

Musical Instruments for Novices: Comparing NIME, HCI and Crowdfunding Approaches

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Abstract Designing musical instruments to make performance accessible to novice musicians is a goal which long predates digital technology. However, just in the space of the past 6 years, dozens of instrument designs have been introduced in various academic venues and in commercial crowdfunding campaigns. In this paper, we draw comparisons in design, evaluation and marketing across four domains: crowdfunding campaigns on Kickstarter and Indiegogo; the New Interfaces for Musical Expression (NIME) conference; conferences in human-computer interaction (HCI); and researchers creating accessible instruments for children and adults with disabilities. We observe striking differences in approach between commercial and academic projects, with less pronounced differences between each of the academic communities. The paper concludes with general reflections on the identity and purpose of instruments for novice musicians, with suggestions for future exploration.

1 Introduction

While listening to music is a nearly universal human activity, not everyone engages in musical performance. The advent of recording and broadcast media in the 20th century reduced the barriers to music consumption, but also lessened the incentive for personal music making in the home. A survey by Nielsen Scarborough found that in 2014, 27.8 million US adults played a musical instrument, down from 29

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million in 2011.¹ A 2014 UK study by the ABRSM² found that 34% of adults currently play an instrument. Though variations in study methodology make a robust estimate difficult to obtain, it is clear that instrumental performers are a minority of the overall adult population.

While electronic technology, through music distribution, has been a contributor to the decline of amateur performance, it is also frequently proposed as an enabler. Perhaps, the argument goes, the ready availability of cheap computing power could help make musical performance more accessible to novices by reducing the traditional barriers to entry of learning a musical instrument. In place of the hundreds of hours needed to achieve basic tone production on many acoustic instruments and the thousands of hours needed to reach full proficiency, a specially-designed digital musical instrument could provide an immediately engaging experience of producing music with minimal prior training. Wessel and Wright (2002) refer to this ease of use as a “low entry fee” and propose that digital musical instruments should also place “no ceiling on virtuosity”.

The idea of new instruments making music accessible has historical roots far predating the digital era. The harmonica, autoharp and tin whistle were designed or marketed as being easy to play. The 19th century saw numerous patents for instrument adaptations designed to make them easier to play, often using keyboard mechanisms to reduce the underlying mechanical complexity of an instrument (Tresch and Dolan, 2013). At the dawn of the digital era, the 1981 Suzuki Omnichord was similarly designed for ease of use by novice musicians.

The past 30 years have seen an abundance of creative new approaches to instrument design for musical novices, many of which are described in later sections of this paper. Another approach, found in both academic and commercial settings since the 1980’s, is the *conductor system* (Mathews, 1991), where a complete piece of music is embedded within the instrument and the performer is given control over high-level features of its playback such as tempo or loudness; see Chew and McPherson (2017) for further discussion.

This paper provides a snapshot of the state of play in digital musical instrument design for novices and non-musicians. It does not aim at a comprehensive review of all such work; rather, it provides a detailed investigation of the last few years of development in four domains: commercial crowdfunding campaigns (Kickstarter and Indiegogo); the NIME conference; human-computer interaction (HCI) conferences; and the community specifically catering to individuals with physical and mental impairments. The paper examines the differences in technical, artistic and commercial approaches across these four domains and seeks to identify some of the implicit assumptions instrument developers make about musical performance. The paper concludes with thoughts on the way forward in addressing this persistently interesting topic.

¹ <https://www.statista.com/statistics/352204/number-of-people-play-musical-instrument-usa/>

² <https://gb.abrsm.org/en/making-music/4-the-statistics/>

2 Crowdfunding Campaigns

This section reviews new musical instruments released on the crowdfunding sites Kickstarter and Indiegogo.³ We searched for all completed campaigns launching new musical instruments which received at least 50,000 in funding in its local currency (dollars, pounds, euro).⁴ Any instrument for live musical performance was considered regardless of its form or who it was marketed to. Albums, performances, site-specific installations, audio effects and other music products were excluded. We identified 30 instruments meeting these criteria, summarised in Tables 1 and 2.

³ <http://kickstarter.com> and <http://indiegogo.com>

⁴ Approximate exchange rate as of January 2018: \$1 = €0.8 = £0.7. For simplicity, and because exchange rates have varied significantly over the 2012-17 period, a fixed threshold of 50k was chosen in each currency.

Table 1 Musical instruments crowd-funded on Kickstarter and Indiegogo. Date indicates when the campaign finished.

Name	Date	Raised	Type	Tagline
Artiphon Instrument 1	13/04/15	\$1.3M	MIDI multi- instrument controller	Strum a guitar, bow a violin, tap a piano, loop a beat – on a single instrument. An intuitive way to create music and play any sound.
jamstik+ the SmartGuitar	07/05/15	\$813k	Wireless MIDI guitar controller	A portable guitar that teaches you to play, sounds like any musical instrument and connects wirelessly so you can play guitar anywhere.
MI Guitar by Magic Instruments	22/06/16	\$412k	MIDI guitar controller	Anyone who has ever yearned to play a musical instrument, the MI Guitar makes it happen in minutes.
gTar: The First Guitar That Anybody Can Play	25/06/12	\$353k	MIDI guitar controller	The gTar is a fully digital guitar that enables anybody to play music quickly and easily with the help of LEDs and a docked iPhone
Oval - The First Digital HandPan	12/07/15	€349k	MIDI percussion controller	A new electronic musical instrument which allows you to play, learn and perform music using any sound you can imagine.
Spolum Drum - the musical instrument of happiness	02/08/17	\$288k	Acoustic metal drum	An instrument for relaxation, meditation, creativity, and happiness! Anyone can play it!
Dualo - The new musical instrument for all	11/05/16	€217k	MIDI isomorphic controller with synth	Experience the joy of creating your own music with one intuitive & stand alone instrument. Play and compose wherever you want.
Lumen: the Electro-Acoustic Handpan	15/05/16	\$182k	Percussion instrument with MIDI	A fully self-contained electronic percussion instrument in the form of a traditional handpan.
KordBot - Music Production Assistant	23/03/16	\$178k	MIDI button controller	KordBot is a MIDI controller that gives you 1000's of chords at the touch of a button, a powerful arpeggiator & step sequencer in one!
dadamachines: music machines for everyone!	02/05/17	€168k	MIDI actuator kit	Tap, move and bang to make sound with the world around you. Hackable & open-source!
QuNeo , 3D Multi-touch Open Source MIDI & USB Pad Controller	09/01/12	\$165k	MIDI pad controller	QuNeo is a break-through 3D pad controller for electronic musicians, digital DJs, VJs & DIY hackers providing multi-touch control.
Minim: Pocket-sized Wireless Instrument for Music Creation	29/08/15	\$145k	MIDI grid controller	Expressively control your favorite music creation apps & software. Make music anywhere with any sound, all on one instrument.
Phenol Patchable Analog Synthesizer	16/01/15	\$142k	Analog synth	An affordable patchable analog synthesizer. Create music and sound like never before with this unique instrument.
Remidi: First Wearable Instrument to Record, Play & Perform	18/03/16	\$137k	MIDI glove controller	Sensors in fingers & palm trigger custom sounds while connected wrist-controller/hand gestures control effects with reverb, echo, etc.
C.24 - The Music Keyboard for iPad	08/08/13	\$136k	portable MIDI keyboard	The C.24 is a two octave wireless music keyboard designed for iPad.
The Vo-96 Acoustic Synthesizer	13/05/13	\$120k	guitar string actuator	-
Hyve Touch Synth: Make the future of musical expression	19/04/17	\$105k	Capacitive touch synth (no MIDI)	A fun, expressive musical instrument you can make, hack and play. Build a beautiful analog synth that responds to touch and movement

Table 2 Musical instruments crowd-funded on Kickstarter and Indiegogo (continued). Date indicates when the campaign finished.

Name	Date	Raised	Type	Tagline
Mogees - Play the World	19/03/14	£96k	Contact mic with audio processing	Mogees turns the everyday objects around you into unique and powerful musical instruments. Play the world!
Joué - The most Expressive and Modular MIDI controller	15/01/17	€91k	MIDI controller	Joué is an innovative instrument simplifying digital music playing and offering a unique level of expressivity and spontaneity.
imitone : mind to melody	10/04/14	\$90k	audio-to-MIDI software	imitone lets you play any instrument with your voice.
The Motion Synth : Turn Movement into Music	19/12/13	\$75k	iOS MIDI controller app with phone case	Transform your iPhone or iPod touch into an intuitive and expressive motion-controlled musical instrument
DrumPants : An Entire Band in your Pocket	10/01/14	\$74k	Wearable MIDI controller	World's first industrial quality wearable musical instrument. Watch someone play it to believe it.
Ototo : Make Music from Anything	02/03/14	£73k	Maker PCB with synth and MIDI	Ototo is an all-in-one musical invention kit which allows you to make an instrument any way you want.
Pianu - A New Way to Play Piano	04/02/15	\$59k	MIDI roll-up keyboard	The fun of Guitar Hero combined with a real musical instrument.
K-Board Pro 4 - Smart Fabric Keyboard	21/12/16	\$57k	MIDI extended keyboard controller	K-Board Pro 4 is an expressive 4 octave MPE keyboard - a new kind of controller that feels and responds like a true musical instrument.
Musicon - Composing & Coding for ages 3 and up!	30/03/17	\$56k	physical acoustic instrument for children	-
Kurv Guitar	23/01/16	£54k	Wireless air guitar controllers	Kurv is a 'stringless' digital guitar that allows anyone to learn and play songs using touch, motion and gestures.
Skoog 2.0 : a new kind of music interface	06/02/15	£54k	tactile instrument with app and MIDI	Wireless Skoog is shipping! Available to order now from [website]
MIDIS - a new breed of musical instruments	08/07/15	€51k	modular MIDI controllers	Make music in a new and intuitive way at home, in the studio or live on stage.
HyVibe - The World's First Smart Acoustic Guitar	30/12/17	\$50k	actuated acoustic guitar	An acoustic guitar that becomes its own amplifier, connected speaker, effect processor & recorder.

2.1 Control Paradigm and Physical Form

22 of the 30 identified instruments are MIDI controllers, which produce symbolic note-level data for a separate synthesis unit. Of these 22 MIDI controllers, 4 of them (Dualo, Ototo, MI Guitar, Lumen) include a built-in hardware synth; the remaining 18 rely on external hardware or software to generate sound, though some come with companion smartphone apps. 3 of 30 instruments (Mogees; Phenol; Hyve) are analog or digital synths using some type of control other than MIDI, though Mogees also supports a MIDI mode, and it is unclear whether Lumen uses MIDI or some other protocol to communicate with its built-in synth. The remaining 5 projects are acoustic instruments (Musicon, Spolum, HyVibe) or actuators for existing acoustic instruments (Vo-96, dadamachines).

24 of the 30 instruments primarily employ note-level control wherein a single action results in a single sound, in the manner of a keyboard, drum kit or other acoustic instrument. (For those instruments which are MIDI controllers without a built-in synth, this determination was made by whether one action produces one MIDI note event.) Of the remaining 6 instruments, 3 (Kordbot, dadamachines, Musicon) use step sequencers or arpeggiators, 2 (Vo-96, Phenol) are based on continuous activation which could be used in a number of different ways, and 1 (HyVibe) is a literal acoustic guitar which could be played in various ways.

11 of 30 instruments explicitly mimic aspects of the form of an existing familiar instrument (Artiphon, jamstik, Oval, Pianu, K-Board, C.24, gTar, MI Guitar, Lumen, Kurv, HyVibe) of which one (Artiphon) is intended to mimic several instrumental forms simultaneously. Overall, 7 instruments are related at least partly to guitar playing (Artiphon, jamstik, gTar, Vo-96, MI Guitar, Kurv, HyVibe) including all four of the top-funded instruments. With the single exception of Musicon, all instruments appear to be primarily designed for solo interaction in the model of a traditional instrument, though most of them could presumably be played within an ensemble.

Some instruments (e.g. Motion Synth) explicitly encode restrictions in the pitch material, for example constraining to diatonic scales, but the nature of the music produced by these instruments is generally left open to the player. None of the 30 instruments primarily take the form of an interactive composition or a conductor system.

2.2 Marketing

The text of each crowdfunding campaign page was analysed in terms of its marketing pitch for the product. An inductive approach was used to group the marketing

into 6 clusters: *accessibility*, *versatility*, *sensitivity*, *portability*, *DIY* and *education*.⁵ The marketing for many instruments fell into more than one cluster.

16 of 30 instruments advertised their accessibility or ease of use, making this the most common marketing pitch. Some descriptions focused on immediate usability: “An intuitive way to create music and play any sound” (Artiphon); “We believe that learning music should be fun and instruments have to be made to be ready to play right away” (Oval); “Above all, it’s about everyone making beautiful music out of ordinary objects. Just plug it in and play the world” (Mogees); “Skoog removes the technical barriers to playing an instrument so that you can focus on your sound. You can be expressing yourself musically in less than a minute” (Skoog).

Other descriptions in the accessibility cluster specifically claim that people without prior experience can use the instrument: “The gTar is a fully digital guitar that makes it easy for anybody to play music, regardless of experience” (gTar); “No experience needed; anyone can just pick it up and play” (jamstik); “We believe that anyone can create music, and we want to make our instruments available to everyone” (minim); “If you can use an app, you can use the Motion Synth!” (Motion Synth); “We believe, that anyone can make music and that most of people have talent, which they don’t even know about” (Spolum).

14 of 30 instruments advertise their versatility, either in their ability to be used in many musical situations or most often, through the ability to play a wide variety of sounds: “Strum a guitar, bow a violin, tap a piano, loop a beat – on a single instrument. An intuitive way to create music and play any sound” (Artiphon); “A portable guitar that teaches you to play [and] sounds like any musical instrument” (jamstik); “A new electronic musical instrument which allows you to play, learn and perform music using any sound you can imagine” (Oval); “Make music anywhere with any sound, all on one instrument” (Minim); “lets you play any instrument with your voice” (imitone).

Interestingly, all of the instruments advertised this way are MIDI controllers, only one of which contains its own synth. Rather, the advertised feature of being able to play any sound is a function of the external MIDI synth to which they are expected to be connected.

9 of 30 instruments advertise their level of sensitivity or nuance. Instruments in this cluster tend to be targeted at least partly at experienced musicians looking for new modes of expression. “While musicians have drawn an impressive amount of creative expression out of simple switches, these limited interfaces lag far behind the possibilities for subtle control offered by modern synthesizers” (K-Board); “It responds to human touch, even your slightest finger movements give you powerful control” (Hyve); “Its an innovative and evolving instrument simplifying digital music playing and offering beginners and professional artists a unique level of expressivity and spontaneity” (Jouè).

9 of 30 instruments advertise their portability: “Play and compose wherever you want” (Dualo); “Make music anywhere with any sound, all on one instrument”

⁵ These classifications inherently involve subjective decisions on which different analysts may disagree; this analysis is intended to provide an overall sense of the marketing of musical instruments, rather than precise numerical insights.

(Minim). 4 instruments (Mogees, Ototo, Hyve, dadamachines) advertise DIY or user-constructable aspects of the instruments. 2 instruments are targeted at education; one (Pianu) at teaching a traditional instrument, the other (Musicon) at children. Two further projects (Mogees, Skoog) are also targeted partly at children.

2.3 Discussion

One of the most striking findings of this survey is the abundance of MIDI controllers (73% of the sample). Some of these take the physical form of traditional instruments, especially guitar, whereas others are “alternate” controllers (Wanderley and Depalle, 2004), but all but one (KordBot) provide control mainly on a single-note level in a manner similar to a keyboard. Novel MIDI controllers enjoyed a heyday in the 1980’s and 1990’s, but their regular use in performance seems to have coalesced around a few standard paradigms: piano-style keyboards, drum pads, grid controllers (e.g. Monome, Launchpad, Maschine), wind controllers.

Another notable finding is that many of the MIDI controllers are advertised as enabling anyone to make music, regardless of experience. What this means in practice is further discussed in Section 6, but in the case of note-level MIDI controllers, the claim should be approached with some caution. Musical performance involves skills beyond basic tone production, including rhythmic and melodic skills, which a novice may not yet have developed. It is unclear the extent to which a different geometric configuration in a controller will enable a faster learning curve than a standard keyboard; longitudinal studies on this question would be valuable.

Crowdfunding is typically used as a vehicle to launch new products which often go on to general retail or direct sale. The instruments in this sample all date from 2012 or later, corresponding to the rise of crowdfunding hardware products, and many date from the past 2 years. It is too soon to assess the sustainability of these new instruments, but it will be interesting to see whether they represent a second renaissance in MIDI controller design.

Finally, the heavy tilt toward instruments marketed to general audiences and instruments which offer MIDI keyboard-like capabilities may reflect a form of selection bias. The instruments in this section were chosen based on the most funded Kickstarter and Indiegogo campaigns. It would not be unexpected for instruments marketed to a wide generalist audience to raise more funding than those targeted to specialist or expert communities.

3 NIME

The international conference on New Interfaces for Musical Expression (NIME), which began in 2002 (with a CHI workshop of the same name held in 2001), is one of several conferences and journals where musical instrument design for novice

users has been a focus. See Blaine and Fels (2003) for a review of some of this early work and Miletto et al. (2011) for a more recent perspective. A survey of authors of NIME papers published between 2010 and 2014 (Morreale and McPherson, 2017) found that 29 of 70 author-respondents (41%) indicated that they made their instrument “for the broader public, including non-musicians.”⁶

We surveyed the NIME proceedings between 2012 and 2017, identifying work presented in the paper, poster or demo tracks which introduced new instruments targeted at non-musicians.⁷ In total, we found 31 papers over this 6-year period (out of 693 papers overall) which introduce new interfaces with the explicit purpose of being open to musical novices or general subjects. Of these 31 papers, one (Harriman, 2015) was a review paper. The papers are summarised in Tables 3 and 4.

The decision of which papers to include was made based on title, abstract and a brief review of the text; although we reviewed all papers from 2012-17, we make no claim our selection is comprehensive, and other analysts might choose a different subset. In this section, we deliberately exclude any papers pertaining to music and disability as this topic is covered in Section 5.

Papers which did not specify who an instrument was intended for were excluded from analysis; a majority of NIME papers did not provide this information, a situation that is further discussed in Section 3.3. Of the 31 papers identified as being relevant, 8 papers (Kountouras and Zannos, 2017; Becking et al., 2016; Jakobsen et al., 2016; Shapiro et al., 2016; Harriman, 2015; Trento and Serafin, 2013; Jensenius and Voldsund, 2012; Trappe, 2012) were aimed at least partly at children, of which 3 (Shapiro et al., 2016; Harriman, 2015; Trappe, 2012) were intended to teach principles of STEM (science, technology, engineering, mathematics). A further 2 papers were aimed at beginning performers of a traditional instrument (flute (Heller et al., 2017), piano (Glickman et al., 2017)). The remaining 16 papers targeted general audiences with limited musical experience. 12 of 31 NIME instruments are specifically designed for multiperson interaction, compared to only 1 of the crowdfunded instruments.

⁶ This survey question allowed multiple responses, so this does not imply that 41% of these instruments were solely or even primarily for non-musicians. For example, 58 of 70 (82%) of authors in the survey also indicated that they built the instrument “for myself,” and 20 of 70 (29%) “for musicians generally.”

⁷ Other conferences where new musical instruments are featured include the International Computer Music Conference, Sound and Music Computing, Computer Music Multidisciplinary Research, and the journals *Computer Music Journal* and the *Journal of New Music Research*. For this study, we restricted our search specifically to NIME as it is the largest such venue and one whose aesthetic and technical priorities we wished to study in contrast to HCI venues.

Table 3 Musical instruments for novices or non-musicians published in the NIME proceedings, 2015-17.

Authors	Title	Year	Type	For whom	Evaluation
F. Heller, I. Ruiz, J. Borchers	An Augmented Flute for Beginners	2017	augmented instrument with visual feedback	beginner flute players	expert and novice feedback, performance
A. van Troyer	MM-RT: A Tabletop Musical Instrument for Musical Wonderers	2017	electromagnetic actuator kit	people who are curious about music	used in performance
S. Kountouras, I. Zannos	Gestus: teaching soundscape composition and performance with a tangible interface	2017	TUI system generating sound textures	children	surveys and observations with children 6-15
T. Kitahara, S. Giraldo, R. Ramirez	JamSketch: A Drawing-based Real-time Evolutionary Improvisation Support System	2017	graphical sketching system for melody generation	novice users	informal feedback
S. Das, S. Glickman, F. Hsiao, B. Lee	Music Everywhere - Augmented Reality Piano Improvisation Learning System	2017	augmented reality piano learning system	beginner pianists	none
D. Becking, C. Steinmeier, P. Kroos	Drum-Dance-Music-Machine: Construction of a Technical Toolset for Low-Threshold Access to Collaborative Musical Performance	2016	interactive composition controlled by Kinect	young children	none
K. Jakobsen, J. Winge, M. Petersen	Hitmachine: Collective Musical Expressivity for Novices	2016	lego interface for collaborative music	novices and children	workshop with children 3-13
R. B. Shapiro, A. Kelly, M. Ahrens, R. Fiebrink	BlockyTalky: A Physical and Distributed Computer Music Toolkit for Kids	2016	modular system for algorithmic MIDI	children, as way of teaching CS	observational; 2 summer camps with children
G. Wang	Game Design for Expressive Mobile Music	2016	several mobile music apps	general public	user comments
K. Bhumber, N. Lee, B. Topp	Pendula: An Interactive Installation and Performance Environment	2016	interactive multi-person composition/installation using swings	not specified	observations during a performance
E. Benjamin, J. Altosaar	MusicMapper: Interactive 2D representations of music samples for in-browser remixing and exploration	2015	visual web app for choosing samples from a song	general public	none
J. Harriman	Start em Young: Digital Music Instruments for Education	2015	survey and ideas paper	children, as way of teaching STEM	n/a
B. Knichel, H. Reckter, P. Kiefer	resonate - a social musical installation which integrates tangible multiuser interaction	2015	audiovisual interactive multiperson installation/composition	museum visitors	user feedback
S. Lui	Generate expressive music from picture with a handmade multi-touch music table	2015	colour pixel to MIDI converter	general public	none

Table 4 Musical instruments for novices or non-musicians published in the NIME proceedings, 2012-14.

Authors	Title	Year	Type	For whom	Evaluation
D. Gabana, A. McPherson	Radear: A Tangible Spinning Music Sequencer	2014	looping drum sequencer based on physical tokens	general public	informal feedback
T. Barraclough, J. Murphy, A. Kapur	New Open-Source Interfaces for Group-Based Participatory Performance of Live Electronic Music	2014	remappable MIDI controllers	musicians of all levels	use in an installation
J. Deng, F. Lau, H. Ng, Y. Kwok, H. Chen, Y. Liu	WIJAM: A Mobile Collaborative Improvisation Platform under Master-players Paradigm	2014	multi-person MIDI note mobile app system	novice musicians playing with one master musician	none
H. Diao, Y. Zhou, C. Harte, N. Bryan-Kinns	Sketch-Based Musical Composition and Performance	2014	iPad + keyboard to draw shapes for MIDI events	general public	user study; quantitative and qualitative
Y. Nakanishi, S. Matsumura, C. Arakawa	B.O.M.B. - Beat Of Magic Box - Stand-Alone Synthesizer Using Wireless Synchronization System For Musical Session and Performance	2014	self-contained Arduino synths or MIDI controllers that link together	musicians and nonmusicians	none
C. Poepel, J. Feitsch, M. Strobel, C. Geiger	Design and Evaluation of a Gesture Controlled Singing Voice Installation	2014	video body tracking vocal synth	non-singers	user study with six subjects
S. Nam, J. Kim, B. Martinson, M. Helmuth	Musical Poi (mPoi)	2013	self-contained synth	general public	none
S. Trento, S. Serafin	Flag beat: a novel interface for rhythmic musical expression for kids	2013	rhythm pattern controller	children ages 3-5	
S. Kaneko	A Function-Oriented Interface for Music Education and Musical Expressions: "the Sound Wheel"	2013	harmonic MIDI controller	non-musicians	questionnaire with 8 adult subjects
J. Chui, Y. Tang, M. Marafa, S. Young	SoloTouch: A Capacitive Touch Controller with Lick-based Note Selector	2013	pentatonic MIDI controller	non-musicians	none
J. Buschert	Musician Maker: Play expressive music without practice	2012	restricted-scale MIDI controllers	non-musicians	none
C. Frisson, S. Dupont et al.	LoopJam: turning the dance floor into a collaborative instrumental map	2012	multi-person installation	general public	use in 3 exhibitions
A. Hansen, H. Andersen, P. Raudaskoski	Two Shared Rapid Turn Taking Sound Interfaces for Novices	2012	turn-taking instrument for pairs of people	non-musicians	comparative study with children 10-13
A. R. Jensenius, A. Voldsund	The Music Ball Project: Concept, Design, Development, Performance	2012	ball-shaped simple musical instruments	general public, including children	informal feedback
E. Shahar	SoundStrand: Composing with a Tangible Interface	2012	interactive algorithmic composition	general public	none
C. Trappe	Making Sound Synthesis Accessible to Children	2012	block-based GUI for algorithmic music	children	workshops with children 9-10
F. Zamorano	Simpletones: A System of Collaborative Physical Controllers for Novices	2012	collaborative instrument for algorithmic music	non-musicians	none

3.1 Control Paradigm and Physical Form

Compared to the crowdfunded instruments, NIME shows a wider diversity of instrumental forms and behaviours. 12 of 31 instruments are MIDI controllers or sequencers. 7 of 31 instruments are self-contained synths (1 overlap with the MIDI controllers (Nakanishi et al., 2014)). 3 of 31 (Heller et al., 2017; van Troyer, 2017; Glickman et al., 2017) are either augmented or acoustic instruments. 6 of 31 projects (van Troyer, 2017; Jakobsen et al., 2016; Shapiro et al., 2016; Barraclough et al., 2014; Diao et al., 2014; Trappe, 2012) are designed as platforms or toolkits for performers to create their own instruments.

While 24 of the 30 crowdfunded instruments featured control on an individual note level, only 6 of the NIME instruments primarily work this way. Instead, 10 of 31 projects are interactive compositions or installations, and 5 of 31 (van Troyer, 2017; Arellano and McPherson, 2014; Nakanishi et al., 2014; Trento and Serafin, 2013; Frisson et al., 2012) are based on manipulating loops. The remainder use a variety of different control metaphors, including programmable algorithmic behaviour (Shapiro et al., 2016).

15 of 31 instruments are based on tangible interaction, either through tabletops (e.g. van Troyer (2017)), interconnectable physical blocks (Jakobsen et al., 2016; Shapiro et al., 2016) or other novel physical interfaces (e.g. Nam (2013)). By contrast, 9 of 31 are screen or mobile-device based. 3 instruments (Becking et al., 2016; Poepel et al., 2014; Frisson et al., 2012) use full-body interaction while 1 (Glickman et al., 2017) involves augmented reality.

These papers were selected for their explicit focus on musical novices. Several, though not all, of the papers address the question of how to provide appropriate forms of control for this population. 6 papers seek to improve accessibility by removing the possibility for error in the form of “wrong notes” or, in some cases, timing asynchrony. The typical approach restricts the pitch material to a (usually selectable) diatonic or pentatonic scale.

Many of the instruments provide visual or tactile feedback. Within this set, 5 instruments have cross-modal mappings at their core, for example generating music from visual material (Lui, 2015; Kitahara et al., 2017) or letting the user create their own visual interface for music creation (Diao et al., 2014).

3.2 Evaluation Methods

Where crowdfunding campaigns are driven by commercial incentives, published papers tend to focus on contributions to knowledge. This means that where Kickstarter campaigns target potential customers, NIME papers are more likely to be addressed at peer researchers rather than potential users. Evaluation of new musical instruments is a persistently challenging topic, a summary of which is beyond the scope of this chapter. For a larger context of evaluation in the NIME community, see Barbosa et al. (2015), which finds that during the 2012-2014 conferences, 44%

of NIME papers included some form of evaluation (excluding those papers where evaluation was determined to be not applicable).

Of 30 papers considered here (excluding the review article (Harriman, 2015)), 8 included a systematic user study including qualitative or quantitative metrics. A further 11 papers included either informal user feedback (6 papers) or self-observations by the author from deployment in performance or installation contexts (6 papers; 1 overlap). 11 of 30 papers contained no explicit evaluation.

3.3 Discussion

While making musical experiences for non-musicians has a long history in NIME and related communities, in the 2012-17 period, only 31 of 693 papers (4.5%) explicitly focus on this question. It is possible that the topic is becoming less prevalent as time goes on, though the survey of 2010-14 authors which found that 41% built their instruments at least in part for the general public (in contrast to another category, “musicians generally”) suggests otherwise (Morreale and McPherson, 2017).

It may be that many authors simply do not indicate in their paper for whom the instrument is built, or that its usability by the general public is secondary to its suitability for experienced musicians. Just as the guitar can be suitable for both experts and non-musicians, some NIME instruments designed for experienced performers have gone on to be used by novices (Ferguson and Wanderley, 2010). More generally, unlike crowdfunding campaigns, academic papers are not intended to market the product itself. Indeed, it is notable that most of the papers in our sample have at least one other stated research goal. These include group interaction, tangible interfaces, childhood education and cross-modal mapping. In most cases, the papers focus on technical attributes of instrument design, rather than social or cultural factors that might explain how to address the needs of one particular community.

Together, these observations suggest that creating musical interfaces for non-musicians may not be the primary end unto itself in many recent papers, but rather a compelling test case for exploring other engineering and HCI research questions. The observations also mean that the selection of papers considered here may not be entirely representative, as some instruments suitable for novices could be left out if the authors did not specify the intended user community. An alternative for the present study could have been to use our own judgment about whether an interface might be suitable for non-musicians – indeed, reading many NIME papers, it seems reasonable that the device is intended for non-musicians even if the authors never specify this – but this would have introduced a different and perhaps more problematic bias than relying on the authors’ own words.

One contrast between NIME and crowdfunding that is likely to persist for any sample of NIME instruments is the frequency with which interactive compositions appear at NIME. This offers an alternative artistically-driven motivation for creating interfaces for non-musicians, though one perhaps focused more on the aesthetic pri-

orities of the creator than those of the user. The implications of creating interactive compositions as musical instruments will be discussed further in Section 6.

4 Human-Computer Interaction

The NIME conference originated as a workshop at CHI 2001 (the ACM SIGCHI Conference on Human Factors in Computing Systems), and NIME has retained links with HCI in the ensuing years (evidenced in part by the current book). Still, the values and methods in HCI need not be the same as those in the specialist community devoted to musical instruments.

In this section we review new musical instruments presented since 2012 at several high-profile ACM SIGCHI conferences in Human-Computer Interaction: Human Factors in Computing Systems (CHI), Tangible and Embodied Interaction (TEI), User Interface Software and Technology (UIST) and Creativity & Cognition (C&C).⁸ Full papers, posters, and interactive demos were considered as long as they were included in the published proceedings (including CHI Extended Abstracts). 10 papers were identified which introduce an instrument aimed at novice audiences; these are shown in Table 5.

⁸ The regional conferences OzCHI and NordiCHI were also surveyed, though no similar works were identified there.

Table 5 Musical instruments presented at relevant ACM SIGCHI conferences 2012-2017.

Authors	Title	Conference	Type	For whom	Evaluation
K. Klipfel	MIDI Motion: Interactive Music Composition Glove	TEI 2017	Hand gesture MIDI controller	not specified	none
F. Lyu, F. Tian, W. Feng, X. Cao, X.L. Zhang, G. Dai, and H. Wang	EnseWing: Creating an Instrumental Ensemble Playing Experience for Children with Limited Music Training	CHI 2017	Gesture-based conductor system	children	field study
G. Chuang, S. Wang, S. Burns, O. Shaer.	EmotiSphere: From Emotion to Music	TEI 2015	Mixed-initiative tangible installation	general public	none
N. Schnell, S. Robaszkiewicz, F. Bevilacqua, D. Schwarz	Collective Sound Checks: Exploring Intertwined Sonic and Social Affordances of Mobile Web Applications	TEI 2015	Mobile web app, triggers sounds	general public	none
B. Bengler, N. Bryan-Kinns	Designing collaborative musical experiences for broad audiences	C&C 2013	Tangible MIDI controller	general public	questionnaire and observations at a public event
G. Griffin, R. Jacob	Priming Creativity Through Improvisation on an Adaptive Musical Instrument	C&C 2013	Virtual instrument controller	general public	experimental study
A. Tanaka, B. Caramiaux, N. Schnell	MubuFunkScatShare: Gestural Energy and Shared Interactive Music	CHI 2013	Mobile-gesture controlled instrument	trained performers and novices	none
F. Morreale, R. Masu, A. De Angeli, P. Rota	The Music Room	CHI 2013	Mixed-initiative interactive installation	general public	questionnaire and observations at a public event
F. Zamorano	SimpleTones: A Collaborative Sound Controller System for Non-Musicians	CHI 2013	Tangible MIDI controller	general public	none
L. Dahl, S. Robaszkiewicz	For Novices Playing Music Together, Adding Structural Constraints Leads to Better Music and May Improve User Experience	UIST 2012	two-person screen-based instrument	non-musicians	experimental study

4.1 Objective

In 7 of 10 cases the objective of the system seems to be enabling those without musical skills to “create music and express themselves” (Chuang et al., 2015). Of these, only EmotiSphere is intended to be used individually; in 5 other cases, (Bengler and Bryan-Kinns, 2013; Morreale et al., 2013; Griffin and Jacob, 2013; Zamorano, 2013; Dahl and Robaszkiewicz, 2012), the experience of collaboratively creating music is an end unto itself, enabling people without particular musical training to experience being part of a collaborative creative musical process. The last system of this set, EnseWing (Lyu et al., 2017), is designed to offer children the experience of playing in an ensemble.

A common theme that brings together most of these 7 works is the focus on playful and social aspects of the experience, which seem more important than the musical output. SimpleTones users reported that they were *playing* rather than *performing* (Zamorano, 2013). Similarly, the visitors of The Music Room (Morreale et al., 2013) described their experience as engaging, intimate, and playful. Half of them reported feelings of being immersed in the experience and following the music rather than actually controlling it (Morreale and De Angeli, 2015). An exception is Dahl and Robaszkiewicz (2012), where musical output quality is explicitly evaluated.

The remaining three instruments are more focused on the actual performance. This is the case of MubuFunkScatShare, in which the collaborative aspect serves to enable novices to explore musical material created by musically trained performers (Tanaka et al., 2013). The focus on music performance is also present in MIDI Motion (Klipfel, 2017), whose aim is to make music performance more intuitive and less complicated for users not familiar with musical concepts, and in Collective Sound Check (Schnell et al., 2015), which aims to facilitate spontaneous collective performances.

4.2 Control Paradigm

Notably, in all 10 cases, part of the musical agency is delegated to the computer, reducing user responsibility in the process of music creation. In 3 of 10 cases (Griffin and Jacob, 2013; Zamorano, 2013; Klipfel, 2017) the user can control the sound at note level while the system encodes some sort of restrictions in the pitches that can be played: the user can only choose from a subset of the chromatic scale in an effort by the system to keep the output harmonious. By contrast, Collective Sound Check (Schnell et al., 2015) and EnseWing (Lyu et al., 2017) are conductor systems: the user does not have to worry about playing the correct pitch but can instead control rhythmic patterns and dynamics.

A different sort of constraint is employed in The Music Room (Morreale et al., 2013) and EmotiSphere (Chuang et al., 2015), both mixed-initiative interfaces in which the music is mostly composed by an algorithmic system, leaving users high-level control on the emotional character of the composition (in The Music Room the

users can deliberately influence the emotional character, whereas in EmotiSphere it is sensed through physiological sensing). The authors justify these design choices in the light of simplifying access to music creation while, at the same time, allowing users to explore and enjoy improvisation with sound in a similar fashion as trained musicians would, letting them actively participate in the social aspects of collective musical improvisation, something usually confined to trained performers (Zamorano, 2013).

Other distinct types of control are offered by Polymetros (Bengler and Bryan-Kinns, 2013), which uses a step sequencer metaphor, and MubuFunkScatShare (Tanaka et al., 2013), which allows users to manipulate pre-recorded sonic material by means of concatenative synthesis.

4.3 Evaluation

A surprising finding amongst the HCI instruments is that only half of the papers (5 of 10) contained any form of evaluation, a smaller proportion than the NIME papers (where 63% contained at least observational feedback). Given the sample sizes and the fact that many of the HCI papers are quite short (e.g. accompanying conference demos), the significance of this difference is unclear. Since NIME has frequently borrowed evaluation methods from HCI (Wanderley and Orio, 2002; Kiefer et al., 2008), this finding suggests that a bidirectional exchange of evaluation ideas might be fruitful.

More generally, the intended aim of most instruments seems to be to provide the general public with novel experiences of music-making for exploratory and experiential purposes. These goals are similar to those of many of the NIME instruments, and the approach taken in most cases could be equally at home at NIME or other music technology conferences. In fact, 6 of 10 first authors and at least one author for 7 of 10 papers have also published at NIME, including one project (Zamorano, 2013, 2012) which is published in both categories.

5 Accessible Instruments for Disability

The term ‘accessible instruments’ is often used to refer to musical instruments designed for use by disabled people. Within this category, a distinction can be drawn between accessible instruments designed to enable virtuosic or masterful performances by physically disabled musicians (here referred to as ‘performance-focused instruments’), and those designed to elicit the therapeutic or wellbeing aspects of music making for disabled people with physical and cognitive impairments and learning difficulties, who may be identified as ‘non-musicians’. Here we refer to the latter case as ‘therapeutic instruments’, referring to the design goals of enabling

musicking for wellbeing purposes, and not necessarily solely for use in formal music therapy.

While many performance-focused accessible instruments require similar learning trajectories as traditional or unadapted instruments (see David Nabb's toggle-key saxophone⁹ or John Kelly's Kellycaster guitar¹⁰), therapeutic instruments often require the ability to 'skip ahead' past the acquisition of musical and instrumental skill in order to focus on the therapeutic aspects of musical participation. In this section we discuss those accessible instruments for which ease-of-use and low barrier to music-making are a key design feature, rather than the ability to give masterful or virtuosic performances. We selected instruments based on two design criteria: enabling devices for people with physical or cognitive impairments and learning difficulties, and an explicit aim to make musical performance and participation 'easy'.

There exist a small number of reviews of and frameworks for Accessible Instrument design within NIME and related fields. Ward et al. (2017) provide a number of design principles for instruments for users with complex needs in Special Educational Needs (SEN) settings. Hunt et al. (2004) discuss topics relating to the use of music technology in music therapy settings. Larsen et al. (2016) and Graham-Knight and Tzanetakis (2015) provide reviews of existing instruments from academia and commercial products, from music therapy contexts and others.

5.1 Commercial Products

⁹ <http://www.unk.edu/academics/music/unk-one-handed-winds-program.php>

¹⁰ <http://cdm.link/2017/09/take-a-look-at-the-kellycaster-a-unique-and-accessible-instrument-built-by-dmlabs/>

Table 6 Commercially available Accessible Therapeutic Instruments

Name	Description	Marketing	Website
Soundbeam	Mid-air gesture sensing and tactile switches	Disabled people in SEN schools and orchestras	http://www.soundbeam.co.uk/
Skoog	Malleable foam cube and accompanying software	Disabled people in SEN schools and orchestras, beginner musicians, experienced electronic musicians, families	http://skoogmusic.com/
Clarion	PC/iPad software designed for use with existing AT devices	Disabled people in orchestras	https://www.openorchestras.org/instruments/
Apollo Ensemble	PC sensor-to-sound mapping software and range of hardware sensors	Disabled people in SEN settings and general music making	http://www.apolloensemble.co.uk/
Beamz	4 or 6 beam 'laser harp' and accompanying software	Disabled people in SEN and music therapy settings, general music making, experienced musicians	http://www.thebeamz.com/

We identified five commercially available products which fit our survey criteria for Accessible Therapeutic Instruments (Table 6), of which one (version 2.0 of the Skoog), was also crowdfunded (see Section 2). All five products are marketed for use by children and adults with learning disabilities or difficulties or physical impairments. They all follow a similar format, consisting of an accessible interface paired with proprietary software for sound production, either via in-software sounds or MIDI routing for use with DAWs and software instruments.

5.1.1 Form

The Soundbeam and Beamz make use of mid-air gestures to trigger events, using optical sensors (Beamz) or ultrasonic sensors (Soundbeam). The Skoog and Ensemble use tactile switches and sensors. The Skoog is a deformable foam cube with a three-dimensional position sensor at the core¹¹, allowing for simple interactions like pressing one side of the cube, or more complex ones such as shaking or twisting. Ensemble focuses on offering a broad range of interaction modes in order to adapt to a range of physical abilities. Apollo's own wireless sensor modules include switches, rotation ('Dice') and RFID sensors, but the system is designed to be used with game controllers, accessibility switches and MIDI or OSC devices. The Clarion is a PC or tablet software program that allows users to design their own on-screen note-triggering areas which can be accessed via cursor control or touchscreen interaction. It is designed to make use of existing Assistive Technology (AT) hardware such as eye gaze and head tracking devices.

5.1.2 Interaction Modes

Of the five products surveyed, two offered only note or event triggering with no additional modulation (Soundbeam and Beamz). Beamz features either four or six event triggering spaces, so is most commonly used to cycle through pre-defined note sequences or trigger samples. Moving the hand towards or away from the sensors continuously has no effect. Soundbeam allows for note selection based on proximity to the sensor, so note sequences can be improvised as well as pre-defined. Apollo and Clarion offer some continuous control over modulation: a continuous sensor such as the 'Dice' module can be mapped to a MIDI control channel in the Apollo Ensemble software, and the position of the cursor within the on-screen region can be mapped to continuous modulation in Clarion. Both Apollo and Clarion opt for user-configurability, allowing for various configurations of hardware and mappings. Skoog's Skoogmusic software allows the continuous data from the sensor to be used to modulate various software instrument's physical modelling parameters (for example overblow or harmonic effects in wind instruments). These can also be adjusted

¹¹ <https://www.soundonsound.com/reviews/skoogmusic-skoog>

and re-mapped depending on the user's motor ability, allowing for note triggering thresholds to be individual set for each side of the cube

5.1.3 Marketing and Target Audiences

Both Skoog and Beamz are marketed at wide audiences, although Skoog's promotional material places its accessibility and ease-of-use more prominently. Beamz appears to be aimed at music therapists and disabled people, but is also marketed towards musicians and people interested in interactive music applications. Apollo, Clarion and Soundbeam are more explicitly marketed towards disabled people. Four of the products included music therapy in their proposed use cases. All five products offer some form of accompanying educational material for use in schools and SEN settings.

5.2 NIME and Related Research

Table 7 Accessible Therapeutic Instruments from NIME and related research

Authors	Title	Year	Type	For whom	Evaluation
A. Nath, S. Young	VESBALL : A ball-shaped instrument for music therapy	2015	malleable foam based music controller	Autistic children using music therapy	no formal evaluation stated, work is ongoing
S. Katan, M. Grierson, R. Fiebrink	Using Interactive Machine Learning to Support Interface Development Through Workshops with Disabled People	2015	mapping several interfaces to music software using machine learning	disabled people interested in general music making	observation of users during workshops
A. Jense, H. Leeuw	WamBam : A case study in design for an electronic musical instrument for severely intellectually disabled users	2015	electronic hand-drum with vibrotactile feedback	learning disabled people using music therapy	observation of use within music therapy sessions
B. Cappelen, A. Andersson	Designing four generations of ‘Musicking Tangibles’	2014	malleable, tangible multisensory interfaces and environments	families with children with learning disabilities	participatory design/case study approach
J. Larsen, D. Overholt, T. Moeslund	The actuated guitar: Implementation and user test on children with hemiplegia	2014	electric guitar with strumming mechanism and accessible foot controller	children with hemiplegic cerebral palsy, potentially using music therapy for motor exercises	semi-structured interviews and observation of musical tasks
M. Grierson, C. Kiefer	NoiseBear: A Malleable Wireless Controller Designed In Participation with Disabled Children	2014	Malleable wireless controller for music software	autistic children in SEN settings	participatory design, observation of sessions with teacher
S. Favilla, S. Pedell	Touch Screen Collaborative Music: Designing NIME for Older People with Dementia	2014	iPad based conductor system using touchOSC and MIDI performances	older people with dementia using music therapy	observation of music therapy sessions, recording and analysis of touch screen data
D. Meekin, N. Bryan-Kinns	moosikMasheens : Music , Motion and Narrative with Young People who have Complex Needs	2013	actuated guitar, glockenspiel and drum stick with iPad interface	learning and physically disabled people in group music making SEN settings	participatory design approach, observations during music workshops
M. Luhtala, T. Kymalainen, J. Plomp	Designing a Music Performance Space for Persons with Intellectual Learning Disabilities	2011	Guitar Hero controllers for cycling through note sequences, triggering chords or note events	learning disabled people using group music therapy	observations during use in group music therapy, semi-structured interviews with users
S. Bhat	TouchTone: an electronic musical instrument for children with hemiplegic cerebral palsy	2010	keyboard based interface with pentatonic scales and large modifier button for affected limb	children with cerebral palsy using music therapy	observation of musical tasks
C. Tam, H. Schweltnus, C. Eaton et al.	Movement-to-music computer technology: A developmental play experience for children with severe physical disabilities	2007	webcam-based note/event triggering software	children with severe physical disabilities using music therapy	post-intervention analysis of interviews

This section concerns instruments coming from accessible instrument research, which both fit our ‘therapeutic instrument’ criteria and focus on ease-of-use and access for non-musicians. This is not a comprehensive survey of all accessible instrument research and NIME research related to disability, but only those papers which describe novel instruments or interfaces for disabled musicians which share similar ‘low barrier to entry’ goals as those described elsewhere in this chapter (Wessel and Wright, 2002). We include papers from other conferences and journals related to NIME, where a novel instrument or adaptation is described. These include: International Computer Music Conference (ICMC), CHI, IEEE Multimedia, Interaction Design and Children (IDC), ‘Music, Health Technology and Design’, and Occupational Therapy International

5.2.1 Form

Of the eleven papers we surveyed which fit our criteria, four described malleable, fabric based pressure sensitive interfaces (Nath and Young, 2015; Katan et al., 2015; Cappelen and Andersson, 2014; Grierson and Kiefer, 2013b), two featured actuated instruments with accessible interfaces (Larsen et al., 2014; Meckin and Bryan-kinns, 2013), two featured webcam or Kinect based interactions (Katan et al., 2015; Tam et al., 2007), one was a keyboard based controller (Bhat, 2010), another was based on a hand drum (Jense and Leeuw, 2015) and one featured a touch screen interface (Favilla and Pedell, 2014). Two describe the use of game controllers to trigger sounds (Katan et al., 2015; Luhtala et al., 2011). Katan et al. (2015) also describe using mid-air gesture sensors such as Leapmotion.

Unlike the commercially available products, instruments in this set deviated from the ‘interface plus host software’ paradigm, with half of the papers describing self-contained units with no requirement for an external speaker (not including Larsen et al.’s actuated electric guitar which is an acoustic instrument but requires external amplification).

5.2.2 Interaction Modes

Larsen et al. (2014) describe a fairly complex mode of interaction, in which users with hemiplegic cerebral palsy fret guitar strings with their unaffected limb and trigger a strumming mechanism via a foot switch. This requires a greater level of instrumental and musical skill for fretting, as the users are not constrained to only pleasing sounds and scales. The instrument is clearly aimed at non-musicians or novices however, as the strings are tuned to an open tuning to allow simple barre chords, and frets are colour coded with an accompanying colour-based score.

Only the WamBam (Jense and Leeuw, 2015) and TouchTone (Bhat, 2010) resembled traditional MIDI-controllers, with note-level control using discrete keys or switches. The moosikMasheens project (Meckin and Bryan-kinns, 2013) has a relatively simple mode of interaction, which is based on touching regions of a touch-

screen interface in order to trigger notes or sequences on the actuated acoustic instruments. Favilla and Pedell (2014) also describe a touchscreen-based interaction, using discrete on-screen buttons and X/Y pads created using the touchOSC app. These were used to trigger and modify abstract synthetic sounds, and then to modulate performance parameters of a MIDI performance of Bach's Goldberg Variations. Luhtala et al. (2011) use Guitar Hero controllers to step through note sequences, trigger pre-defined chords, or trigger notes from a pre-set scale or arpeggio.

Katan et al. (2015) describe a number of hardware interfaces including webcams, Kinects and game controllers, mapped to music software via the Interactive Machine Learning software Wekinator (Fiebrink, 2010). This allowed users to rapidly prototype various mappings and interaction modes by using Wekinator to 'learn' their preferred gestures. Wekinator is discussed further in Rebecca Fiebrink's interview in Chapter 16 of this book (Holland and Fiebrink, 2019).

5.2.3 Use Cases, Target Audiences and Evaluation

6 of 11 papers mentioned music therapy explicitly as an intended use case and method of evaluation (Nath and Young, 2015; Bhat, 2010; Tam et al., 2007; Jense and Leeuw, 2015; Favilla and Pedell, 2014; Luhtala et al., 2011). Two mentioned music therapy implicitly (as either a potential use case or a motivation for design) (Cappelen and Andersson, 2014; Larsen et al., 2014). Two were concerned with music education in SEN settings (Grierson and Kiefer, 2013b; Meckin and Bryan-kinns, 2013), while one paper was concerned with enabling general music making activities for disabled people (Katan et al., 2015).

The target audiences for these papers were predominantly children. Three papers mentioned children with learning disabilities as their target audiences (Nath and Young, 2015; Grierson and Kiefer, 2013a; Meckin and Bryan-kinns, 2013), two of which were explicitly aimed at autistic children. One paper included families with children with learning disabilities (Cappelen and Andersson, 2014). Two included children with only physical disabilities (Larsen et al., 2014; Bhat, 2010). Three papers described instruments intended for adults with learning disabilities (Katan et al., 2015; Luhtala et al., 2011; Jense and Leeuw, 2015), and one described a system for older people with dementia (Favilla and Pedell, 2014).

Most papers featured an evaluation of the instrument, which was typically based on observations during their use in music lessons or music therapy sessions (eight of eleven papers). One paper included analysis of touchscreen data captured during therapy sessions (Favilla and Pedell, 2014). Three used a participatory design case study approach for both developing the instrument and evaluation (Cappelen and Andersson, 2014; Grierson and Kiefer, 2013a; Meckin and Bryan-kinns, 2013).

5.3 Comparison of Commercial and NIME Instruments

Common to all five commercial products was the ability to play a large variety of sounds, and calibrate or configure the interface to suit a wide range of users. This reflects the fact that in music therapy and SEN settings (the markets at which these products are mostly aimed), clients or students will have a wide range of physical abilities, musical tastes, and cognitive development. For cost and practicality reasons, it would be desirable to use a single device which can be adapted to suit a user's needs. At the same time, the focus on variety of sounds is also found in other crowd-funded instruments not explicitly designed for accessibility.

Most of the five commercial devices do not use the MIDI protocol to communicate with their proprietary software, but they all follow the 'interface plus host software' paradigm: none of the instruments are restricted to any one sound scheme, and none produce sound acoustically or via inbuilt amplification. While some of the most successful performance-focused accessible instruments are bespoke designs, built for a single user's needs (for example, many of the instruments supported by the One-Handed Musical Instrument Trust's annual awards¹²), specialised devices for a single user are not feasible in many contexts in which therapeutic instruments might be used.

When comparing NIME and related research to commercially available instruments marketed for similar accessibility use cases, what is most striking is the breadth of form and interaction modality within the former group. More idiosyncratic interfaces appear within this subset, from actuated electronic instruments to interactive furniture installations with abstract shapes. This perhaps represents the results of exploratory and participatory design processes, where commercial viability is not such an issue, and discovering novel methods of improving interaction with music for this audience is a key design goal. That said, the flexibility of many of the instruments within this group is greatly reduced due to single modes of interaction and reduced sound sets. Again this could reflect the lack of a need for commercial viability, or as a result of a participatory design process for a single group with similar needs.

6 Discussion

The four preceding sections show that interest remains high in creating musical instruments aimed at non-musicians. Collectively, these papers and products represent over 80 instrument designs, most of which date from the past 6 years. Moreover, earlier references (Paradiso, 1999; Robson, 2001; Blaine and Fels, 2003) show that this goal is not a new one, so it is likely that there have been hundreds of attempts to address this particular topic in the period since real-time digital synthesis became widely available.

¹² <http://www.ohmi.org.uk/ohmi-competition-darr.html>

Comparing approaches across the four surveyed communities, the most significant contrast appears to be between commercial instruments (crowdfunded products and commercial products aimed at disabled individuals) and academic papers. Most of the commercial instruments are MIDI controllers which, whatever their physical configuration, manage musical events on a note-by-note basis, or much more rarely, on a sequence-level basis. What might be seen as a limitation of MIDI – its lack of a signature built-in sound – is framed as an advantage of versatility (“play any sound you can imagine”).

By contrast, the academic projects tend to give the performer higher-level control over precomposed or algorithmically generated material. The level of variety within each community (NIME, HCI, accessible instruments) appears to be at least as broad as any systematic difference between the communities, and there is substantial overlap in authorship between NIME and HCI communities.

These differences might be explained by the incentive structures in commercial versus academic work. Achieving commercial success requires reaching a broad audience, which may be more easily achieved with an instrument capable of generic note-level control, which makes relatively few assumptions about the kind of music the performer wants to play. By contrast, academic communities often value intellectual novelty. A new interactive paradigm, whether or not it is ultimately successful from the user’s point of view, is more likely to be publishable than a new implementation of a well-established concept.

6.1 Whose Artistry?

No music technology can be aesthetically neutral. Every instrument imposes certain assumptions about the nature of the music it creates (Magnusson, 2009; Gurevich and Treviño, 2007), a topic further discussed in Chapter 8 of this book “Material-oriented musical interactions” (Mudd, 2019). The piano keyboard assumes that music should be composed of a set of discrete events with pitch material organised in semitones. The step sequencer assumes that music should be composed of repeating patterns, typically in multiples of 4 beats. Even in the ostensibly general-purpose MIDI instruments offered on Kickstarter, the demo videos offer hints of how the designers conceptualise their musical uses, with diatonic scales and use of layered loops common.

Still, many of the instruments introduced at NIME and the HCI conferences go a step further in explicitly incorporating particular musical styles or even particular pieces into the fundamental operation of the instrument. The result are instruments low in what Jordà (2004) would term *macro-diversity* (ability to play in different styles) and *mid-diversity* (ability to play different pieces), though perhaps still high in *micro-diversity* (ability to exhibit nuances within a piece). The results might be seen as an artistic collaboration between the instrument creator and the user(s).

The balance of artistry between designer and performer would appear to be at its most extreme in the popular *Guitar Hero* and *Rock Band* series of games, where

both the audio and the sequence of buttons that must be pressed are fully precomposed. In a detailed study of these games, Miller (2009) finds that a third of players nonetheless say that the experience makes them creative, and that an online culture of performance virtuosity has emerged around the games despite the fixed audio tracks. Curiously, 74% of players in Miller's survey already play a musical instrument, with half playing guitar. This suggests that the game does not simply appeal as a way of enabling non-musicians to have the experience of making music, but may appeal to players for entirely different reasons.

6.2 Target User Communities

It is worth considering who are the target users of these instruments, and to what extent the design decisions are aligned with their skills and interests (a topic further discussed in Malloch and Wanderley (2017)). In the music and disability literature, the characteristics of the target population are often clear. For the rest, the claim that an instrument is for "everyone", frequently found in crowdfunding campaigns but also implicit in many academic papers, is encouragingly democratic but also vague from an evaluation point of view. Are the instruments primarily intended for users with musical knowledge (perhaps avid listeners) who possess no instrumental experience? Are they for music hobbyists or even experienced performers looking for something new? For complete novices with neither instrumental nor aural training?

For note-level MIDI controllers, the expectation that someone would use it to play their favourite music is predicated not only on having a command of the physical interface, but also on the experience and aural skills to put notes together into melodies and harmonies. While technical innovation could potentially make the physical actions easy to execute, musicianship also takes considerable practice, suggesting that these instruments may not be targeted at complete novices. Indeed, if the ease of producing pitched sound were the only requirement to enabling musicianship by novices, then the MIDI keyboard and the theremin would have long ago satisfied the needs of most prospective musicians.

Data on who backs a crowdfunding campaign is typically not publicly available, but it would be interesting to study whether the backers of the most popular Kickstarter instruments are new to making music or whether they are already skilled instrumentalists. Similarly, a study of the legacy of the academic instruments along the lines of Morreale and McPherson (2017), could reveal the extent to which these instruments succeeded in reaching a broad population.

6.3 Virtuosity and Style

For conductor systems and instruments featuring higher-level control of musical patterns, Blaine and Fels (2003) highlight the tradeoff whereby limited control can

improve initial ease of use while reducing the upward path to virtuosity. Jordà (2004) also addresses this topic in his metric of *instrument efficiency*, defined as the ratio of musical output complexity to control input complexity. Whether any instrument has achieved the goal set out by Wessel and Wright (2002) of a “low entry fee with no ceiling on virtuosity”, or whether this goal is even fully achievable, remains uncertain. Certainly some traditional instruments which have been marketed for their ease of use, such as the harmonica, have also been used virtuosically by skilled musicians.

A final set of questions concerns the nature of music itself. Many instruments for novices are promoted as allowing anyone to make music, but “music” is not one homogeneous entity but rather an umbrella term encompassing a huge variety of genres, styles and techniques. Few people would learn a traditional instrument to generically create music of any arbitrary style; most people are motivated to participate in particular genres, often ones they also listen to.

Yet style and genre receive comparatively little systematic attention in most papers and crowdfunding campaigns for new instruments. One might speculate that in many cases, digital instrument creators are people who have significant musical experience, perhaps being proficient at one or more traditional instruments. (A survey of the musical background of instrument builders would itself be an interesting study.) To what extent are these designers creating tools to make the kind of music they themselves are interested in?

In the case of interactive compositions, it seems evident that the designer is seeking to share their own aesthetic outlook with others (Schnell and Battier, 2002; Murray-Browne et al., 2011). But what of the simplified instruments and MIDI controllers which offer control on an individual note level? Particularly for those instruments that restrict “wrong” notes through imposing certain scales and temporal quantisation, the possible output might not be versatile enough to create music in most traditional or popular styles. In this case it is worth considering the designer’s priorities. If the quality of the musical output is the primary goal, then would the designer themselves be interested to create or listen to music with the constraints they have set up? If not, is there an implicit assumption that non-musicians would be more likely than experienced performers to want to make this kind of music? Surveys and ethnographic studies could help elucidate the expectations of would-be musical performers.

On the other hand, many instruments may not be motivated by the characteristics of the musical output at all, but rather the in-the-moment experience of the person using it. Long-term engagement might or might not be a priority. This experience-oriented approach is often most explicit in the papers around therapeutic instruments and instruments for children, but it could equally well apply to anyone, just as games such as Guitar Hero can target the general population. There is surely no single correct approach to creating new digital instruments, but clarity in design goals and target population can be helpful for potential players and fellow designers alike.

7 Conclusion

This paper has explored recent commercial and academic work on new musical instruments aimed at novices or non-musicians. The breadth of new designs over only 6 years' time shows how enticing a goal this remains for many instrument builders. We found a clear difference in approach between commercial instruments, where note-based MIDI controllers were prevalent, and academic projects, where interactive compositions and higher-level control metaphors were more common. By contrast, difference in design and evaluation strategies between NIME and HCI conferences were not self-evident, although instruments targeted for therapeutic use for individuals with disabilities followed their own set of priorities that did not entirely overlap with other instruments presented at NIME and HCI conferences.

Future study could focus on the legacy and evolution of such instruments. Crowdfunding is a venue for launching new ideas to the public. Can a similar variety of novel easy-to-play controllers be found on the shelves of established music shops, or are these projects inherently limited in duration of appeal? Do academic papers on these instruments show systematic development over time that suggests that authors are incorporating ideas from the previous literature? And for any given instrument, to what extent is it desired or expected that players would maintain a long-term engagement with it, in comparison to how long they might continue to play a traditional instrument?

The ability to perform music may best be viewed not as an engineering or societal problem to be solved, but as an open-ended creative opportunity where new ideas will always be welcome and even necessary. A reflective approach considering the breadth of previous work may in fact enhance the creativity of future designers in developing new musical outputs and creating engaging new experiences.

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