A Method for Learning Netytar: An Accessible Digital Musical Instrument

Nicola Davanzo and Federico Avanzini
University of Milan, Dept. of Computer Science, Via Celoria 18 20-133 Milano, Italy
nicola.davanzo@unimi.it, federico.avanzini@unimi.it

Keywords: ADMI, Accessibility, Musical Instrument, Learning.

Abstract: Accessible Digital Musical Instruments (ADMI) are increasingly raising interest within the scientific community, especially in the contexts of Sound and Music Computing and Human-Computer Interaction. In the past, Netytar has been proposed among these. Netytar is a software ADMI operated through the eyes using an eye tracker and an additional switch or sensor (e.g., a breath sensor). The instrument is dedicated to quadriplegic users: it belongs to the niche of gaze operated musical instruments, and has been proven effective and functional through testing. Although there are several other gaze operated ADMIs available in market and literature, a formal method for studying music with them has not yet been proposed. The present work introduces a simple study method based on a set of exercises. This can be useful for approaching musical performance with Netytar, but it's also potentially generalizable for learning other similar instruments. The exercises are illustrated, discussed and explained in view of an improvement. A simple musical notation is introduced. At the end of a learning cycle, a user is expected to be able to perform simple melodies, and have a basis with which to learn other new ones. In the future, the method will be tested with the target users.

1 INTRODUCTION

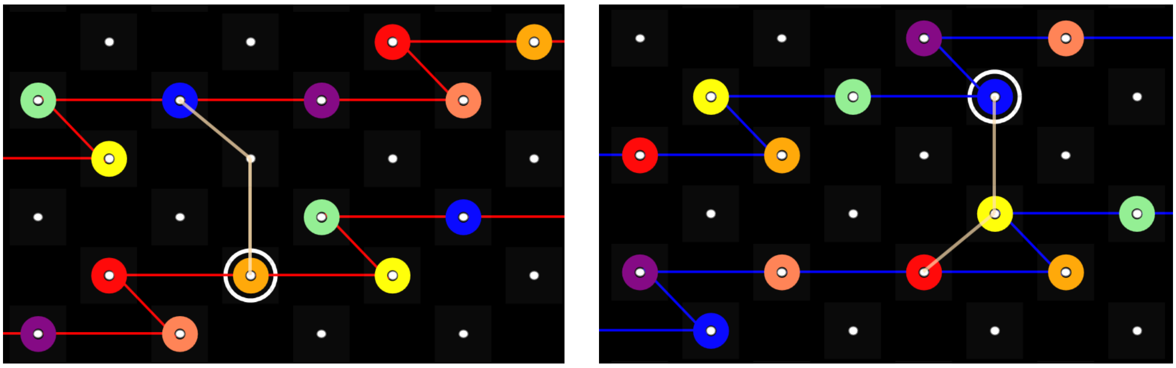
As demonstrated by the recently published works dedicated to the topic, Accessible Digital Musical Instruments (ADMIs) are conquering an important slice of literature. Several works (Larsen et al., 2016; Hornof, 2014; Frid, 2019) offer reviews of the state-of-the-art instruments dedicated to users with various types of disabilities: physical, cognitive, sensory. Among them, a significant portion (both in literature and market) is dedicated to various types of physical impairments and related applications. Available interfaces targets space from rehabilitation purposes (Correa et al., 2009), to hemiplegic paralysis (Harrison and McPherson, 2017), quadriplegia (Jamboxx, nd), and extreme conditions such as lock-in syndrome (Vamvakousis and Ramirez, 2014, 2016), where the user is unable to control any muscle other than those that move the eyes. The recent work by Frid (Frid, 2019) reports and categorizes a total of 83 musical interfaces, showing that 39.8% of them are dedicated to people with physical impairments. Within this portion there are the so-called gaze controlled musical instruments (Bailey et al., 2010; Refsgaard, nd; Morimoto et al., 2015; Vamvakousis and Ramirez, 2016), i.e. instruments operated by the eyes using an eye tracker. These exploit alternative interaction channels to limbs and hands, which are used for playing the vast majority of traditional musical instruments. They are therefore generally dedicated to users with conditions such as quadriplegic paralysis.

In 2018, Netytar (Davanzo et al., 2018) was proposed: it is a monophonic musical instrument operated through gaze, blinking and an additional switch or sensor (a breath sensor in its current version). In the aforementioned work, Netytar has been compared to a state-of-the-art instrument of that time: the *EyeHarp* (Vamvakousis and Ramirez, 2016). Preliminary tests showed that in some respects it was slightly more precise and effective. In addition to the layout differences, this difference in performance can be explained by specific design choices, in particular the absence of smoothing filters on the gaze data to avoid delays (more on this in Sec. 2).

Despite the abundance of ADMIs, and gaze operated instruments in particular, there is a general lack of teaching methods for them in literature.[1] This and numerous other factors may discourage their use

[1]One notable exception is the MUSA project, which involved teaching music to users with disabilities using the EyeHarp. See https://www.upf.edu/web/musa (Accessed on: 29/02/2020).

Davanzo, N. and Avanzini, F.
A Method for Learning Netytar: An Accessible Digital Musical Instrument.
In *Proceedings of the 12th International Conference on Computer Supported Education (CSEDU 2020) - Volume 1*, pages 620-628
ISBN: 978-989-758-417-6



(a) (b)

Figure 1: Two examples of Netytar's keyboard surface as it appears while running the software instrument. Keys appear as circles. A white trace flashes and slowly disappears showing the notes played in the immediate past, while a white circle surrounds the currently selected note. In Fig. 1a, a major scale is highlighted with red connectors, while in Fig. 1b a minor scale is highlighted with blue connectors. Color code for keys is as indicated in Tab. 1.

both by private users and by centers for rehabilitation or hospitalization with music teaching or music therapy departments. As an example, as highlighted by Marquez-Borbon and Martinez Avila (2018), the lack of repertoires and communities dedicated to a specific Digital Musical Instrument (DMI) in general could negatively affect its diffusion. Ward *et al.* (Ward et al., 2017) outline a group of guidelines for the development of musical instruments dedicated to Special Educational Needs (SEN) contexts, highlighting that technology is often overlooked, being seen as too complex, useless, or "geeky".

This paper purpose is to address the lack of training methods by introducing one (described in Sec. 4) for learning Netytar, conceived and designed to cover some aspects of gaze-based musical interaction. This consists of a series of exercises dedicated to non-musicians who approach music for the first time using the instrument. Such exercises are aimed at covering different aspects of a first experience with a musical instrument, both gaze based and in a general sense. This method should be validated by experimental observations, which refer to future publications. Finally, although the method is focused on Netytar, some sections (particularly *Musical calisthenics*, Sec. 4.1) could be easily adaptable to other gaze based musical interfaces. Sec. 2 provides a review of the main features included in the instrument. Lastly, Sec. 5 describes further possible developments to improve the described method.

2 Netytar

The original implementation of Netytar has been described elsewhere (Davanzo et al., 2018). Here we resume the main features, as well as some improvements introduced in later implementations.

Table 1: Color code for keys on Netytar's keyboard. Colors represent grades on the selected scale (major or minor), and not absolute note values.

Grade in scale	Color
1st	Red
2nd	Orange
3rd	Yellow
4th	Green
5th	Blue
6th	Purple
7th	Peach

As already mentioned, the musician interacts with Netytar through the eyes and a dynamic switch or controller (e.g. breath sensor). Using the jargon of DMIs related literature, we can describe the mapping between physical action performed by the user and musical performance parameters in this way: Gaze point controls note selection, moving on a virtual keys surface displayed on screen; Blinks are employed to execute repeated notes (same note executed two or more times) and to interact with some properties of the surface (e.g. to highlight different scales); Breath is used to control note dynamics (e.g. intensity), in the same way as an acoustic flute.

Netytar's layout was conceived so as to avoid interaction problems common to other interfaces based on eye tracking. A major one is a consequence of the so-called "Midas touch" issue, first described in (Jacob, 1995): even if saccadic movements are very fast, keys crossed by the line defined by such movements may be involuntarily activated. Example screenshots of Netytar's surface are provided in Fig. 1. As a con-

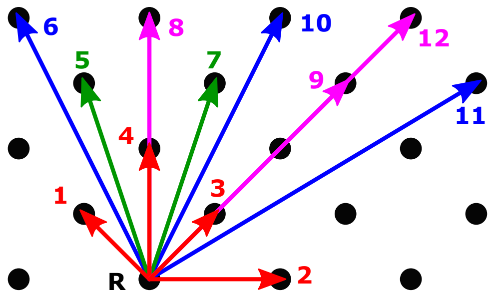


Figure 2: Vectors indicating possible ways to trace intervals on Netytar's keyboard. Numbers indicate semitones from the starting note (indicated with an *R*). Colors follow the cathegories defined in Sec. 4.2, exercise *T1*: *adjacent* group is colored red; *distant easy* green; *distant hard* blue; *obstructed* purple.

sequences of this layout, the following characteristics emerge, which are specifically addressed by the study method proposed in Sec. 4:

- *Isomorphism of the Keyboard Layout*. Netytar's layout has been discussed extensively in (Davanzo et al., 2018). Netytar's virtual keyboard is characterized by keys of equal shape and size, which obey to the following property: a vector connecting two keys corresponds to a precise and constant musical interval, regardless of the transposition (i.e., the relative position on the interface). This should make the transposition of musical sequences on different keys easy. Moreover, it could make the relationships between notes clearer and more immediate, due to geometrical consistency. Among other isomorphic layouts, this one has been chosen in order to avoid as much as possible intermediate key crossings for the most common musical intervals (see Fig. 2), proposing a partial solution to the aforementioned "Midas Touch" problem. Moreover, sequences of notes can be described as paths or geometric shapes composed of broken lines, potentially making memorization easier. Some studies investigate in greater detail the learnability of various isomorphic layouts (Maupin et al., 2011), as well as differences between isomorphic and non-isomorphic layouts (Stanford et al., 2018). There is evidence that isomorphic layouts have benefits among musicians, but results among non-musicians are mixed, leaving home for further experimentation. In the latest version of Netytar[2] keys are arranged in accordance with the so called *SMARC* effect: a layout in which the highest notes are found in top-right and the lower notes in the bottom-left should be more natural and immediate (Rusconi et al., 2006). Figures 2 and 3 provide a graphical explanation in terms of intervals and absolute notes.
- *Immediate Reaction*. Some interfaces based on gaze interaction (e.g. EyeHarp[3]) employ algorithms, fixation-discrimination, and other kinds of spatial filters to alleviate problems such as movement inaccuracy, the aforementioned Midas touch issue, noise introduced by the eye tracker sensor, and others. Netytar does not employ filters. As a consequence, latency in the feedback is reduced, which can make the instrument more reactive but more challenging to learn.
- *Colored Keys*. While many musical interfaces employ differently shaped keys (e.g. piano) or spatialization (e.g. EyeHarp) to help note localization, Netytar relies explicitly on highly contrasting colors to indicate notes on the keyboard. Consequently, it is possible to look for the next note with the "corner of the eye", without having to reach it with the gaze (taking advantage of color sensitivity in the areas outside the fovea (Lou et al., 2012)). The color code employed by Netytar is provided in Table 1.
- *Auto-scrolling Capability*. Netytar features an auto-scrolling algorithm which smoothly moves the surface on both vertical and horizontal axes, in such a way that the point which falls under the gaze point is always scrolling to the center of the screen. The purpose of this feature is to extend the keyboard dimensions beyond the size of the screen (allowing for a potentially infinite surface). This feature exploits the *smooth pursuit* movements, described in Sec. 3, which can be performed by eyes: such a feature would be difficult or impossible to introduce in a fingered touch screen based instrument).

3 GAZE INTERACTION IN MUSIC

This section focuses on the most important aspect of Netytar: gaze-based interaction.

While breath is a widely explored interaction channel in aerophone intruments (but also in other non-musical applications related to accessibility (Jones et al., 2008; Mougharbel et al., 2013)),

[2]https://github.com/Neeqstock/Netytar. Accessed on: 29/02/2020.

[3]http://theeyeharp.org/eyeharp-download/, 'Complete Manual (PDF)'. Accessed on: 29/02/2020.

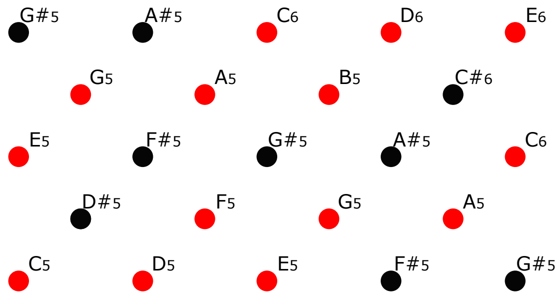


Figure 3: Netytar's keyboard layout, explained indicating the position of absolute notes, in a section ranging from *C5* to *E6*. Keys assigned to notes of the C major scale are indicated in red, while black keys denote accidentals.

gaze-based interaction is still rather young. In everyday life the eyes are a passive organ. Playing music or, in general, interacting with a computer through the eyes implies their use as an active input system: something we are not actually used to (Zhang and MacKenzie, 2007). Eyes move in a very peculiar way, which differs from finger movements. A basic understanding of these movements is needed in order to justify the exercises developed in Sec. 4. For the purposes of this work, a summary of the classification proposed by (Hornof, 2014) may suffice (more detailed discussions can be found in dedicated publications).

Gaze point is the point in space (or, in software applications, the point on the screen) where the person looks at. Eyes generally move through *saccades*, which are jerky movements, lasting about 30 ms, during which the gaze point moves from one discrete point to another. These are interspersed with *fixations*, where the gaze point remains, indeed, almost fixed on a position. Usually a fixation lasts from 100 ms to 400 ms. That said, the eye is unable to perform fluid movements unless it has a target to lock on: this is called *smooth pursuit*, a fluid movement which follows the movement of a target. *Blinks* are sometimes not recommended as an interaction channel due to their potentially involuntary nature (Jacob, 1995), but are employed in some applications, like Netytar. Finally, even during a fixation eyes are not perfectly still but make small random movements within 0.1° of the visual angle, called *jitter*. Among these ocular movements, Netytar mostly exploits saccades, fixations and smooth pursuits (the latter especially in relation to the "auto-scrolling" capability mentioned in Sec. 2). These movements can be activated voluntarily, but many can occur involuntarily and unconsciously. Involuntary saccades, for example, occur on a regular basis even during fixations Purves et al. (2001). Those may preclude musical performance, which requires very precise control.

There is evidence for gaze anticipating physical movement (Gesierich et al., 2008) and interactions in virtual environments (Badler and Canossa, 2015), a behavior which the performer must learn to avoid during gaze-controlled musical performance. Those lead to the anticipated execution of a note with respect to the prescribed tempo, unless the introduction of filters to compensate by creating latency. Such behavior was also noticed in (Vamvakousis and Ramirez, 2016, Sec. 2.2.2, 'Melody layer evaluation'). Netytar does not use filters in order to improve the precision at higher tempos (Davanzo et al., 2018), thus not providing any aid to avoid anticipations.

Rhythmic capabilities of the eye are limited. Hornof (2014) reports an eye-tapping experiment which shows that eyes are unable to deliberately perform more than 4 saccades per second (approximately one saccade every 250 ms). According to the author, this seems to be an upper limit which cannot be overcome, not even through training. In systems like Netytar where notes are selected through gaze pointing, this translates into a maximum limit in note changing speed. We however make the hypothesis, supported by direct observations, that more trained people could manage to maintain rhythms with greater precision. Next section will discuss the proposed study method to reach this and other goals while learning music with Netytar.

4 LEARNING METHOD

The main objective of the proposed method is to provide the users with a basic set of exercises, which should make them able to explore the instrument by themselves and deepen its practice, having gained a certain familiarity with the movements and understanding the rationale of the interface. Exercises are designed for simplicity, and are given in order of difficulty: some are preparatory to others and should be performed in the prescribed order, at most mixing them up between categories and going back to the previous ones from session to session. It is assumed that at the end of a certain number of iterations, the user will be able to perform simple melodies, as well as to learn new ones independently. Broader aspects of musical theory are not addressed in this paper, given that adequate literature already exists. The focus is instead on performance aspects and on the use of the instrument. Nonetheless, it may be useful to combine the proposed exercises with pure music theory provided by other sources.

The method consists of three categories of exercises, which correspond to three related sections:

- **Musical Alisthenics:** i.e. exercises designed to train motor skills of the eyes and breath in view of the required performance;
- **Musical Techniques:** performed using the instrument;
- **Musical Practice:** where the performer applies the acquired skills for musical purposes. This part is particularly important to provide motivation for the student.

These three categories are discussed in detail in the next subsections. For each exercise, a sentence is provided to describe its aim and discuss the expected improvement.

4.1 Musical Calisthenics

Eyes are governed by muscles. Constant training could improve or stabilize their rhythmic performance, as well as reducing fatigue.

People with physical disabilities may have reduced coordination in the residual movement channels, as well as a lack of rhythmic ability. This part of the training therefore consists of a series of exercises aimed at improving these aspects: improve sensitivity in the awareness of eye movements, noting and bringing to consciousness involuntary movements, jitter and other peculiarities; perform muscular stretching, so as to accustom the eye to perform large movements while keeping the head still, without suffering fatigue and pain; accustom the eye to make saccadic movements rhythmically, perceiving muscle tension. Similar exercises are given for breath as well, which is the second interaction channel employed by Netytar. Exercises are as follows, divided by those dedicated to the eyes (with prefix *CE-*) and those dedicated to the breath (with prefix *CB-*):

(CE1) Arhythmic Stretching and Smooth Pursuit. An assistant places themselves in front of the student, holding two colored objects. The student is instructed to move with the gaze from one object to another with saccadic movements, at a moderate pace while keeping the head still. The objects are initially placed close to each other, and their distance is slowly increased (horizontally, then vertically in the subsequent iteration), until the limits of the visual field are reached. Then, the distance is gradually decreased again. The exercise must be interrupted if the user experiences excessive discomfort or pain, especially near the limits of the visual field. A short session, in which the student is asked to concentrate and observe an object moving smoothly in front of them in the most precise way may be added (bringing the *smooth pursuit* movement to consciousness). **Aim:** an improvement in eyes mobility is expected after this exercise, as well as reduced fatigue while making long saccades.

(CE2) Rhythmic Blinking. Using a metronome, starting from slow tempos then repeating the exercise at faster ones, the student is asked to blink both eyes in time, at every tick. It is possible to introduce rhythmic dictation exercises to introduce complex rhythms, possibly in combination with simple notions of rhythm theory. **Aim:** this exercise is designed to familiarize the student with the concept of rhythm, before moving on to more difficult eye-tapping exercises.

(CE3) Rhythmic Eye-tapping. An assistant places themselves in front of the student in the same way as *CE1*. The student performs *CE1* in a timed manner with a metronome (one saccade per tick). The assistant can also provide feedback on the correct timing through direct observation. This exercise is potentially more difficult than *CE2*, given the anticipatory characteristic of the gaze movement discussed in Sec. 3. Since when playing Netytar the new note will sound exactly at the end of the saccadic movement, the student must become accustomed to this characteristic, as well as to perceive objects outside the fovea before even performing the movement. **Aim:** an improvement in anticipatory movement reduction is expected as a consequence of this exercise.

(CE4) Rhythmic Fixation. The student is asked to perform *CE3*, but instead of performing a saccade for each tick, they will perform one saccade every four, concentrating on keeping the fixation as stable as possible on the object between the saccades. **Aim:** this exercise aims to bring to a conscious level the involuntary movements of the eye, which can preclude a voluntarily stable fixation. A precision improvement is hence expected.

(CE5) Rhythmic Color Tapping. Several objects with different (possibly highly contrasting) colors are placed in front of the student. A sequence is established a priori (e.g. *"red, yellow, blue, green"*). The student is then asked to perform timed eye-tapping (like in *CE3*) by fixating on the objects in turn, cycling along the predetermined sequence. After a few cycles, the student is asked to close their eyes: the objects are re-positioned randomly, then they repeats the exercise. **Aim:** this exercise could be useful to strengthen the ability to find objects outside the fovea, taking advantage of the color sensitivity discussed in Sec. 3.

(CE6) Rhythmic Mixture. This consists of a variant of *CE5* (i.e., with two or more objects) where the student performs a mixed sequence of eye-taps (corresponding to note changes), blinks (corresponding to repeated notes) and fixations (corresponding to holding a note), timed by metronome ticks. Possible repeated sequences could be, for example: *tap, blink, tap, blink...* or *tap, fix, blink, fix, tap, fix, blink, fix....* By introducing a simple symbolic notation, more complex sequences can be outlined, to be read and played in real time, while increasing the difficulty (as happens with *solfeggio* in traditional music education contexts). **Aim:** this exercise is aimed at strengthening the independence between saccadic movements (useful for selecting a new note) and blinking (useful for performing a repeated note).

(CB1) Stabilizing Breath. The student is asked to blow into the breath sensor's mouthpiece with as constant and stable intensity as possible for a few seconds. In subsequent iterations, the level of breath intensity to be achieved is varied. **Aim:** this exercise should improve breath stabilization.

(CB2) Breath Crescendo. The student is asked to perform a "crescendo", i.e. a continuous increase of intensity, to reach a peak, and then gradually decrease to a resting position, all in the smoothest possible way. This should be performed at different speeds at each iteration. **Aim:** this exercise aims to strengthen control over the change in intensity.

(CB3) Breath Tapping. Once the metronome is set, the student emits breath with constant intensity for a predetermined number of ticks, then stops the emission for as many ticks. They will repeat the exercise in a continuous cycle. An example would be: *two ticks blowing, two pause ticks, two ticks blowing, two pause ticks, etc.*. **Aim:** this exercise should improve rhythmical breath control.

(CB4) Breath Tapping with Short Bursts. Again with a metronome, the student will perform breath emission impulses at each tick (at slow rhythms) or interspersed with a variable number of ticks (at more sustained rhythms), estabilished a priori. **Aim:** this exercise could be useful to gain confidence with the timed release of breath, as well as to strengthen the required muscles (i.e. diaphragm).

4.2 Musical Techniques

Once the rhythmic control of the eyes has been strengthened with exercises in the previous section, this next set of exercises should be performed directly on the Netytar's interface. These aim to transfer the acquired motor skills to simple technical musical sequences, which are preparatory to melody performance. Exercises in this category are noted with the prefix *T-*.

(T1) Interval Tracing. Playing Netytar, the difficulty associated to performing different musical intervals while avoiding the activation of intermediate keys is uneven: with respect to some intervals, distances between keys are large and paths narrow (sometimes obstructed). Intervals, with reference to the chosen isomorphic layout, could be roughly divided into 4 ranges of difficulty: **adjacent**, or in the immediate vicinity of the key (1, 2, 3 and 4 semitones); **distant easy**, i.e. not adjacent but not obstructed by other keys, therefore rather simple to perform (5 and 7 semitones, corresponding to perfect 4th and 5th); **distant hard**, or described by unobstructed but narrow, distant or difficult paths (6, 10 and 11 semitones); **obstructed**, or described by paths obstructed by other keys (8, 9 and 12 semitones), however playable through a rapid saccadic movement or breath interruption. These 4 groups are shown in Fig. 2. Having established this classification, the proposed exercise consists in performing, in both directions, in turns and in repetition, intervals with difficulty *adjacent* and *distant easy*. Notes can be played as quarter notes with a metronome. A variant can be introduced by performing a repeated note with a blink between each note change. **Aim:** this exercise should improve the association of geometric movements within the keyboard with given musical intervals, in addition to improving the confidence with the keys layout.

(T2) Scales Tracing. Major and minor diatonic scales are performed using a subset of the *adjacent* group described in *T1*. It should therefore not be difficult for the student, once *T1* has been trained, to perform this next exercise: the major and minor scale are performed in ascending and descending directions with a metronome, one note per tick. It is possible to introduce repeated notes as indicated for *T1*. As a variant, it could be useful to introduce also major and minor pentatonic scales. **Aim:** this exercise should increase the performer's knowledge of the keyboard and its melodic capabilities, and improve the performer's playing precision.

(T3) Arpeggio Tracing. In this exercise, the student plays various arpeggios using a metronome, one note per tick. Although it is advisable to start from

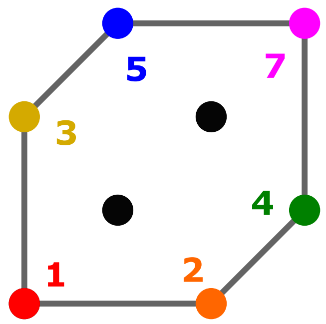


Figure 4: A possible closed shape for exercise *T4* in Sec. 4.2. Color code for keys is as in Tab. 1.

simple major and minor arpeggios with single triads, major or dominant 7th arpeggios could be introduced. These arpeggios trace very short and simple paths on Netytar's virtual keyboard, and should be repeated transposing them to other keys, so that the user becomes familiar with its isomorphic properties (described in Sec. 2) and the concept of transposition. **Aim:** the expected improvement given by this exercise is comparable to the previous, with respect to arpeggios.

(T4) Complex Shape Tracing. This exercise consists in defining arbitrary shapes and trace them with gaze on Netytar's keyboard, playing the notes following the metronome. Shapes can consist of open shapes (to be performed in an ascending or descending direction), or closed shapes (to be performed both clockwise and counter-clockwise). Examples of these shapes could be given by a complex, multiple octave chord arpeggio, or by the closed shape made by the 1st, 3rd, 5th, 6th, 4th and 2nd degrees of the major scale (as illustrated in Fig. 4). The student could be stimulated to invent and perform new shapes and "test" them. **Aim:** in addition to precision improvements, this exercise should introduce the performer to keyboard exploration.

(T5) Shapes with Returns. Many traditional musical instruments study methods involve "repeated pattern" exercises. An example could be given by this sequence constructed on the major scale: *C D E, D E F, E F G, F G A, G A B, A B C* (to be played in both ascending and descending manner). **Aim:** this exercise could be preparatory to performing less linear and more complex phrases.

(T6) Complex Rhythms. All the previous exercises are revisited, adding complex rhythms instead of the "one note per tick" pattern. Examples could be given by the execution of 2/4 notes followed by 1/4 notes, with or without the introduction of repeated notes. Sequences should be estabilished and given a priori. **Aim:** this should be the final introduction to melodic phrasing. The following section consists indeed in the execution of actual music pieces.

4.3 Musical Practice

This section of the training consists of giving the student simple tunes to be played with Netytar, to put into practice the improvements given by previous exercises. This work will not focus on providing a list of melodies, given that there are already several texts and advice on the subject, dedicated to other instruments but still suitable. As an example, the *My Breath My Music* foundation is active in the music education field within SEN contexts (teaching people with disabilities in the upper limbs how to play the *Magic Flute*[4] instrument), and offers a training program composed of simple melodies freely available on their website[5]. It should also be noted that it is probably simpler for the student to play an already known melody than learning a new one. The musical tradition however varies from culture to culture. In different contexts it is possible to identify different pieces to propose. The following lend themselves to be useful guidelines for identifying simple tunes for Netytar.

- Identifying the type of musical intervals the performance requires helps to determine their difficulty. A difficulty classification is indicated in Sec. 4.2, for exercise *T1*.
- Tracing and transcribing passages using the notation described in Sec. 5.1 can help in the process, highlighting also the amount and localization of the required eye movement.
- The upper bound in speed imposed by the nature of saccadic movements, discussed in Sec. 3, should be taken into account, providing some constraints for the tempo.
- A good difficulty progression should take into account the rhythmic complexity of the piece. A homogeneous rhythm should be simpler.

5 FURTHER DEVELOPMENTS

This section will discuss further possible developments to enhance the proposed methodology.

[4]https://mybreathmymusic.com/en/magic-flute. Accessed on: 29/02/2020.

[5]http://mybreathmymusic.com/en/liedjes-spelen-voor-beginners. Accessed on: 29/02/2020.

These include a possible notation for exercises and melodies, and ideas for replacing the assistant for exercises in Sec. 4 with software.

5.1 Notation

In order to propose a simple way to write down new exercises, which could be developed by a possible teacher or assistant, a simple notation is introduced. This does not aim at being as complete as traditional staff notation, but relies on the idea of indicating the "geometric shape" described by a short musical sequence and therefore provide simple mnemonic support that does not require previous knowledge in reading notes on the music staff. It can be described using the following rules:

- Notes that make up the sequence are connected by a broken line, following Netytar's virtual keyboard layout and colors. The line can also be "folded on itself" to indicate to go over the same interval several times.
- Only a small number of bars should be drawn in a single image (1 bar or few more, depending on the complexity).
- The temporal progress of the sequence is indicated by a color gradient along the line: a color (e.g. green) indicates the beginning of the sequence, another color (e.g. red) the end. Otherwise, if not possible, only the two endpoints could be noted down with color.
- A repeated note is indicated by single or multiple symbols (e.g. an **O**) placed next to the keys. This information could be otherwise omitted for visual simplicity.

An example is given by Fig. 5, which represents the first bars of the song "Twinkle, Twinkle, Little Star" *(C, C, G, G, A, A, G, F, F, E, E, D, D, C)*.

It should be noted that while playing an instrument that requires the performer to use their gaze as an interaction channel, music cannot be read at the same time using traditional staff notation. A future development of Netytar could implement the simple notation described above so that the score can be displayed directly on the keyboard while playing, providing a significant aid to the performance An interactive version of the notation (similar to a score follower) could include a cursor (e.g. a circle) which moves in a timed manner on the next note to be played following the path, effectively "gamifying" the musical performance.

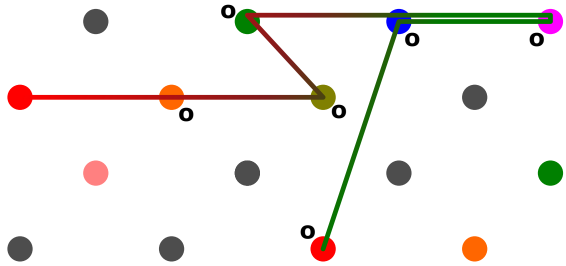


Figure 5: The first bars of the popular tune *Twinkle, Twinkle, Little Star*, drawn using the notation exposed in Sec. 5.1.

5.2 Automating Exercises using Software

Most of the exercises described in Sec. 4 should be performed with a human assistant, which provides visual elements and gives feedback. However, a simple additional software interface could be created as a replacement, thus making the user autonomous in practising, providing also more precise and objective feedback. Visual objects indicated in Sec. 4.1 (*CE1, CE3, CE4, CE5,* and *CE6*) can be easily replaced by virtual objects on screen, providing also auditory or vibrotactile feedback (using an actuator) upon successful gaze selections of each item. Breath-related exercises in Sec. 4.1 (*CB1, CB2, CB3* and *CB4*) could be more effective if supported by an intensity indicator on screen. The use of other gaze controlled applications unrelated to the musical purpose could strengthen eyes control abilities and confidence with gaze interaction (e.g. eye controlled text writing software such as the freely available *GazeSpeaker*[6]).

6 CONCLUSIONS

A study method has been presented for allowing people who have never had prior music experience to approach the accessible digital musical instrument Netytar. Choices are motivated through an analysis of the relevant properties of the instrument and eye interaction in a general sense. A review of the relevant characteristics of Netytar has been proposed. Possible future developments to automate the training have been indicated in Sec. 5.2, along with the introduction of a simple musical notation suitable for Netytar in Sec. 5.1. Further future works will include testing the proposed methodology with the target users, performing case studies and user experience assessment, measuring also possible improvements in users mu-

[6]https://www.gazespeaker.org/. Accessed on: 29/02/2020.

sical performance using objective methods, as happened in previous Netytar evaluations (Davanzo et al., 2018).

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