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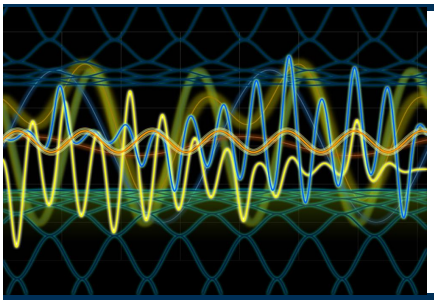

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User Evaluation of 3D-Printed Personalized Saxophone Mouthpieces

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Along with the skill set and the anatomy of the saxophonist, the design of the mouthpiece is a determining factor for the eventual performance of the instrument. Hence, the expectations and needs of saxophone mouthpieces are diverse and personal. Therefore, the ability to tailor a mouthpiece to the personal needs of a saxophonist becomes a valuable asset. Digital manufacturing technologies, such as 3D printing and computational design tools, enable providing such on-demand and personalized products affordably. This study employs the previously proposed mouthpiece personalization method that benefits these technologies to personalize saxophone mouthpieces. This study aims to assess the ability of personalized mouthpieces to answer the players' needs and to understand the experience of players in this process. For this purpose, a two-phase user study is devised, where players first co-create their personalized mouthpieces, then test and evaluate these. Five saxophone players from the Royal Conservatoire Antwerp participated in the study. The players in the user study confirm the performance variance in seven out of ten cases, and they prefer personalized mouthpieces in four out of five cases. The results of this study contribute to the understanding of saxophone mouthpiece personalization, and the players' experience in this process.

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1. INTRODUCTION

Advancements in digital manufacturing technologies allow rapid changes in product design and manufacturing by integrating information systems with flexible manufacturing processes. Such advancements enable highly personalized and still affordable products to customers on demand.[5] In this regard, personalization may add value and present new opportunities in musical instrument-making due to the personal nature of the instruments in terms of both ergonomics and performance. A prominent example of this personal need is the selection of saxophone mouthpieces. The sound of the saxophone is produced in the mouthpiece with the oscillation of the reed, and thus both the design of the mouthpiece and the reed have a significant effect on the produced sound and the playability of the instrument.[8] Besides these, the oral cavity of the player also has an important role in the eventual performance.[2,7,9] Therefore, different players may obtain different results using the same mouthpiece. The choice of a mouthpiece may also depend on the required performance; such as for different music styles or playing environments.[3,6] As a result, the choice of a mouthpiece is very personal, and saxophonists often seek one that provides the sound they wish or fits their playing habits. Therefore, the personalization of 3D-printed saxophone mouthpieces presents a great opportunity to fine-tune the performance of the mouthpiece to the expectations of the musicians.

In the preceding study, we developed a mouthpiece personalization method that includes a design template for alto saxophone mouthpiece that can be adjusted to the specific needs of musicians.[4] This design template is based on a mass personalization design methodology,[5] where the design parameters of the mouthpiece are connected to the performance needs of players. An acoustical analysis was carried out to obtain quantitative relations between parameters and mouthpiece performance. To that aim, twenty-seven 3D-printed mouthpieces (Figure 1) with nine varying design parameters (such as the tip opening, the baffle height, etc.) were tested using an artificial blowing machine,[1] to determine their effects on four selected mouthpiece performance features (loudness [1], brightness [2], resistance [3] and flexibility [4]). Based on the statistical analysis of the experiment results, the influence of the design parameters on the mouthpiece features was implemented in a design template. In the proposed method, according to the requirements of each player, an algorithm modifies the design parameters of the template and generates a personalized design that is manufacturable.

Figure 1: 3D printing mouthpieces (left), various mouthpiece designs used in the experiments (right).

[1]The sound level of the instrument.
[2]Tone color descriptor to define how bright or dark the produced sound is.
[3]The ease of producing sound.
[4]The possibility to adjust the pitch.

This study aims to test the previously proposed mouthpiece personalization method with saxophone players to understand whether their perception of the mouthpiece performance is in agreement with the quantitative results from the artificial blowing machine. Furthermore, the objective is to understand the players' experience with co-creating a personalized mouthpiece and to measure their satisfaction with the final outcome. For this purpose, we devised a user study with five saxophonists. The study consists of two sessions; the first is a co-creation session with the participants to define the personalized mouthpieces, and the second session is a blind comparison of mouthpieces, including the personalized one, and the performance evaluation of the personalized mouthpiece.

2. METHODS

This study employs the mouthpiece personalization method proposed in the previous study,[4] which includes a workflow to co-create personalized mouthpieces with saxophone players. According to this workflow, the preferences of the player are collected, then converted into a personalized design, and then finally manufactured with a 3D printer. Due to the length of the process and the manufacturing step, the study is designed in two phases (Figure 2). The first phase is to collect information and perform the co-creation activity with the participants. The second phase is testing and reflecting on the 3D-printed mouthpieces, including a personalized one; initially, a blind comparison, and then an informed evaluation of the personalized mouthpiece.

Five master-level saxophone students from The Royal Conservatoire of Antwerp (Antwerp, Belgium) participated in the study. All participants had at least 10 years of experience. The study was conducted by having individual sessions with each participant in both phases. Each session in both phases took 40 to 60 minutes. All participants performed with alto saxophone mouthpieces. Participants were provided a new Vandoren V16 reed (strength 2.5) in each session, with the exception of two cases where participants were not comfortable with the given mouthpiece-reed combination, and were allowed to use a softer reed (strength 2).

A. PROCEDURE

i. Phase I

The first phase of the study started by informing the participants about the project, tools, and the study procedure. Following that, information on existing mouthpiece preferences and habits of the participants was collected through a survey.

The major part of this phase was co-creating a personalized mouthpiece design with the participants. According to the employed mouthpiece personalization method, participants were allowed to control four performance-related features of the mouthpiece. For this purpose, a *Graphical User Interface* (GUI) (Figure 3) was used to collect the preferences of the participants. To allow participants to understand the scale of change, they were provided with reference mouthpieces representing the lowest and highest end of the scale for each controlled feature.

Following a brief warm-up, each participant was asked to choose the desired features of the mouthpiece, starting with the most valued one. For each controlled feature, the participant played the two reference mouthpieces and specified the personal preference using the slider on the GUI. This was repeated respectively for each feature in the order of participant's preference. If the preference of a feature was not possible, participants were informed that they could modify other features until reaching a desirable trade-off.

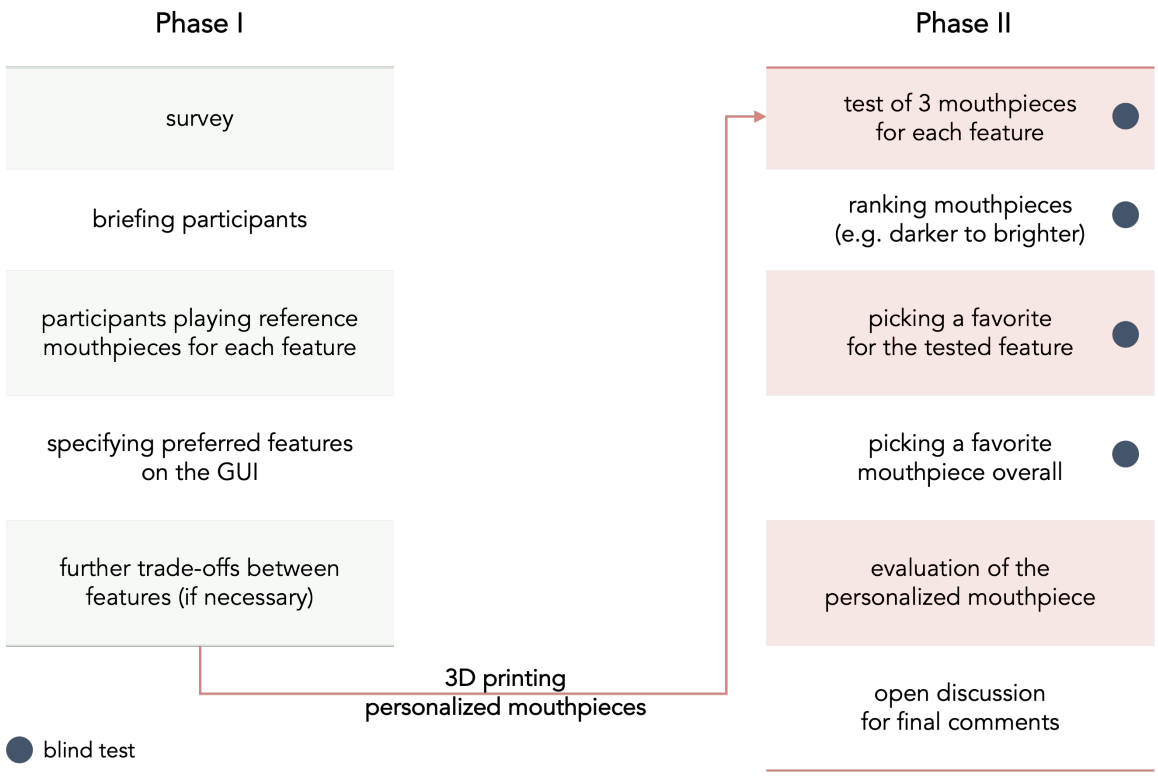

Figure 2: Procedure of the user study.

ii. Phase II

Following the first phase, a personalized mouthpiece design for each participant was obtained, and these were manufactured for the second phase. In the second phase of the study, participants performed a blind comparison between the personalized and reference mouthpieces. To avoid very long sessions that could affect the participants' judgment, they were asked to compare the mouthpieces for only the two most important features of their choice. They compared three mouthpieces for each feature and ranked these according to the performance of the given feature (e.g., from lowest to highest resistance), and then stated their favorite among these three mouthpieces. Eventually, they were asked to pick an overall favorite mouthpiece among the ones they played during the blind comparisons (i.e. four reference mouthpieces and a personalized mouthpiece).

At the end of the blind comparison part, the participants were informed about which one of the mouthpieces was the personalized one for themselves and asked to perform one more time with it. Following this, participants stated their level of satisfaction with each feature of the personalized mouthpiece on a 5-point Likert scale (from 'very unsatisfied' to 'very satisfied'). Finally, they were asked to comment on the overall experience with the co-creation process.

3. RESULTS

A. SURVEY RESULTS

According to the survey, the participants are positive towards personalized mouthpieces, but they are rather hesitant against 3D printed ones. The participants are generally satisfied with their current mouthpieces, but they would still consider a new one with some adjustments, mainly in brightness and resistance.

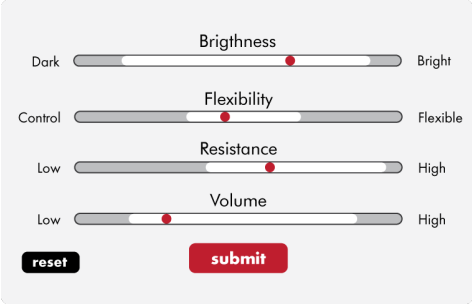

Figure 3: GUI used in the co-creation sessions with participants.

Each participant reported possessing at least 3 different mouthpieces, however, only a few claim to use different mouthpieces for different occasions. The most important criteria affecting their mouthpiece selection appeared to be the brand and the material of the mouthpiece. All participants stated that the most important mouthpiece feature was brightness, while the other three features in the subject were close in average, and of diverse importance among participants.

B. BLIND COMPARISONS AND EVALUATION OF THE PERSONALIZED MOUTHPIECES

In the blind comparisons of mouthpieces by performance features, 7 out of 10 times, participants ranked the mouthpieces correctly, according to the estimation of the personalization model. When choosing a favorite mouthpiece for the given feature, out of these 10 rankings, the participant's personalized mouthpiece was the choice in 8 instances. When asked to pick an overall favorite mouthpiece blindly among the ones tested in this phase, 4 out of 5 participants preferred the mouthpieces personalized for themselves.

Following the blind comparisons, participants tested the mouthpieces personalized for themselves and rated their level of satisfaction with each feature. Figure 4 presents the satisfaction level with each mouthpiece feature for all participants in combination. Comparing this with the participants' choice of features, they were more satisfied with the features they stated were more important, which they modified first in the co-creation session. A similar result also appeared in the final discussions; four of the participants asked for slight adjustments in the features that they modified last.

C. PARTICIPANTS' FEEDBACK ON THE CO-CREATION PROCESS

During the final discussions, participants provided noteworthy suggestions and feedback on the personalized mouthpieces and the co-creation process. Participants had a consensus about choosing the facing (tip opening[5] and lay length[6]) of the mouthpiece themselves. In the current personalization model, these design parameters were assigned automatically according to the desired mouthpiece features. They also stated that testing the personalized mouthpiece for a longer term (e.g. a month) might allow for giving better feedback. One suggestion that emerged about the co-creation process was personalizing the mouthpiece based on the current mouthpiece of the user, instead of reference mouthpieces. Participants stated that this would allow them to obtain the desired performance from the personalized mouthpiece easier.

4. DISCUSSION

Comparing the survey results at the beginning of the study and the final comments at the end, the perception of personalized and 3D-printed mouthpieces improved significantly among the participants. The results

[5]The distance between the tip of the mouthpiece and the tip of the reed.

[6]The distance between the tip of the mouthpiece and the reed separation point from the mouthpiece.

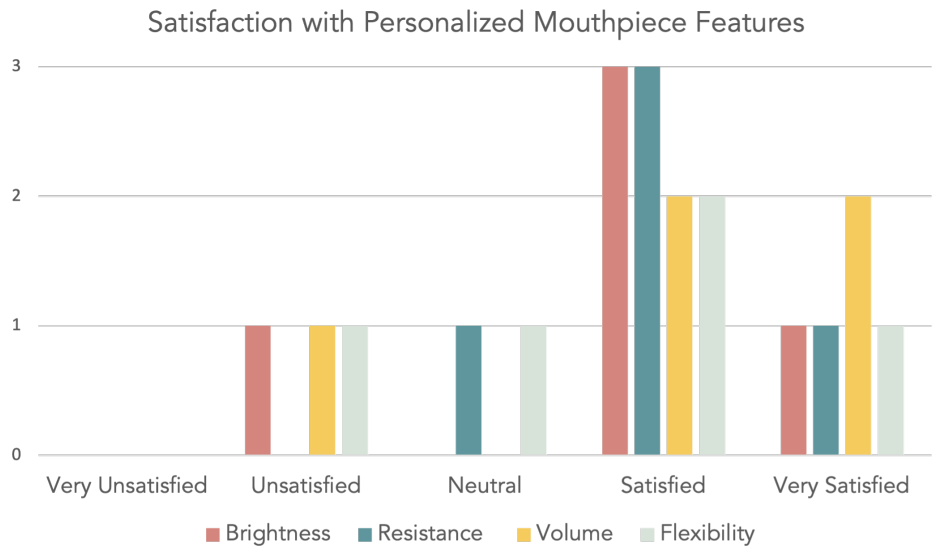

Figure 4: Participants' level of satisfaction with the features of their personalized mouthpieces.

of the blind comparisons demonstrated that the used mouthpiece personalization method has sufficient ability to modify the performance of the mouthpiece in line with the participants' perception. Furthermore, both for individual features and overall, participants mostly preferred their personalized mouthpieces. This also supports the ability to deliver mouthpieces that are more suitable to users.

Participants were largely satisfied with the performance of their personalized mouthpieces. However, some of them asked for further adjustments. This is a possible limitation of the co-creation process. Even though the participants could understand the scale of changes through reference mouthpieces, it might have been challenging to specify the desired feature precisely. One potential way to improve the results is to repeat the co-creation process and iterate the design further toward the desired performance. An important remark here is that the participants asked for further adjustments of the features they specified last, which gave them much less design freedom on those features (i.e. the possibilities to adjust a certain feature diminish after other features have been specified). Technically, it is not possible to obtain all feature combinations, and this is why it is important to decide the features in the order of personal preference, to have more freedom on the most important ones. Therefore, users should be informed better about this point, and the necessity to reach a trade-off.

Participants' feedback on facing parameters (such as the tip opening and lay length) demonstrated the importance of considering user habits in the process. Figure 5 shows the difference in the lay length and tip opening between the participants' own mouthpiece and the personalized mouthpiece. As seen in the figure, there is a significant difference between the own and personalized mouthpieces for participants 4 and 5. A mouthpiece with a different facing may require some time to adapt, which may not be desirable by all users. In addition to controlling the mouthpiece features, allowing users to modify facing parameters may be a better approach. However, since these parameters affect the performance, players would have less design freedom on the mouthpiece features. It is important to inform them about such trade-offs during the co-creation process.

As some participants indicated, allowing them to test the mouthpieces for a longer term may provide more meaningful results and feedback from the players. Even though the participants had the chance to play with the personalized mouthpiece for a while, they might need more time to get used to a new mouthpiece. This is especially the case for the ones with different facing parameters.

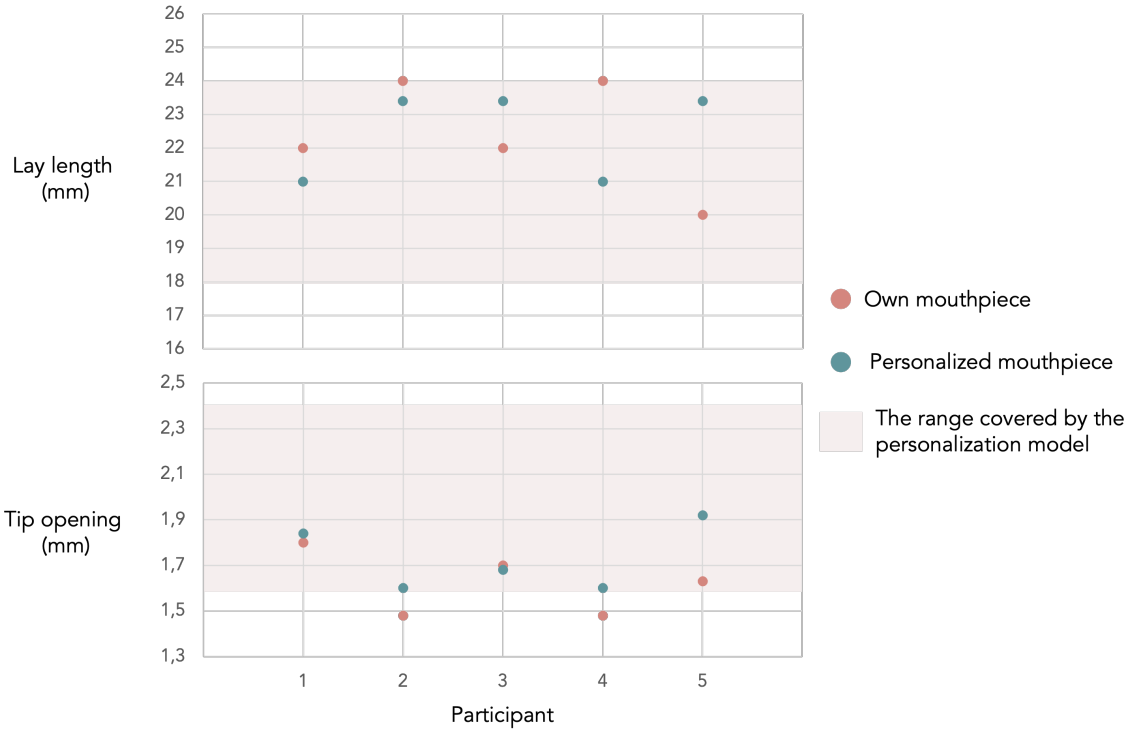

Figure 5: Lay length and tip opening comparison between the participants' own mouthpieces and the personalized mouthpieces. Highlighted areas show the ranges of these design parameters included in this study.

In the co-creation process, the participants were provided reference mouthpieces representing both ends of the scale for each mouthpiece feature. The aim was to allow them to understand the scale better and state their preference in between. Some participants indicated that having their own mouthpiece as a reference would have made the decision easier. This would surely help users since they are accustomed to their own mouthpieces, and what they would want different may be more clear. However, in terms of building a personalization method, this is rather challenging. A library of commercially available mouthpieces, and an assessment of their features through experimentation would be necessary.

5. CONCLUSION

This study has investigated the experience of saxophone players co-creating a personalized mouthpiece, their satisfaction with these mouthpieces, and the applicability of the previously proposed mouthpiece personalization method that automatically creates mouthpiece designs according to user input. For this purpose, a two-phase user study was performed; in the first phase, users co-created their personalized mouthpieces using reference mouthpieces and a GUI to state their preferences, while in the second phase, they had a blind comparison of reference and personalized mouthpieces and finally evaluated the personalized ones. The results supported the applicability of the proposed personalization method and demonstrated the possibility of better meeting the needs and desires of saxophone players.

The employed co-creation scenario was performed sufficiently to reach a satisfactory design for the participants. However, considering the participants' feedback, there is surely room for improvement, especially in terms of considering user habits. In this regard, the main highlights are participants' requests to control the facing parameters, to have their own mouthpieces as a reference and starting point for modifications, and to test the personalized mouthpieces for a longer period. Therefore, it is important to take into account user

habits with their existing mouthpieces and to allow them to get familiar with the personalized mouthpiece for a better evaluation of it. Future approaches to personalized mouthpieces may focus on these points to provide more satisfactory results.

The findings of this study contribute to the understanding of how to deliver more satisfactory performance with the saxophone mouthpiece according to players' personal preferences. The tested co-creation scenario with saxophonists provided a valuable example of personalizing a musical instrument and the experience throughout the process. With the help of digital manufacturing technologies and systematic design modifications, such an affordable personalization approach can be extended to different musical instruments.

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