Animal-Centred Sonic Interaction Design:
Musical Instruments and Interfaces for Grey Parrots

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ABSTRACT
This paper describes our research and the methodology used to design musical instruments and interfaces aimed at providing auditory enrichment for grey parrots living in captivity. Based on the cognitive, physiological, and acoustic abilities of grey parrots, and their intrinsic interest in acoustic and physical interactions, we have developed and tested various interactive instrument prototypes from an animal-centered design perspective. In a previous study, we analyzed the physical and musical skills of a group of grey parrots, and here we present our design results for auditory enrichment in the context of Animal-Computer Interaction (ACI) and artistic research. Our investigation should lead to a better understanding of how grey parrots interact with technological mediators, respond to sound devices, and create "parrot music," with potential benefits for their well-being while living in captivity.

Author Keywords
Sonic interaction design; interactive musical interfaces; grey parrots; auditory enrichment; animal-computer interaction; animal-centered design.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Wild animals should not live in captivity, but if they are forced to, special efforts are needed to promote adequate and dignified living conditions for each species. In the context of our research, we refer to the relatively new field of ACI in combination with the field of New Interfaces for Musical Expression (NIME). ACI deals with the various aspects of animal-machine interaction, for example, in human healthcare, the agricultural industry, or for animal entertainment. The increased use of technology for animals raises many technological, design, and ethical issues that ACI seeks to explore from an animal-centered point of view [1].
One focus of ACI is devoted to the study of the effects that sound and music have on animals, and how these can be used to enrich the environment of captive animals. In 2018 at the ACI conference in Atlanta, a workshop [2] was held on this topic for the first time. Within the "Sound Jam" workshop, prototypes were developed and presented for different animal species. In addition to chimpanzees and elephants, new interaction design ideas were also developed for African grey parrots.

In the context of ACI, several studies have been devoted to the use of audio technologies to enrich the living environment of animals in captivity. Fiona French is, for example, currently investigating the potential of technological enrichment for captive elephants. The design of the interactive toys for elephants focuses on acoustic enrichment and physical experiences [3,4]. A further relevant ACI study was carried out with zoo orangutans by Patricia Pons, who developed a sound-based interactive system for auditory enrichment. Instead of providing orangutans with human music, the system allowed the primates to explore different types of sounds by manipulating tangible objects. The sound preferences of the orangutans were incorporated into the design process, thus constituting an animal-centered approach [5].
Recent research in the field of cognitive biology has questioned the concept of animals listening to human music as a form of enrichment [6-9]. Since most of the music is selected by humans, this can often lead to anthropomorphic biases. Therefore, the music should be attuned to the animals' acoustic skills and potential. Studies have shown that many non-human species actually possess musical skills [10-12] and also display entrainment to auditory stimuli [13,14]. Animal species such as grey parrots, cockatoos, elephants, primates, pigeons, and carps have been found to be able to discriminate between different composers or different genres, prefer music to silence, or can move in rhythmic synchronicity to the musical beat.

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The idea of animals becoming anthropomorphic musicians, playing traditional acoustic instruments, is common in the literature and in popular culture. Thus, musical instruments and interfaces that involve animals as musical agents can also be found in the NIME context. The introduction and development of new technologies in this field also opens up new possibilities to include animals in the music-generating process. The projects we could identify in the NIME community are mostly combinations of a computer vision system for tracking animals and a sound-generating system, which is controlled by the animals' movement. A very common approach in this field is fish-based interfaces. In addition to that, there are many other interesting approaches in the context of NIME that we will analyze later in the chapter on related works.

BACKGROUND

In 2016, the authors of this paper started a collaboration with an artistic research project of the Austrian artist collective *alien productions* and the zoologists and animal keepers of *ARGE Papageienschutz*. The principal goal of this collaboration has been to design and develop musical instruments and interfaces for a group of grey parrots held in care at an animal shelter near Vienna. This research is based on the previous results of an ongoing art project called *metamusic*, which *alien productions* began in 2012. Based on an artistic approach, the collective has been observing how grey parrots react to musical stimuli, exploring whether they can become active participants in interactive sound installations, and assessing whether they are capable of producing "parrot music" (new music that does not have to sound like music to human ears) by themselves. In addition to that, the project has also produced artistic output for human listeners while improving the quality of life for grey parrots in captivity with musical instruments and toys. The artist group mainly deals with the realization of exhibitions and performances. Our role as musical interaction designers consists of the design and evaluation of dedicated musical instruments for the parrots.

Grey parrots are highly intelligent and have become popular pets due to their exceptional ability to mimic human speech. Irene Pepperberg has conducted numerous studies on the cognitive abilities of grey parrots, displaying that they have cognitive levels comparable to those of 4 to 6-year-old humans on some tasks [15]. In 2009, researchers challenged the claim that spontaneous entrainment to music is unique to humans. In two studies, they reveal the existence of spontaneous motor entrainment in nonhuman species [13,14].

There have also been other investigations focusing on the musical talents of grey parrots, such as Luciana Bottoni's "Teaching a musical code to a parrot: Frequency discrimination and the concept of rhythm in a grey parrot" (2006). The researchers taught an African grey parrot to use basic elements of music, such as intonation and rhythm. The frequency analysis and comparison between the parrot's sequences and randomly generated strings confirmed the acquisition of the intonation concept, and the amplitude peak of the notes showed the grey parrot's tendency to maintain rhythmic regularity [11].

In 2012, Franck Péron demonstrated the existence of personalized musical preferences in grey parrots. He installed a touchscreen in an aviary, which could be used at any time by the birds. He observed that the birds not only were able to use the electronic device but also discovered that parrots showed different individual musical tastes and preferences [16]. Since grey parrots are highly intelligent and are known for their complex cognitive and communicative abilities, they need enrichment and attention in captivity, otherwise they can become distressed. Self-harming behavioral disorders such as feather plucking are a common symptom among grey parrots when held in captivity or isolation [17].

A TAXONOMY OF RELATED WORKS

In our extended review paper, "Animals Make Music: A Look at Non-Human Musical Expression," [18] we proposed a classification based on the role animals can play as an element or an agent in musical environments and performances. We distinguished between: (1) animals as control source; (2) animals as unconscious performers; (3) animals as trained performers; and (4) animals as voluntary performers. In the following section, we will present some projects which we have found to be relevant within the NIME and ACI fields.

1. Animals as control source

Most of the musical implementations we have found in the field of NIME use a video tracking system to observe animals and create sounds based on the movements of these animals.The most common species used in these systems is aquarium fish. Since the mid-2000s, this idea has been explored in different fields and with various fish species. For example, "The Accessible Aquarium," a long-time project of the Georgia Institute of Technology in Atlanta, is based on the field of informal learning environments [19].

Other fish-based projects such as *FuXi: A Fish-Driven Instrument for Real-Time Music Performance* [20], *Submersed Songs* [21], *Quintetto* [22], *Musica sull'Acqua* [23], *Sonification of Fish Movement Using Pitch Mesh Pairs* [24], and Ken Rinaldo's *Augmented Fish Reality* [25] take an artistic approach and employ musical instruments and interfaces for sound installations or musical performances. Although all of the projects mentioned above use a video tracking system, they differ from each other in the way in which sound is mapped to the fish movement and what kind of musical response was generated. Although it has been shown that some fish species, such as carp, display a certain musicality, can discriminate between different styles of music [26], and have vocal communication skills [27], these particular musical abilities have not yet been investigated or employed within the fish-based projects found in NIME.

2. Animals as unconscious performers

This category deals with projects that involve animals directly touching or triggering musical interfaces, instruments, or sensor systems. The *Intelligent MIDI Sequencing with Hamster Control* project by Levy Lorenzo [28] was a musical instrument that generated sounds based on the movements of six hamsters. Each hamster was placed inside a single narrow track in which it could only move in a lateral direction. This allowed the hamsters to walk, sit up, and turn around while still remaining within the range of the distance sensor. The sounds generated depended on the distance of the hamster from the sensor. Another well-known art project is *from here to ear* [29] by Céleste Boursier-Mougenot. The installations of the project combine a set of traditional musical instruments—mainly electric guitars and drums—that serve as a resting place for finches, which then produce sounds upon contact with the strings. The audience is invited to enter the installation space and mingle with the finches, whose movements generate an aleatoric live musical piece. Since it has been shown that even finches have certain musical abilities [10,12], it would be interesting to provide them with musical instruments that are adapted to their particular physical skills and musical potential.

3. Animals as trained performers

Elephants are another popular species that have been given musical instruments to enrich their lives in captivity. An early attempt in this regard was made by the *Thai Elephant Conservation Center* with its *Thai Elephant Orchestra* [30]. With the intention of creating music for humans, the animal keepers designed and built massive conventional acoustic musical instruments adapted to the physical abilities of the elephants. In 1997, the orchestra made its first recording with five elephants, and subsequently released an audio CD in 2001. From the very beginning, it was clear that elephants could be taught to play complex musical patterns through the use of rewards and endless repetition.

4. Animals as voluntary performers

The musician David Rothenberg is investigating the sounds animals make, which he considers and defines as music. He is making music for and with other animal species, such as birds, bugs, and whales, in order to understand their acoustic expressions and communicate with them. For example, he performed a duet with a singing humpback whale off the coast of Maui. He played the clarinet, and a sound spectrum analysis determined if the whale changed its song in response to the clarinet performance. Rothenberg claims that creating interspecies music is a valuable tool for understanding the complex sounds made by humpback whales [31]. As already mentioned above, Fiona French and Patricia Pons's studies in the context of ACI also included the use of audio technologies to enrich the living environment of animals in captivity. Fiona French investigated the potential of technological enrichment for captive elephants. The design concepts for elephants also focused on acoustic enrichment interfaces [3,4]. Patricia Pons worked with orangutans on a sound-based interactive system for auditory enrichment. Instead of providing orangutans with human music, the system allowed the primates to explore different types of sounds by manipulating tangible objects. [5] We would also place our present research project in this category because the grey parrots voluntarily participated in the musical interaction and design process.

METHODOLOGY

The design of interactive technologies for grey parrots in the field of artistic research and musical interaction design is new and therefore requires careful consideration regarding an appropriate and responsive framework for the process of developing such environments. Our process for designing musical instruments is based on the findings of cognitive science and animal behavior studies, as well as our own observations and an analysis of the physical and acoustic capabilities of the various participating grey parrots. One of the main goals of our project is to develop an approach that allows grey parrots to voluntarily participate as actively as possible in the design process without the application of any forceful training or reward system. The voluntary participation of the grey parrots in our different experiments is ensured by allowing the grey parrots to freely decide whether they wish to participate in the research activity and by creating experimental setups that assure the exercise of free by allowing the grey parrots to move away from the experiments at any time. We take the fact that the grey parrots actively move towards the instrument, generate sounds with it, and respond to the sounds as a sign of their voluntary participation.

Participatory Design

In addition to the observation of the grey parrots' behavior when dealing with the various stages of our prototypes, we also use the playful interaction between animal and human as a co-design method for the development of musical instruments for this parrot species. The joint musical play, or as we call it, the "Jam Sessions," have yielded several insights into the individual preferences of each grey parrot and their general forms of interacting with natural, artificial, or technical artifacts. We believe that this participatory design approach leads to more creative outcomes and also fulfills all ethical research principles. The reactions and observed preferences of the grey parrots when interacting with the proposed devices has continuously informed our iterative design process.

Intrinsic motivation plays an important role in this context. The cognitive challenge of interacting with musical instruments and the musical response should themselves be a reward and enrichment for the grey parrots. Making music is the spontaneous and voluntary activity undertaken for the parrots' personal enjoyment. The reward is the inherent playful activity and its sonic response, and not just an action to get food. In short, playing with music replaces the peanut as a reward system and therefore should encourage the animal to continuously interact and play with the musical interface. Beyond the process of observation, measurement, and analysis, a more reliable methodology that allows the grey parrots to participate in the design process itself has yet to be found. The design should avoid any conditioning of the animals but instead support their inherent acoustic capabilities and needs. Instead of providing grey parrots with what we believe is pleasant to their ears, our musical interface approach gives them control over the sonic stimuli. In our approach, the grey parrots can explore different types of interactions with the devices and sounds by playfully interacting with the musical interfaces.

Exploring Sonic Preferences

In our report on testing the acoustic skills, sonic expressions, and musical preferences of grey parrots in captivity [32], we have previously documented the basic findings based on a preliminary examination of our group of parrots in the animal shelter. The maximum sound level in the aviary was measured to be 104 dB. The grey parrots communicated, on average, at a level between 60-90 dB. We recorded a frequency range from a minimum of 600 Hz to a maximum of 3800 Hz. Most of the utterances of the grey parrots were in the range between 1200 to 2400 Hz. A frequency analysis showed that the basic frequency in the grey parrots' communication was substantially higher than in humans. This led us to the design question of whether we should pitch up the sounds and music we were working with in order to make it easier for the grey parrots to perceive them. We also tested the grey parrots' hearing abilities by exposing them to various sound stimuli. Our observations suggest that their lower limit of sound perception is around 150 Hz and the upper limit is around 7000 Hz. We observed particularly strong acoustic feedback from the grey parrots at around 5000 Hz. For investigating the grey parrots' musical preferences, we subsequently developed two test stations—the *rope swing* (Figure 1) and the *joystick device* (Figure 2), which were used to perform different sonic experiments at the animal shelter.

Figure 1. Rope swing test station

We observed that music with a continuous beat was favored over single notes or musical sequences. It often happened that the grey parrots spontaneously entrained by bobbing their heads with the continuous beat and responded with vocal utterances. We could not prove whether grey parrots tend to prefer music with human voices over music without human voices, nor could we identify a particular pitch preference. Another basic insight was that the musical taste of grey parrots is apparently very individual as in humans.

Figure 2. Joystick test devices

Interaction Design

Interaction design and its evaluation is the basis of Human-Computer Interaction (HCI) and thus also a fundamental part of NIME and ACI. Animal interaction not only always includes an animal and a certain technology, but often a human participant, researcher, and/or animal keeper [33]. In our case, this means the interaction between animal and instrument often also includes keepers, artists, and researchers. Interaction refers to the way in which parrots handle and respond to the musical instruments and interfaces and is obviously primarily determined by the physical and cognitive abilities of each species. What happens exactly within the animal while interacting is generally unknown, but we, in collaboration with the animal keepers, are trying to interpret their behavior. Therefore, the animal keepers participated in the process through their zoological knowledge and experience with the parrots. We observed the parrots' behavior when playing, exploring, and interacting with the musical instruments and other artifacts within their environment. A good understanding of the parrots' body language and posture is essential for determining positive and negative responses to the design of the instruments. Grey parrots primarily interact with instruments by means of their beak, but sometimes a leg is also involved as a support, for example, to hold a device. In general, the parrots like to chew, pull, and peck on most artifacts and interfaces, with a visible desire to disassemble or destroy them. In order to encourage this behavior, we have had good results from providing them with a wooden branch equipped with a piezo pickup. This setup has evolved and is presented below as the *branch instrument*. Branches are generally used as an enrichment toy for the aviaries, and the parrots like to nibble and chew on them and peel off the bark. We have encouraged this natural behavior of the grey parrots and added a sonic stimulus to it by amplifying the sound that occurred during these interactions. This has allowed us to find a good starting point through the use of familiar materials in combination with encouraging natural behaviors such as pecking or chewing.

Physical Design, Materiality and Color

As mentioned above, a good strategy is to use materials which the grey parrots are familiar with. In the context of our project, this generally refers to the existing equipment and enrichment of the aviary. Commonly used materials are, for example, wood for perches, metal grids, ropes, cardboard, plastic toys, and fresh branches. During our initial experiments, we tried to protect the technical instruments from being damaged by the parrots by explicitly trying to build them very sturdy. But it quickly became clear that the instruments were far more interesting for the parrots if they at least partially appealed to their exploratory and destructive drive, as we observed with our piezo-equipped wooden branch.

In the case of the tube instrument described below, we initially used a cardboard tube, which was well-received by the parrots. As the cardboard tube quickly suffered damage, we tried replacing the cardboard tube with a natural and sturdier bamboo tube. Surprisingly, the parrots then completely ignored the instrument and were reluctant to play with it. According to the animal keepers, the grey parrots are not familiar with bamboo, and the material is therefore suspicious to them. Therefore, we had to take a step back and tested different materials for the tube instrument. We finally decided to use transparent acrylic glass as the material for the tube. This material has been well-accepted by the parrots. It is familiar to them, as many enrichment toys use this acrylic material.

In general, the neutral appearance and the strength of plastic tubes makes them a good material for the instrument cases and also adds a functional aesthetic that matches our needs. The neutral monochrome colors (white, grey, transparent) of the tubes make sense to us because we do not want the parrots to be distracted by the color of the instruments and thus not engage with the generated sounds. For example, the grey parrot Wittgenstein is very interested in red objects and can be easily motivated to interact with instruments by using red attractors. We assume that such color-motivated interactions have little relevance for our research on auditory enrichment for grey parrots. We have therefore strived for a neutral color design. The use of colored wood cubes from parrot toys has helped somewhat in initially drawing the parrots' attention to the instrument and its usability. We have subsequently observed that the grey parrots react differently to the colors and materials of the instruments. Other attributes such as the smell and the taste of the material might play an important role here, but we have not been able to investigate this in further detail. Generally, we make sure that no sharp edges or toxic materials are used.

INSTRUMENT IMPLEMENTATIONS

To test the parrots' acoustic and musical interactions, we carried out experiments at the parrot shelter in Vösendorf near Vienna. The shelter is home to approximately 190 parrots of various species. Most of them are captive-born, hand-raised, and used to human speech, and some of them show behavioral disorders such as Feather Destructive Behavior (FDB). FDB is a syndrome in which the bird pulls out its own feathers. The actual subjects of our experiments were a group of 15 grey parrots between the ages of 4 and 40 years old. They were housed in one group in a 5m x 4m x 3m indoor aviary, with an additional outdoor aviary of approximately the same size. All experiments took place in the indoor aviary. The aviaries were enriched with parrot tools, and the parrots had free access to food and water. For the experiments, the parrots were not separated, not trained, and there was no conditioning of any kind. The grey parrots were free to interact with the musical instruments and were only rewarded and intrinsically motivated though the sonic feedback generated by their actions. There was no rewarding by food, and when they showed signs of distress, the Jam Session was immediately interrupted.

Table 1. Overview of instruments presented below

Name	Type	Interaction	Sound
Gong instrument	Electro-acoustic percussive	Beak, leg; knocking, walking	Metallic, percussive
Chime instrument	Acoustic	Beak, leg; pulling, chewing	Metallic, percussive
Branch instrument	Electro-acoustic percussive	Beak, leg; nibbling, wiping	Woody, metallic; percussive
DJ instrument	Digital sampler	Beak; rotating, nibbling	Digital scratching
Tube instrument	Acoustic-digital effect	Beak, leg; pulling	Spring reverb
Vox instrument	Digital effect	Beak; utterance, nibbling	Reverb, delay, pitch shift
Reel instrument	Digital drum sampler	Beak, leg; rotating, nibbling	Digital percussive

The designs of our instruments have been informed by our research of the literature, our earlier sonic interaction experiments with grey parrots [32], and the anecdotal experience and observations from the ongoing *metamusic* project. An instrument from this initial project period that has worked particularly well is the gong instrument.

Gong Instrument

The *gong instrument* (Figure 3) had been developed for a previous exhibition at the Höhenrausch in Linz during the summer of 2015 as part of the *metamusic* project. The instrument consists of a floating metal plate, which is mounted with metal springs on top of a case. The plate is equipped with a piezo pickup for sensing the impact interactions, and the case houses and protects the necessary electronic equipment. The gong is a percussive instrument in which the grey parrots generate sound by continuously pecking with their beak onto the metal plate. In the exhibition installation, these pecking sounds were amplified, manipulated with sound effects such as reverb effect, and played back to the parrot aviary via a general PA system. Since pecking is a natural territorial behavior in parrots, the instrument was very well-received and used regularly. However, the smooth surface of the instrument made it difficult for the parrots to walk and rest on the instrument. For this reason, blue sandpaper was applied to the surface of the case of the instrument. It remains unclear how the sounds which were played back to the aviary affected the other grey parrots. During our observations, we were unable to detect any stress behavior such as other birds in the aviary fleeing, but we generally suggest that the sound should preferably come directly from a speaker inside the instrument to not affect other parrots in the aviary.

Figure 3. Wittgenstein on gong instrument

Since then, we have been focusing on designing further experimental musical instruments and carrying out different sonic experiments for enrichment and use in installations and performances. Based on our research on sonic experimentation with grey parrots [32], our focus is now on further expressive acoustic capabilities of grey parrots.

Chime Instrument

This simple and purely acoustic percussive instrument is based on a wind chime with the audible musical notes G-A-B-D-A-G-B-D. The eight tones are produced by eight metal rods within a cylinder which are struck by a disk attached to a cord with a wind sail.

The sound of the wind chime was positively received by individual parrots such as Wittgenstein and Rosi during our jam sessions and was therefore adapted as an enrichment instrument for the grey parrots. The cord to operate the instrument was renewed and instead of the wind sail a colorful piece of wood from a parrot toy was attached to the cord. As an additional protective resonator, a cardboard tube was used. This modification was also designed to motivate the parrots to interact with the instruments case. Cardboard in various shapes is often used for enrichment in the parrot shelter, and we assumed that the use of this material would make the instrument more familiar to the parrots and motivate them to chew on and tear at the instrument. We observed various parrots interacting with the *chime instrument* (Figure 4).

The parrots interacted with the instrument by pulling on the rope with their beak or a leg; nibbling and destroying the piece of wood attached to the rope; or, less frequently, nibbling on the cardboard resonator. Mostly, they interacted with the attached piece of wood, and it is therefore questionable to what extent the responsive sound of the instrument was the motivation for the interactions. The color of the attached piece of wood also had an impact on the frequency of the interactions. For example, with a red piece of wood, we observed more interactions than with other colors. Through these interactions, a sound carpet was created, which could subsequently be picked up by a microphone and amplified for the performance setting described below.

Figure 4. Rosi on chime instrument

Branch Instrument

The *branch instrument* (Figure 5) is an electroacoustic instrument that makes the grey parrots' interactions with the branch and the additionally attached ludic elements audible. As described above, branches are often used for enrichment in the aviary of the parrot shelter. The parrots sit and move on the branches, peel off the bark, and rub their beaks or knock on the wood.

We chose a branch from a regional elderberry shrub because we thought its particularly soft wood and soft bark would stimulate the interest of the grey parrots in destroying the branch. By building piezo microphones into the branch, the instrument made the grey parrots' interactions with the branch audible. Additionally, to encourage playful interactions with the instrument, a metal spring was mounted, which could be used to make additional sounds with the two wooden cubes mounted on a cord next to the spring. We observed that the grey parrots moved naturally on the branch while their movements were amplified. The additional spring toys aroused the interest of the parrots, and they played with them. We could not observe a change in the grey parrots' behavior due to the responding sounds generated by their actions.

Figure 5. Detail of the branch instrument

DJ Instrument

The *disc jockey (DJ) instrument* (Figure 6) is based on a 15-cm diameter foraging wheel, which was originally designed for the playful enrichment of the feeding process. Foraging wheels are not only used for feeding but are also employed as physical and cognitive enrichment toys by providing challenges in which the parrots have to spin a wheel to collect their treats. The parrots usually use their beak to spin the wheel. The appearance of the instrument and the way in which the parrots interacted with the device strongly reminded us of a DJ scratching vinyl records on a turntable and therefore we adapted our sound design to this analogy.

The feeding wheel is attached to a bent right-angled plastic pipe and equipped with a rotary sensor that triggers sounds when the parrots turn the wheel. In addition, visual feedback is provided by a LED attached to the wheel. In keeping with the turntable theme, we also designed a corresponding scratching sound as a sonic reward for the parrots. Since the scratching sound was well-received by the parrots, we have decided to further develop this instrument into a parrot turntable.

The adapted right-angled pipe houses a Raspberry Pi computer, an Arduino board, and an amplified speaker for direct sonic feedback. This setup makes it possible to directly trigger scratching sounds when the wheel is turned. It is possible to load different audio files into the instrument. When the parrots turn the wheel, it scratches through the audio file. Depending on the speed and duration of the rotation, different scratching sounds, similar to DJs' vinyl scratching, are generated. The instrument is battery-powered and can be easily installed at different locations and therefore in the different territories of the individual grey parrots in the aviary. In general, grey parrots are very territorial animals, and therefore individual birds were not always free to move within the aviary. The mobility of the instrument compensates for this behavioral limitation. Since the parrots were already familiar with this form of spinning interaction, they were quickly able to learn how to operate the instrument in order to receive their sonic treat. Some parrots immediately engaged with the *DJ instrument*. The grey parrots Pauli, Nepomuk, and Cocomiso showed interest in interacting with this instrument and used it for a period of several minutes. The parrots intuitively found out how to trigger the scratching sounds and in response started bobbing their heads and responded with utterances. This kind of behavior can be interpreted as positive feedback and indicates excitement and interest.

Figure 6. DJ instrument played by Pauli

Tube Instrument

The *tube instrument* (Figure 7) has been designed as a collaborative instrument in which a parrot can play "hand-in-hand" with another parrot or a human collaborator. Grey parrots mostly live in monogamous relationships and prefer to engage in activities with their partners. The tube instrument therefore intends to stimulate the birds' interest in interacting and discovering things together or interacting with other humans who are part of their flock in the aviary.

Figure 7. Tube instrument showing a collaborative interaction

The instrument consists of a tube with a spring reverb installed inside that can be triggered from both sides by pulling on ropes that reach out from each end. The instrument is battery-powered and consequently also mobile and mostly generates reverberating sounds. The

sonic response comes directly from a small amplified speaker placed inside the tube. The grey parrots interacted with the instrument exclusively by pulling on the rope with their beaks, thus creating a metaphorical tug-of-war. As already described above, we initially used a cardboard tube, which was later replaced by a bamboo tube. After switching from cardboard to bamboo, the parrots did not want to interact with the instrument, so we had to carry out material tests and opted for acrylic glass for the final version of the tube instrument (Figure 8). In the context of a musical performance, this instrument could also be used as an effect device by additionally modulating external sound sources by interacting with the instrument.
Regarding the collaborative design, our tug-of-war approach turned out to be appropriately chosen, since two parrots could interact simultaneously with the instrument. They enjoyed the competitive and destructive experience and also responded to the sonic reverberations generated by their activity. We often observed that some grey parrots fluffed their feathers, which animal experts interpret as a sign of positive excitement.

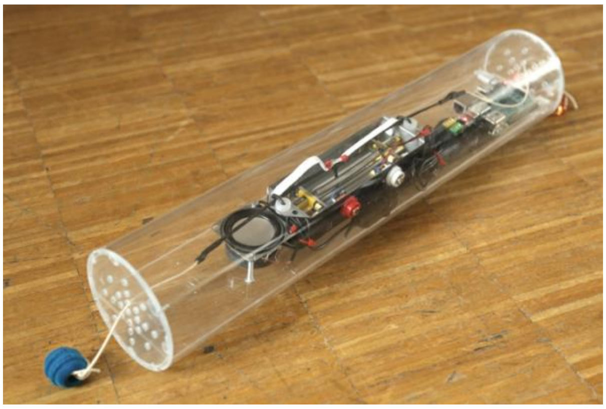

Figure 8. Tube instrument final version

Vox Instrument

Grey parrots show the exceptional ability to mimic human speech and environmental sounds [11,15,34] and therefore we also focused on designing an instrument that specifically encourages this behavior. We developed a vocal feedback instrument into which the parrots should shout, speak, or sing. The idea was to record the sounds of the parrots and then play back an auto-tuned feedback with delay and reverb effects of their utterances. Such a practice could hypothetically even lead to the self-training of pitched notes.
The *vox instrument* consists of a plastic pipe system with three openings. A colorful children's microphone is mounted to the larger open end and receives the sounds of the parrots. At the other two smaller open ends, small speakers are installed for a direct sonic feedback. The necessary electronics such as a Raspberry Pi, soundcard, and amplifier board were also built into the pipe system. Once the microphone registers sound from the grey parrots, these sounds are slightly delayed and transformed by the instrument. The result is a call-and-response interaction between the grey parrot and the instrument that involves different sonic elements, such as reverb, echo, and pitch shift. The grey parrots interacted with the *vox instrument* (Figure 9) by nibbling and chewing on the microphone and the pipe with their beaks and showed responses to the instrument's sonic feedback. A direct speaking or singing into the microphone or call-and-response interaction with vocalizations has not been observed so far.

Figure 9. Cocomiso on vox instrument

Reel Instrument

Another design idea involving the construction of a drum sequencer instrument is based on the outstanding rhythmic entrainment capabilities of parrots. This instrument is intended to be used by the parrots to generate rhythmic patterns. We have observed that some parrots bob their heads to continuous beats [32]. Thus, this drum machine instrument could encourage and promote this behavior. Our first experimental approach towards such an instrument utilised bending rulers (Figure 9), which allowed the parrots to modify different beats and rhythmic patterns by bending the flexible ruler. Tests with this bending ruler prototype were not satisfactory. Although the parrots were interested in interacting with the rulers, they had difficulty bending the rulers with the integrated sensors to trigger the sound. Therefore, we had to rethink the interaction concept.

Figure 9. Prototype with bending ruler

The following concept of the *reel instrument* (Figure 10) is like the DJ instrument in that it is based on an enrichment toy for creating a challenging and playful feeding process for the parrots. With this toy for physical and cognitive enrichment, the parrots must turn four wheels with their beaks to collect their treats. We equipped the four wheels with magnets that could individually activate reed switches to trigger different sounds. As previous experiments have shown [32], percussive sounds are well-received by the parrots and therefore we used drum sounds for this instrument. Each of the four wheels has been assigned a specific drum sound. By turning the wheels, the individual sounds are triggered, and turning different wheels allows the parrots to generate rhythmic drum sequences. The instrument includes a Raspberry Pi computer, an Arduino board, an amplifier, and a speaker for direct sound feedback. Some grey parrots showed interest in interacting with the device and used it. The parrots triggered different drums sounds and responded with head movements and utterances.

Figure 10. Reel instrument

In our design process, we were always careful to consider whether the musical interfaces we have developed actually have potential benefits for our grey parrots. It has been shown that the parrots have individual preferences in terms of interaction styles and sonic feedback. Since we have always worked with a group of grey parrots, we do not know what the side effects of the musical output of a single parrot, for example, when pecking on the gong instrument, might be on the rest of the group. In captivity, the parrots need environmental enrichment and cognitive challenges. Toys and foraging exercises are intended to reduce the chance of behavioral problems. Confronting the grey parrots with cognitive challenges when interacting with musical instruments could provide additional enrichment for them and help reduce behavioral problems such as feather picking, fearfulness, and aggression. Grey parrots are flock members and like to be where the action is. Thus, our approach towards developing collaborative instruments also appears adequate. In addition, our musical instruments and interfaces provide the animals with individual control over their shared sonic environment. The sonic interaction between animals, instruments, and humans can help foster social relationships, compensate for a lack of social interaction, and eventually improve the quality of life of grey parrots living in captivity through the musical activities.

PUBLIC PRESENTATION

In June 2019, we had the public presentation of the *metamusic* PEEK project at the parrot shelter of the *ARGE Papageienschutz* in Vösendorf near Vienna. The artistic research project in cooperation with the artist group *alien productions*, the *ARGE Papageienschutz* and the *Tangible Music Lab* was dedicated to the design and development of musical instruments for grey parrots over a period of three years. The event included an exhibition, various talks by experts, performances, and an installation of an aviary with seven African grey parrots. The public presentation format allowed us to focus on the various aspects of this project and led to a discussion between the audience, participating artists, and experts. The central feature of the event was an aviary installation, which was specially built for the final project presentation at the parrot home. For six days, this aviary was home to seven grey parrots of the *ARGE Papageienschutz*. They were chosen by the animal keepers to take part in this installation setting due to their interest in interacting with the instrument prototypes at the animal shelter, their health, and their partnering situation. The aviary consisted of an indoor and an outdoor area and was equipped with all the appropriate inventory and toys. The indoor area served mainly as a resting place for the parrots. The outdoor aviary (Figure 11) housed the final series of experimental musical interfaces and instruments that were adapted to the physical capabilities and sonic preferences of grey parrots.

Figure 11. Detail of outdoor aviary with instruments

The seven instruments described above plus the two test stations *swing* and *joystick* were made accessible for musical interactions. Since it was not possible in the short period of time to carry out experiments with the six individual novel instruments, we mounted all of them at the same time in the outer aviary and observed this sound installation for parrots as a whole. In general, it can be said that the parrots took some time to get used to their new living environment and factors such as the hierarchical and territorial behavior of the animals seemed to play a greater role in this new environment in comparison to the aviary where we carried out earlier tests. Particularly important was the positioning and accessibility of the instruments; depending on this, some were used frequently and others less often. The aviary was not always under observation and no data was collected on how often the individual instruments were used, but we did observe several interactions with the installed instruments. Especially two dominant grey parrots named Wittgenstein and Nepomuk were observed performing such activities. Both parrots liked to stay in the outdoor aviary and claimed a lot of space there. Others, such as Cocomiso, who usually likes to interact with instruments, showed little interest and mostly stayed in the indoor aviary. The *gong instrument*, which was familiar to the parrot Wittgenstein, was again received very well and after a few minutes she already knocked with her beak on the metal plate of the instrument. The *DJ* and *vox instruments* also worked well, for example. Both instruments were easily accessible to the parrots and aroused their interest. The *reel instrument*, which was exposed in the front of the aviary and more difficult to access, did not work as well. Since the two parrots, who liked to play with the tube instrument at the bottom of the aviary, did not participate in the presentation, this instrument was not played very often.

Part of the public presentations were performances by the artist group together with the grey parrots. In the presence of the audience, an artist and an animal keeper animated the parrots to interact with the instruments and other sound-producing artefacts with the intention of performing a musical piece. The presence of the audience had a big impact on the grey parrots, often drawing their attention away from the instruments and performers to the persons outside the aviary. In summary, as an auditory enrichment approach for grey parrots in captivity, the installation setting was more effective than the performances where the focus was shifted to interspecies curiosity between the grey parrots, the human performers, and the audience.

CONCLUSION AND FUTURE WORK

The aim of this study was to design and develop musical instruments and interfaces for grey parrots in captivity. The instruments were intended to offer cognitive and auditory enrichment and intrinsically motivate the parrots to interact with sonic artifacts. We described our animal-centered design approach towards the implementation of such technology and the possible benefits for the grey parrots.

At the final project presentation in collaboration with *ARGE Papageienschutz* and the artist group *alien productions*, we showed some outcomes of our practice-oriented and art-based research approach towards developing these novel types of musical instruments and interfaces for grey parrots living in captivity. We strongly believe there is a chance to foster relationships between grey parrots and humans by opening new creative and even artistic communication processes based on sound and music. The project could also expand the horizon of ACI and NIME research by developing musical instruments and interfaces for animals and could also provide further contributions to design concepts in this discipline, for example, in the design of interfaces for humans with reduced cognitive and physical abilities. Ultimately, we hope to identify cross-species design patterns for musical instruments through our research, which may even become relevant to human-centered design aspects.

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