This layer does not modify the formal semantics of the BPMN diagrams. Instead, it provides a visual interface through which users can observe chord construction steps, select tonalities, and intuitively navigate harmonic relations. By separating the formal process model from its visual realization, the framework maintains analytical rigor while remaining accessible for non-expert users.

The Chord Wheel Diagram, described in the following section, represents a concrete implementation of this visualization layer and demonstrates how process-based harmonic models can be integrated into interactive educational tools.

2.2.1 Integration with Chord Wheel Diagram

The Chord Wheel Diagram extends this principle by mapping BPMN logic to an interactive interface. Each chord can be visualized both as part of the tonal circle and as a BPMN process sequence. This combination supports not only theoretical understanding but also practical exploration for learners, especially guitarists.

3 Problem Solution

To evaluate the proposed approach, we conducted a qualitative usability study with 13 participants of different skill levels. The study used the Chord Wheel Diagram (www.aakordy.cz) integrated with BPMN-based models of chord construction Figure 4.

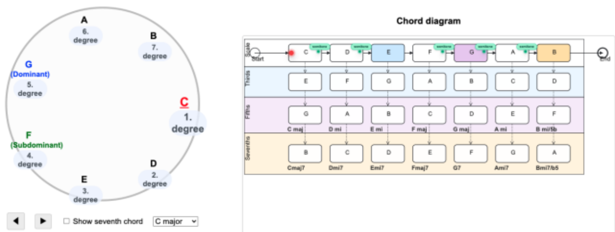

Fig. 4: Chord Wheel Diagram interface
Source: [21]

Participants were asked to locate chords within given tonalities, build triads and seventh chords, and explain harmonic relationships. Eye-tracking analysis was employed to identify elements with the highest cognitive load, i.e., points where users spent the most time thinking.

The results show:

- Beginners and hobby musicians found the BPMN-based diagrams clearer than traditional notation.

- The chord wheel provided intuitive navigation, while the BPMN diagrams supported stepwise reasoning.

- Eye-tracking confirmed that certain decision points (e.g., distinguishing major vs. minor thirds) required the most cognitive effort, but diagrams helped participants resolve them more effectively.

The figures illustrate how BPMN models can represent triads, sevenths, and extended chords, and how these correspond to positions on the chord wheel.

Together, they demonstrate that process modeling reduces ambiguity, clarifies harmonic logic, and lowers cognitive barriers for non-professional learners (Figures 5 and 6).

The ICERI 2025 conference study presentation [22] provided additional qualitative validation of these findings, while the current paper extends that work by incorporating eye-tracking analysis.

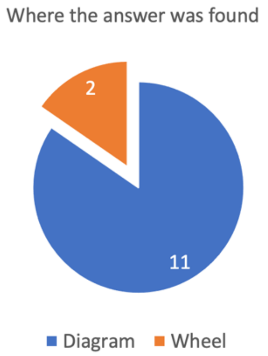

Fig. 5: Where the answer was found at the Chord Wheel Diagram
Source: created by the authors

The participants generally succeeded in identifying the correct chord tones. As shown in the diagrams, the majority correctly recognized the type of chord built on the 7th degree (Figure 6) of both C major and Bb major, with most responses corresponding to a diminished or minor chord structure, while a smaller proportion left the chord undefined or incorrectly labeled it as major. When moving from recognition to construction tasks, most participants were able to accurately build the G major triad, selecting the correct chord tones (G–H–D). However, some mistakes appeared, such as the substitution of D–E–F, which illustrates confusion between scale tones and functional chord tones.

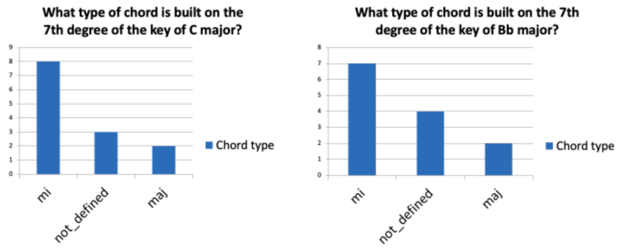

Fig. 6: Chord types built on the 7(degree)
Source: created by the authors.

The challenge became more apparent with the G7 chord, where only a part of the group was able to add the correct seventh (G–H–D–F). Errors included additions such as H–C–D–E or H–D–F–A, suggesting either overextension of the chord structure or misinterpretation of functional harmony - Figure 7. One participant, an absolute beginner in the 41–60 age category, was unable to construct the G major triad and failed to build the G7 chord entirely. In contrast, another participant aged 61+, who was an active musician, completed both tasks without error. These results highlight that prior musical experience strongly influences the ability to navigate chord construction tasks, while beginners struggle particularly with distinguishing correct chord tones from scale tones.

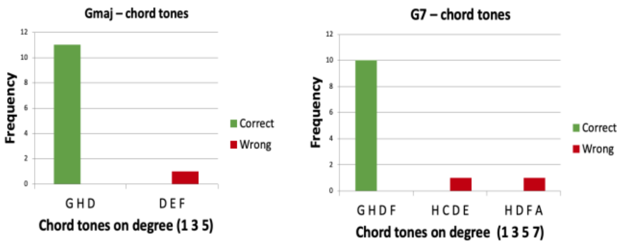

Fig. 7: G major and G7 tones answer.
Source: created by the authors.

3.1 Eye-tracking Study

For analysis, the interface was conceptually divided into regions of interest (ROI), including the chord wheel, the BPMN process diagram, and the tonality selection controls. User attention was evaluated based on fixation concentration and transition sequences between these regions. Longer fixation durations were interpreted as indicators of increased cognitive effort, understood in this study as areas where users experienced greater difficulty or uncertainty during task execution.

Although the number of participants was limited, this approach follows established principles of usability research. As argued in [8], testing with a small number of users is sufficient to uncover the majority of usability problems, with approximately five participants revealing around 70–75% of usability issues, and marginal gains observed beyond eight participants. In our study, the focus was therefore not on statistical generalization, but on identifying recurring cognitive bottlenecks and interaction patterns.

In addition, eye-tracking data are recorded with millisecond-level temporal resolution, and the resulting heatmaps are constructed from cumulative fixation durations rather than from single gaze samples. For this reason, the present analysis can be described as semi-quantitative. While it does not involve statistical hypothesis testing, it is grounded in objective temporal measures of visual attention that allow consistent identification of regions associated with increased cognitive load. This analytical framework supports qualitative interpretation while providing a structured basis for future quantitative evaluation with larger samples.

Eye-tracking provides valuable insight into how users navigate the chord wheel and BPMN-based chord diagram. In our study, we worked with five participants of different age groups and musical backgrounds. Figures 8, 9 and 10 present one representative recording, which clearly shows how the user's gaze moved across the interface.

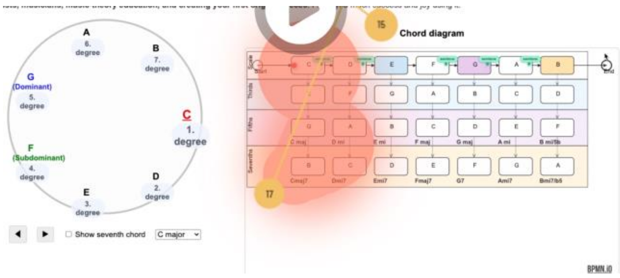

Fig. 8: Eye-tracking recording from the usability study. It shows the participant's areas of interest and focus while performing the task. The attention is directed toward the diagram and the notation used to construct the C major chord.
Source: created by the authors with tool, [21]

The heatmaps in Figure 8, Figure 9 and Figure 10 indicate which elements received the most visual attention and in what sequence the participant's eyes shifted. For instance, when selecting a tonality, the user first focuses on the scale selector before moving to the corresponding chord positions within the wheel.

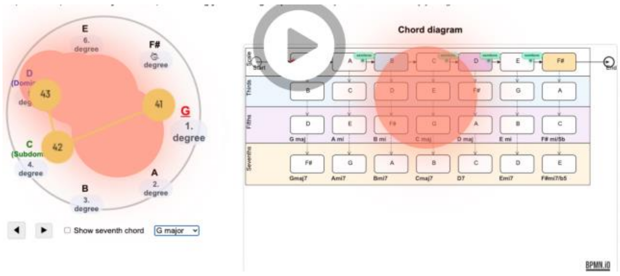

Fig. 9: Example of navigation within the chord wheel and reading of tones generated by the system in the process diagram
Source: created by the authors with tool, [21]

The subsequent fixations reveal how the participant explored the tonic, subdominant, and dominant regions, and then transitioned to the process diagram to confirm chord construction.

This sequential visual pattern illustrates not only where participants concentrated their cognitive effort but also how they combined exploration of tonal centers with verification in the procedural model. Eye-tracking thus enabled us to identify critical decision points, such as choosing between major and minor qualities, and to better understand the strategies applied by both novice and experienced musicians.

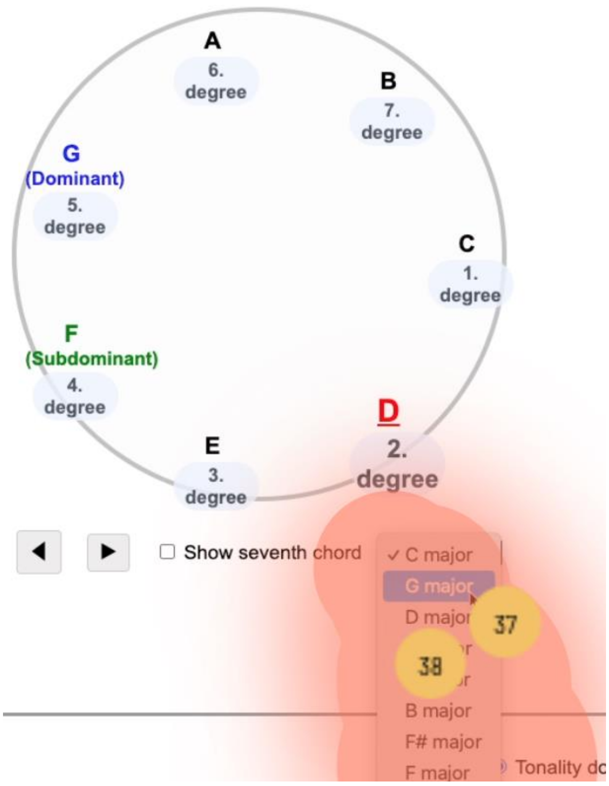

Fig. 10: Example of the use case for key selection while answering a question from the attached survey
Source: created by the authors with tool, [21]

After completing the eye-tracking tasks, participants were asked to respond to a survey integrated in the application, which allowed us to qualitatively link gaze behavior with self-reported levels of comprehension and perceived task difficulty.

4 Discussion

The presented approach demonstrates that BPMN process diagrams combined with the chord wheel can provide an accessible and engaging entry point into harmonic understanding. At the same time, our study must be interpreted cautiously. The evaluation was qualitative in nature, involving 13 participants in total and a sub-sample of 5 participants for the eye-tracking tasks. While such numbers are sufficient to illustrate usability patterns and highlight critical points of cognitive load, they cannot provide statistical generalization. This limitation reflects the exploratory stage of the research and underlines the need for future quantitative studies with larger and more diverse groups.

Table 1. Comparison of selected harmonic modeling approaches

Approach	Representation	Process	Scale	Teaching
Tonnetz	Geometric	No	Low	Medium
Spiral Array	Algebraic	No	Medium	Low
Probabilistic	Statistical	No	High	Low
Grammar-based	Symbolic	Partial	Medium	Low
BPMN + Chord Wheel	Procedural	Yes	High	High

Source: created by the authors

The comparison summarized in Table 1 shows that the proposed BPMN-based approach is not intended to replace existing models of harmonic representation. Instead, it complements them by focusing on procedural transparency and explicit decision points during chord construction. While geometric and probabilistic approaches are well-suited for analytical description or predictive tasks, the BPMN framework emphasizes the step-by-step construction process and makes harmonic choices directly observable. This characteristic is particularly relevant in educational and learning-oriented contexts, where understanding how harmonic structures are formed often outweighs formal completeness or predictive accuracy.

Compared with established teaching resources such as A Modern Method for Guitar: Volumes 1, 2, 3 Complete [4], widely used at Berklee College of Music, or the Berklee Practice Method: Keyboard – Get Your Band Together [5], our proposed method remains at an early stage of development. Both Berklee resources represent professionally designed textbooks supported by decades of pedagogical experience and are aimed at future professional musicians and composers. By contrast, the process-model-based approach targets hobby musicians who are unlikely to pursue systematic music study but wish to understand harmony more intuitively and with less investment of time. The study suggests that this audience can benefit from a rapid and visual tool for constructing chords and understanding tonal relations.

Nevertheless, several limitations must be addressed. The method is particularly well-suited to guitarists, for whom chord shapes are often abstract and require theoretical grounding. Pianists, in contrast, already possess a comparable visual framework through the keyboard layout, and the added value of this approach may therefore be limited. Similarly, the utility of BPMN diagrams for players of wind, string, or percussion instruments is likely to be less direct, though the universal logic of harmony still applies.

Our findings also resonate with recent contributions in WSEAS Transactions on Advances in Engineering Education. For example, a study on educational game design [23] presented an interactive maze application aimed at enhancing logical reasoning and cognitive skills through visual, step-based engagement. This approach parallels the proposed method in its emphasis on visual interaction, cognitive stimulation, and active problem-solving. Similarly, another study [24] demonstrated that even complex technical concepts—such as bitwise operations in computer science—can be made accessible for self-learners when presented through clear, structured, and visually supported problem-solving materials. Both studies reinforce the growing recognition that educational effectiveness increases when abstract concepts are represented as interactive, process-based experiences rather than static information.

In the same spirit, this work proposes a human-centered framework that bridges computational modeling, process logic, and harmonic analysis. Although the sample size is small, the qualitative results indicate that visual process modeling can help amateur musicians internalize harmonic rules without the cognitive overload typical of symbolic notation. Future research should aim to combine this visual framework with adaptive and gamified elements [21], and to test its impact on diverse learner groups, following principles of pedagogical accessibility discussed in related studies, [22].

5 Conclusion

This study demonstrated that musical harmony can be effectively modeled using Business Process Model and Notation (BPMN) as a formal yet accessible framework for visualizing tonal relationships. The integration of BPMN with the Chord Wheel Diagram provides a dual-layered visualization where the procedural logic of harmony is linked to its spatial representation within tonal centers. Together, these tools allow users to perceive harmonic relations as structured processes rather than isolated symbols.

Building upon the research results [7], the research confirmed that BPMN diagrams can rigorously describe chord formation and harmonic progressions, serving as a process-oriented alternative to traditional notation. The ICERI 2025 conference study presentation [22] further validated these findings through qualitative usability testing, while the current paper extends that research by incorporating eye-tracking analysis. The results presented here reveal how beginners and hobby musicians benefit from reduced cognitive load when engaging with visual, step-based representations of harmony. Eye-tracking patterns clearly showed how participants focused on decision points in the process model and cross-referenced them with tonal positions in the chord wheel, demonstrating how process diagrams support guided reasoning in real time.

While this approach does not aim to replace traditional music education or professional-level training materials such as Leavitt [4] or Schmeling and Hoffmann [5], it serves as a pedagogical bridge for self-taught learners and amateurs seeking an intuitive entry into harmonic analysis. The small sample size (13 participants, 5 eye-tracking) reflects the qualitative, exploratory nature of the research, but still reveals distinct usability patterns consistent with Nielsen's principles of cognitive load reduction [8]. Future quantitative validation with larger and more diverse samples remains necessary.

Furthermore, parallels can be drawn with recent WSEAS contributions. Study [23] showed that visual, gamified, and interactive learning environments enhance cognitive engagement, while study [24] demonstrated how abstract problem-solving concepts can be made accessible through structured visual representation. Our findings align with these principles—illustrating that visual process logic not only aids comprehension but also motivates learners through immediate feedback and interactive discovery.

In summary, BPMN-based harmonic modeling supported by eye-tracking evaluation demonstrates that the same analytical frameworks used in software engineering can be successfully transferred to music theory to visualize and teach harmony. By transforming abstract tonal relationships into procedural diagrams, this approach encourages human-centered learning, reduces cognitive barriers, and bridges the gap between computational modeling and musical understanding.

References:

[1] Christoph Riedweg (2008). *Pythagoras: His Life, Teaching, and Influence*. Cornell University Press. p. 27. ISBN: 978-0-8014-7452-1.

[2] Hiley, D.; Payne, T. B.; Bent, M.; Chew, G.; Rastall, R., *"Notation: III and IV*." In Sadie, S. (ed.), The New Grove Dictionary of Music and Musicians (2nd ed.). London: Grove, 2001, [Online]. https://books.google.gr/books/about/The_New_Grove_Dictionary_of_Music_and_Mu.html?id=rG8ywAEACAAJ&redir_esc=y (Accessed Date: January 30, 2026).

[3] Christensen, T. (ed.), *The Cambridge History of Western Music Theory*. Cambridge University Press, 2002. ISBN: 0 521 62371 5.

[4] Leavitt, W.," *A Modern Method for Guitar: Volumes 1, 2, 3 Complete*. Boston: Berklee Press Publications, 1999, https://www.scribd.com/document/719347748/a-modern-method-for-guitar-volumes-1-2-3-complete-berklee-methods-by-william-leavitt-z-lib (Accessed Date: January 30, 2026).

[5] Schmeling, P. & Hoffmann, R., "*Berklee Practice Method: Keyboard – Get Your Band Together*." Boston: Berklee Press Publications, 2001. ISBN: 9780634006517.

[6] Temperley, D., "*The Cognition of Basic Musical Structures*." Cambridge, MA: MIT Press, 2001.

[7] Pavlicek, J., Pavlickova, P., Brnka, M., Rydval, J., *"BPMN for Displaying the Progression of Musical Harmony and Chords – Case Study."* In: Almeida, J.P.A., Di Ciccio, C., Kalloniatis, C. (eds), Advanced Information Systems Engineering Workshops,

CAiSE 2024, LN in Business Information Processing, vol. 521, Springer, Cham. https://doi.org/10.1007/978-3-031-61003-5_23.

[8] Nielsen, J., "*Usability Engineering (Interactive Technologies).*" Morgan Kaufmann, 1993. ISBN 0-12-518406-9.

[9] Chew, E., "*Mathematical and Computational Modeling of Tonality: Theory and Applications*," International Journal of Computational Mathematics in Music, vol. 1, no. 1, pp. 35–53, 2005. DOI: 10.1007/978-1-4614-9475-1.

[10] Euler, L., Tentamen "*Novae theoriae musicae ex certissismis harmoniae principiis dilucide expositae*". Saint Petersburg Academy, [Online]. https://archive.org/details/tentamennovaethe00eule/page/n5/mode/2up (Accessed Date: January 10, 2026).

[11] Harasim, D.; Affatato, G.; Moss, F. C., "*midiVERTO: A Web Application to Visualize Tonality in Real Time*" arXiv preprint, 2022. https://doi.org/10.1007/978-3-031-07015-0_31.

[12] Bunks, C.; Weyde, T.; Slingsby, A.; Wood, J., "*Visualization of Harmonic Structure: Reducing Cognitive Load in Jazz Progressions*," Eurographics Proceedings, 2022. https://doi.org/10.2312/evs.20221102.

[13] Paiement, JF., Eck, D., Bengio, S. (2006). Probabilistic Melodic Harmonization. In: Lamontagne, L., Marchand, M. (eds) Advances in Artificial Intelligence. Canadian AI 2006. Lecture Notes in Computer Science(), vol 4013. Springer, Berlin, Heidelberg. https://doi.org/10.1007/11766247_19.

[14] Tojo, S., Oka, Y., & Nishida, M., "*Analysis of Chord Progression by HPSG.*" Artificial Intelligence and Applications, 2006. https://api.semanticscholar.org/CorpusID:27963899.

[15] Hedges, T., Roy, P., & Pachet, F., "*Predicting the Composer and Style of Jazz Chord Progressions*." Journal of New Music Research, 2014. https://doi.org/10.1080/09298215.2014.925477.

[16] BPMN Introduction and History. Trisotech, 23 Jan. 2022, [Online]. https://www.trisotech.com/bpmn-introduction-and-history/ (Accessed Date: Januaey 5, 2026).

[17] Kocbek, M., Jošt, G., Heričko, M., & Polančič, G., "*Business Process Model and Notation: The Current State of Affairs*." Computer Science and Information Systems, 12(2), 2015. https://doi.org/10.2298/CSIS140610006K.

[18] Hassen, M. B., Keskes, M., Turki, M., & Gargouri, F., "*BPMN 4KM: Design and Implementation of a BPMN Extension for Modelling the Knowledge Perspective of Sensitive Business Processes*." Procedia Computer Science, 121, pp. 1119–1134, 2017. https://doi.org/10.1016/j.procs.2017.12.121.

[19] Pavlicek, J., Rod, M., & Pavlickova, P., "*Usability Evaluation of Business Process Modelling Standards – BPMN and BORM Case Study*." In International Conference on Advanced Information Systems Engineering, pp. 93–104. Springer, Cham, 2021. https://doi.org/10.1007/978-3-030-79022-6_9.

[20] Pavlicek, J., Hronza, R., Pavlickova, P., & Jelinkova, K., "*The Business Process Models Quality Metrics*." In Workshop on Enterprise and Organisational Modelling and Simulation, pp. 134–148. Springer, Cham, 2017. https://doi.org/10.1007/978-3-319-68185-6_10.

[21] Pavlicek, J., "Akordový kruh - Chord Wheel Diagram," online application, [Online]. https://www.aakordy.cz (Accessed Date: Januaey 5, 2026).

[22] ICERI 2025 – Conference: ICERI2025, the 18th annual International Conference of Education, Research and Innovation, At: Sevilla, DOI: 10.21125/iceri.2025.1584.

[23] Nalbant, K.G., Kaygusuz, M.D. and Tunc, D., 2025. *Educational game design for kids: A case study with a Python maze game*. WSEAS Transactions on Advances in Engineering Education, 22, pp.95–106. DOI: 10.37394/232010.2025.22.11.

[24] Dolinsky, M., 2025. *Teaching schoolchildren to solve problems on the topic "Working with bits"*. WSEAS Transactions on Advances in Engineering Education, 22, pp.9–16. DOI: 10.37394/232010.2025.22.2.

Contribution of Individual Authors to the Creation of a Scientific Article (Ghostwriting Policy)

The authors equally contributed in the present research, at all stages from the formulation of the problem to the final findings and solution.

Sources of Funding for Research Presented in a Scientific Article or Scientific Article Itself

No funding was received for conducting this study.

Conflict of Interest

The authors have no conflicts of interest to declare that are relevant to the content of this article.

Creative Commons Attribution License 4.0 (Attribution 4.0 International, CC BY 4.0)

This article is published under the terms of the Creative Commons Attribution License 4.0
https://creativecommons.org/licenses/by/4.0/deed.en_US