

Style and Constraint in Electronic Musical Instruments

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ABSTRACT

A qualitative study to investigate the development of style in performance with a highly constrained musical instrument is described. A new one-button instrument was designed, with which several musicians were each asked to practice and develop a solo performance. Observations of trends in attributes of these performances are detailed in relation to participants' statements in structured interviews. Participants were observed to develop stylistic variations both within the domain of activities suggested by the constraint, and by discovering non-obvious techniques through a variety of strategies. Data suggest that stylistic variations occurred in spite of perceived constraint, but also because of perceived constraint. Furthermore, participants tended to draw on unique experiences, approaches and perspectives that shaped individual performances.

Keywords

design, interaction, performance, persuasive technology

1. INTRODUCTION

This paper builds on previous work in the area of designing for style in new musical interactions. Drawing on the work of Brand and Hertzmann [1], Gurevich, Stapleton and Bennett [7] drew a distinction between style and structure. They define structure as a set of qualitative states and transitions between states that compose an interaction. Pitching a baseball for example could be described as a progression through states of grip, windup, leg kick, push-off and release. Style in this case describes the quantitative realization of that structure for a specific instance of a pitch. Variations in style will be influenced by the choice of activity within the structure – a curveball might look different than a slider – and by the particular attributes of the pitcher. They define personal style to be a pattern of similarities across different realizations that are attributable to an individual; a pitcher's style will appear to be somehow consistent from one pitch to the next, regardless of the particular pitch selection.

Gurevich, Stapleton and Bennett [7] argue that within the NIME discourse, this concept of style is more useful than the traditional discussion of expression, as it disentangles

behaviour and action (and the perception thereof) from confounding phenomena like emotion and the construction of meaning that are implied by the term *expression*. The frequently stated desire for virtuosity in NIME [3] can then be considered in terms of style; a virtuosic performer can not only realize difficult or complex structures, but can do so with a style deemed desirable. Therefore, a NIME spectator should be able to distinguish between structure and style, between what the performer is doing and how they are doing it.

1.1 Constraint

Constraint was observed to play an important role in discerning structure and style [7]. An extremely constrained interaction would make structure quite apparent to the spectator, but may limit the degree of stylistic variation. Conversely, a loosely constrained interaction might lead to a great diversity of styles but also to a difficulty in recognizing the structure underpinning a particular realization. Gurevich, Stapleton and Bennett [7] conclude by positing that designing for style can be framed in terms of identifying a level of constraint which balances these competing concerns, but without a clear indication of what constraint is or how it is achieved.

Redstrom [10] and others [2] have argued that truly "neutral" designs cannot exist; all designs steer users toward particular behaviours. In this context, constraint can be taken to mean a limitation of the variety of behaviours suggested by the design. It is important to note that we do not define constraint in terms of the number of possible actions offered by the design; this would more closely be related to the number of affordances [9]. In terms of actual affordances, one can actually accomplish a great diversity of activities with a "keyed" connector, for example. What makes a design constrained is the strong indication it gives the user of a singular method of use. In other words, constraint is defined by both the inherent physical and perceived limitations of an interface.

Additionally, we distinguish between the externally imposed constraints in an interaction and the constraints perceived by a user to be inherent in a novel design. Externally imposed constraints limit the number of interactions of a device that under normal circumstances would suggest a diversity of behaviours. For example, given a 101-key computer keyboard, which suggests a wide variety of behaviours, one could easily constrain the interaction of a user by telling them to "press the 'f' key." We are concerned with the behaviours that result spontaneously from the inherent design constraints in the absence of significant external constraint. In relation to style one would of course expect that as the number of actual affordances or possible actions an interface enables increases, so would the diversity of observed behaviours, given a sufficiently large sample size. To be

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clear, this is not the purpose of the present study. Rather, in considering constraint as a limitation on suggested behaviours and stylistic variation as related to the diversity of actual behaviours, we are interested in investigating the relationship between constraint and style, between suggested and actual behaviours.

In particular, this study looks at a case of extreme constraint: When a design attempts to steer users toward a very limited set of behaviours, what kinds of variations actually emerge, and why? This can be framed as an example of persuasive technology [4, 8], but where that field generally tries to optimize a design's ability to elicit a limited range of desired behaviours from users, we are interested in facilitating a diversity of behaviours.

To this aim, a new instrument was designed for this study, in order to ensure that there was no established performance practice or other normative convention that would act as an externally imposed constraint that might steer all or selected participants toward a distinct pattern of behaviour. Overall conditions were controlled to try to minimize explicit externally imposed constraints; the focus was primarily on constraints inherent in the design. Where external constraints were necessary in order to structure the activity assigned to the participants, we attempted to apply them uniformly.

This study is exploratory in nature. Given the previously observed relationship between style and constraint, the aim was to unpack that relationship by observing how design and human factors contribute to the development of style in performances with a highly constrained electronic musical instrument. It should be noted that this is not meant to be a case-study of an instrument design; the purpose is not to evaluate this particular device's value as a musical instrument. Rather, we use it as a means to investigate the relationship between constraint and style in a musical context.

2. METHOD

The idea of the study was to give a number of performers each an identical copy of a novel constrained electronic instrument. Participants created a short solo performance with the instrument and were subsequently interviewed in order to identify aspects of their relationship with the device, or other cognitive, social, or experiential factors that may have contributed to the development of style. The performances and interviews were videotaped and analyzed in order to compare features that contributed to stylistic variations between participants. The analysis of the qualitative data was based on a Grounded Theory [6] approach.

2.1 Instrument Design

A simple electronic musical instrument was designed specifically for the study. An obvious way to constrain a device is to limit both the number of controls and the outcomes that are mapped to those controls. We therefore tried to create a device with a minimum number of physical controls and sonic parameters, and a one-to-one mapping between them. The instrument that was created consists of an unadorned project box (10.8 x 19.0 x 3.4 cm) with a single momentary pushbutton on its top surface whose only control is the duration of a single tone. A tone of fixed pitch and amplitude sounds from a speaker embedded in the box for long as the button is pressed. Holes drilled into the box allow the sound to project from the box. The tone is generated by a simple 555 timer oscillator circuit.

We attempted to tune each copy of the instrument to the same frequency, however the nature of the 555 circuit caused the pitch vary with the charge level of the battery,

thus making it impossible to set the frequency to be exactly the same in each. At the time of performance, they were all within a two octave range centered around approximately 1kHz.¹ An LED on the box would illuminate while the button was pressed as a way to give visual feedback. Battery drain was an issue in a prototype version of the instrument. Compensating for this would have required significantly increasing the complexity of the circuit, and so a power switch was added to the side of box as a compromise.

2.2 Procedure

Participants consisted of 9 volunteer undergraduate and postgraduate music students. Each participant received one copy of the instrument and was instructed to practice with it over the period of one week. Each was told that at the end of this time, they would be asked to give a solo performance with the instrument lasting no more than two minutes. Participants were informed that they would be interviewed subsequent to the performance. No further instructions or information regarding the instrument's design or purpose were given at the time.

The performance sessions were conducted in vacant private offices in the authors' department. Apart from the performer, only the interviewer was present in the room, although the performers were aware that the sessions were being video- and audio-taped. Performers were given no directions as to their physical comportment, and all were presented the opportunity to sit, stand, or use a table surface according to their preference. The performances began once the participants felt ready to do so, and they were not instructed to stop by the interviewer; the decision to end a performance was left to the performer. The structured interview followed the conclusion of the performance. After the performance sessions, a background information questionnaire was distributed via email in order to assess the level and diversity of experience and expertise in music, improvisation and performance of each participant.

2.3 Analysis

Videos of the performances and interviews were analyzed in order to extract data based on both direct observation of the performances and participants' interview accounts. Expecting that at least some stylistic variations would be observed, the purpose of the interview was to shed light on what might have led participants to generate their particular performance realizations and to trace the differences in motivations, impressions and approaches across participants. Although specific lines of questioning were developed in order to elicit data in these categories, most of the participants volunteered a significant amount of the desired information in response to the initial question, which prompted them to describe their approach to what they had just played.

The interview addressed the following areas of interest:

1. Variations in musical content – personal performance approach taken during the improvisation, the range of material played;
2. Impressions of the instrument – initial reactions, understanding of the interface, expectations, perceived limitations or problems and previous experience with other similar instruments;
3. Variations in physical interaction – range of playing styles and physical posture;
4. Learning process – approach to practicing and level of engagement with the instrument;

¹In interviews, only one participant commented on the high pitch of the instrument. There were no observable differences between performances that correlated to the pitch height of their instrument.

1a : Observed note-silence pairs 1b : Note-silence duration matrix

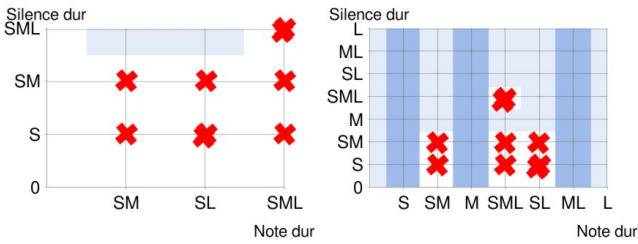


Figure 1: Note-silence durations

5. Development of skill – perceived improvement through practice and skill self-assessment;
6. Suggestions for further development of the instrument.

The video from each performance was manually inspected in an effort to identify similarities, differences and emergent themes that are present across performances. The general approach was to define a series of categories that catalogued different aspects of performance. Within each category, a set of codes classified behaviours or activities; each performance was assigned one or more codes in each category based on the presence or absence, and in some cases frequency, of the associated activity. In most categories, codes were not predetermined; that is, new observed activities would generate new codes as the analysis progressed. There were subsequently refined to consolidate similar or redundant codes. Nineteen categories were used, among which six generated the data discussed in this paper. These are: note durations, silence durations, posture, ways of holding the instrument, ways of playing the instrument and musical variations. Categories are explained below as the pertinent observations are introduced. Interview transcripts were coded using freely assigned tags. Subsequently, these were analyzed for semantic and thematic similarities, and a refined set of codes was developed. Coded transcript sections were then correlated against each other, and against performance observations in order to identify patterns and relationships across participants’ behaviours and comments.

3. OBSERVATIONS

The following section describes observations of performance and interview data and relates these onto the concepts of style and constraint as defined above. The two kinds of data are presented side-by-side in order to examine how participants’ accounts of their experiences with the instrument may relate to how they played.

3.1 Style within the Constraints of the Instrument

In the narrowest view of the interactions enabled by the instrument, the performer can control onset and offset durations by pressing and releasing the button. We can therefore consider the musical results in terms of two parameters: note durations and silence durations. The diversity of note and silence durations is one way to consider stylistic variation between performers; a performer that plays exclusively short notes with long silences in between has a different style as one who plays only long notes interspersed with very short silences. Based on observed trends in the performances, we classified both note and silence durations into three categories: Short (<1 s), Medium (1-3 s), and Long (>3 s). Performances were then classified based on the presence or absence of notes and silences of each duration class. For each of note durations and silence durations there are therefore 7 different possible permutations. Of these, only

3 were observed for both note and silence durations among the 9 performances.

Note durations: **SM, SL, SML**

Silence durations: **S, SM, SML**

We can therefore classify each performance in terms of the pair {Note,Silence}, where each element represents the set of note and silence durations observed in that performance. This leads to a total of 49 possible pairs that could characterize each performance. As Figure 1a shows, among the 9 performances, 7 unique {Note,Silence} pairs were observed, indicating a high degree of stylistic diversity between the performers. However, Figure 1b indicates that these performances were concentrated into a narrow region of the overall set of possibilities. There is a definite tendency toward both short note and silence durations and a clear avoidance of exclusively long and medium/long notes and silences. The avoidance of long notes is evident also in the interview data; when asked their initial impressions of the instrument, 4 participants described the sound of the instrument as monotonous or static, one indicated that it was excessively loud. According to another, “let’s say that if you play it for too long, well... it’s not very pleasant.”

While the presence of long silences was low – only two made use of them during their performance – one performer described the deliberate use of silence as a stylistic choice that creates more musical possibilities: “You’ve been playing a lot and then all of sudden you drop out or you’ve been playing something rhythmic and then you drop out. Then you’re setting up this situation where’s there a lot of room to play around.” We suspect that for most participants, the externally imposed constraint of the performance context had significant influence on the trend toward short silences. The context of the experiment likely led participants to focus on playing the device, rather than not playing it; they were instructed to confine performances to within 2 minutes, and hence the lack of long silences.

Three significant trends therefore emerged from the analysis of note and silence durations. First, the limited distribution of {Note,Silence} pairs and specifically the tendency away from long notes, indicates that an extremely constrained design can steer users toward a normative style of use, as is to be expected. However, within this region, we observed very little overlap in styles, suggesting that individual performers’ contributions based on their particular experience, motivations and choices led to individualized realizations. Finally, we expect that however minimal, externally imposed constraints on the structure of the interaction (in this case the duration and context of the performance) also contribute to trends in user behaviour.

3.2 Diversity of Behaviour

A normative style of use can further be seen if we look at attributes of the performances beyond note and silence durations. Four other categories of variation were annotated and coded: *postures, ways of holding the instrument, ways of playing the instrument and musical variations.* **Posture** was coded in terms of spine angle, foot position, arm position, elbow position and choice of sitting or standing. Among these, 2 variations were observed in each class for a total of 10 codes. Although no participants elected to stand during their performance, it was available as an option and therefore we include it in the analysis. **Ways of holding** the instrument referred to the position of the instrument in the hands and around the body. Here, 7 variations were observed, as indicated in Table 1.

Ways of playing the instrument describe physical engagements that directly led to sound production or modification. Most of the codes in this category, also listed in

Table 1: Categories and codes

Posture	Ways of holding	Ways of playing	Musical variations
Sitting down	Box on table	Button press with finger	Rhythmic beeping
Straight back	Box on lap	Button press with thumb	Arrhythmic beeping
Leaning forward	One-handed	Finger tap on box	Rhythmic tapping
Arms to side	Two-handed	Thumb tap on box	Arrhythmic tapping
Arms projected	Held by length	Hand tap on box	Sound filtering
Elbows free	Held by width	Manual filtering	Mechanical noise
Elbows resting on lap	Box rotated on any axis	Spatialization	Simultaneous events
Both feet flat on floor	-	Use of power switch	-
Legs crossed	-	Compound gestures	-
Standing up	-	-	-

Table 1, are self-explanatory. **Compound gestures** refers to the use of more than one simultaneous way of playing. This code is only assigned when one or more technique is used at the same time, in order to differentiate this practice from the sequential employment of different ways of playing. **Musical variations** describe the diversity of sonic results achieved in terms other than note and silence durations, including exploitation of mechanical noise of the button, rhythmic elements and manually filtering the sound emanating from the speaker with one hand. **Rhythmic playing** was ascribed when sound events were organized with an audible pulse; **arrhythmic playing** was ascribed when no pulse could be detected. **Simultaneous events** refers to multiple musical variations occurring at the same time, for example tapping the box while playing beeps with the button. **Musical variations** are distinct from ways of playing in that some variations can be achieved through multiple ways of playing. Similarly, some ways of playing can lead to different musical results. As explained previously, codes were assigned when the associated activity was present at least once during the performance; multiple codes could be assigned to each performance.

Figure 2 shows the frequency distributions for posture, ways of holding, ways of playing and musical variation, with the x-axis ordered from most-to-least frequent behaviours. All four resemble a roughly exponential decay, indicating that there is a tendency toward a normative overall playing approach characterized by two or three frequent behaviours, with divergent styles appearing less frequently. We expect that as the sample size increases, the tails would grow longer as more performers introduced personal variations, but that we would also see further consolidation in the region of “normal” activity.

In comparing these other performance attributes to note-silence durations, some interesting correlations emerged. The activity of manual filtering occurred in 5 performances. All of these performances were among the 7 that included long note durations. That is, in all but two performance with long notes, the performers manually attenuated or filtered the sound of the instrument. Among these, 4 variously described the sound of the instrument as “monotonous,” “static,” “loud,” or having “limited... musical dynamics”. The 5th performer who employed this technique specifically mentioned manual filtering as a method of introducing variation to the static sound of longer notes: “...at first I only sustained the tone, left it pressed and after awhile tried to vary it in some way. And the way I did that was to dampen the speaker.” Of the 2 participants who played long notes but did not manually dampen the sound during performance, one described discovering the technique during rehearsal but rejecting it before his performance: “And then with... doing like muffling it just to see, you know... it just sort of went ‘wah wah wah.’”

The observed correlation between notes of long duration and manual filtering suggests that some users can find “hidden affordances” [5] to overcome a perceived constraint of the interface. In the case of one participant quoted above, manual filtering (described as “dampening”) was discovered as a way of realizing the desire to introduce variation to the

static sound. Another participant who used manual filtering had a similar reaction, but to the overall simplicity of the interface rather than any limitation in particular. This participant quite literally thought the instrument had hidden affordances: “*Its simplicity made me think that there was something I was missing. So it made me, you know, wonder what I was missing. And then I realised there wasn’t.*” He reiterated this idea later in the interview, this time suggesting the monotony was a source of limitation: “*I kind of knew that it had only one sound, but I thought that there was something else to it that I was kind of missing...*”

Some of these non-obvious affordances were a result of mechanical noise in the button, as reflected in the ways of playing and musical variations listed in Table 1. When the button was partly depressed, this noise caused a chaotic sound from the oscillator circuit. Other timbral effects could be achieved by turning on and off the power switch with the button depressed. Several participants explored the conditions under which these sounds could be achieved, exploiting and incorporating them into their practice; others acknowledged the possibility but stayed within the bounds of the perceived constraint during their performances.

3.3 Approaches to Practice

Participants tended to describe their approach to performance in terms of their evolving relationship with the instrument through practice. Most participants were initially struck by a sense of limitation of possibilities, indicating that the intended constraint of the design effectively steered them toward a limited set of behaviours. A diversity of strategies emerged through which some performers overcame the apparent constraint.

The sense of “*something missing*” expressed previously is also described by nearly half of the performers. This group of participants commented that when they first received the instrument they believed it would do “*more complex things.*” The expectation these performers had about the instrument was unfulfilled; during their practice with the device, they began noticing the limitations of the interface. Some participants effectively stopped exploring the instrument at this stage and elected to operate entirely within the immediately apparent constraint. One participant said, “*It just has that one sound it makes and the one way to trigger it.*” The limitations of the instrument discouraged these performers from further exploration.

Other participants approached the constraints in terms of specific aims or problems to be solved. The aforementioned techniques of manual filtering and spatialization were realized when the performers encountered a particular problem, “*running out of patterns,*” or “*I discovered the envelope thing [manual filtering] because I tried to make the volume softer. At first the volume seemed too loud to me and then I covered it to make it less loud. I mean, I realized that it could be another musical parameter.*” In a similar fashion, several participants mentioned that by moving the instrument in space, they attempted to achieve another type of variation in sound: “*And then practicing another, like another type that with that limitation can achieve another sound. Either not having the sound directed towards me, but trying to vary it, covering it, moving it [moves box around] basically.*” A second case involves a similar type of exploration: “*I tried rotating it to get different sounds across my face... And rotating it came from running out of patterns. And so I thought ‘I need to do something different.’”* This group of performers saw the limitations of the instrument as problems to be solved which in turn led them into alternative ways of interacting with the instrument.

Some participants discovered ways of operating the in-

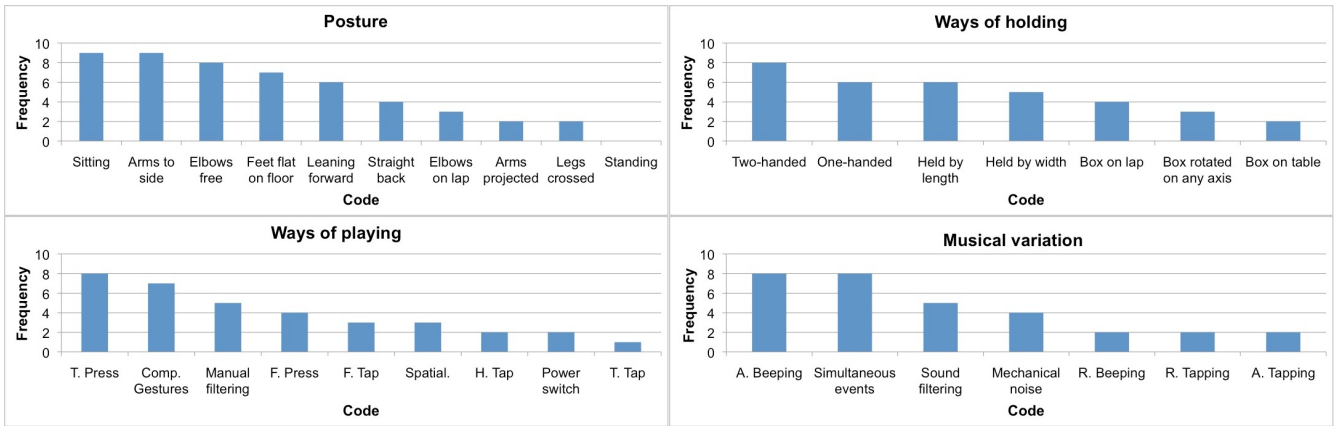


Figure 2: Code frequency distributions

strument outside of initially perceived constraints, but viewed these as an insufficient means to achieve satisfying results. This opinion is exemplified by one participant’s comment: “I tried changing – trying to close it to change the volume or something like that – trying to dampen it like this [puts hand over speaker] to see if it could do anything else. But it seemed that it didn’t – it didn’t do much. It’s like a very pure tone, so it wasn’t possible to do much – much change.” He continued, “It seems to me like it does [have limitations], of course. Because it does not have any height [in pitch], nor dynamics, nor any other sort of variation.”

Despite the fact that many performers ascribed a sense of simplicity and/or limitation to the instrument, a select few were undeterred and expressed that they were able to find valuable musical potential. Unlike the previous group of participants, their explorations weren’t bounded by specific goals or problems. The instrument became a rich platform for exploration and the discovery of diverse musical and interaction possibilities. As noted by one, “I find limitations being a good thing. And you know the idea is you could sort of make something musical out of anything, it’s an attractive aesthetic I guess... It’s definitely a rich environment... I was sort of sceptical initially, but... right away, I was actually ‘you could do this, you could do that.’” Among them, two distinct approaches emerged from the observational data. We describe them in terms of a vertical versus horizontal approach.

In the vertical approach, participants described identifying a new technique and attempting to exhaust all of its musical potential, until something else emerged. One performer commented, “I like to explore during the performance... and so starting to just do something rhythmic and then I noticed there’s this kind of flaw or something like that [plays instruments]... so I thought ‘that’s something to exploit.’ So the instrument sort of led me to the next [musical event].” When unexpected affordances arose, they were capitalized upon and further incorporated into practice, but these participants described no intentional search for new possibilities: “It just sort of revealed itself. The first thing... well when you look ‘oh, that’s a button,’ so just means I have to do something pulsed. Then I noticed, and I don’t know if it was intentional or not, but those little flaws and stuff, that noisiness that helped a lot. So I can actually change timbre a little bit.”

In the horizontal approach, participants attempted to enumerate all the possibilities or affordances of the instrument. Performers exhibiting this behaviour described exploring as many different ways of physical interaction and musical content possible. This approach is embodied by one performer who said, “... it no longer goes ‘beep’ ...

Table 2: Total ways of playing/musical variations

ID	Total ways of playing	Total musical variations
1*	7	5
2	5	4
3	5	4
4	4	3
5	4	3
6	3	5
7	3	3
8	3	1
9*	1	3

let’s hit it, bite it, or let’s throw it around. I was like ‘what to do, what to do?’ Afterwards I said, ‘How is it that I can’t get anything else from it!? Well, today I will not play beep but I will only hit it.’” Once a new way of interacting with the instrument was discovered, there was a need to pursue another one. This participant seemed to conceptually separate activities that were “by design” from unintended ones, although all were fair game in performance: “I discovered that there were small things that were not part of that sound and that maybe were not the same... they’re not of the same principle of the box. I’m talking about its purpose [plays and sings the pitch]. Well, before doing that there were some other sounds that are not perceived... and you would listen to a ‘crick, crack, crick’ and that I think can be exploited.”

The two participants whose previous comments exemplified the vertical and horizontal explorative approaches also stand out clearly in their performance data, specifically in the numbers of ways of playing and musical variations. As seen in Table 2, these individuals represent the two extremes of the set in terms of the total number of ways of playing.

Participant ID 1 had the most different ways of playing, as well as the highest number of total musical variations of all participants. Several changes of posture and of ways of holding the instrument were apparent during the performance as well. This is the participant quoted above with regard to the horizontal approach. In contrast, participant ID 9 exemplified the vertical approach in describing his practice. While this is the only participant who performed with just a single way of playing, his total number of musical variations is close to the average (3.44). This participant similarly showed no changes in posture or in the ways of holding the instrument during the performance. He described “mastery” as a priority, and appeared to only discover some techniques that were common among other participants during the interview: “Or if I wanted to master this sort of spatialization technique... that you could do with a violin or a clarinet or you experiment with it. You know, let’s see, oh I never ooh! [dampens speaker] I never really tried the vibrato.”

Although these performers had radically different

approaches, they were unified by their distinctly exploratory attitude. This would seem to be corroborated by their self assessments of skill; they assigned themselves the two lowest ratings of the group, scores of 1 and 2 on a scale of 1-5. Participant ID 1's explanations for this rating reflected a need for further exploration and discovery in order to improve: "2... Because to be an expert I would need more time, perhaps... because you can always do something else, something different." Participant ID 9 similarly commented on time investment but suggested that technical mastery is not the only component to skill. He gave himself a score of "1 for sure. A complete beginner. I think there's a level of competency I think you can develop [but] the rest is more a matter of musicality."

Both of these participants were clearly undeterred by the constraint of the interface. When presented with an instrument with very few controls that was expected to steer them toward a single mode of operation, neither thought that they had exhausted its potential even after a week of practice. This is a stark contrast to the sole performer who gave himself the highest skill rating, saying, "If a master is a person who can turn this on and press it, then, let's say [I'm a] 5." Participants 1 and 9 furthermore reflected radically different styles in performance: one focusing on a single activity, the other on a diversity of techniques. This further reinforces a personal contribution to style; what these performers brought to the interaction was as significant, if not more so, than the instrument itself in determining their playing styles. However, we propose that the very fact that the instrument was so constrained helped to make space for this personal element to emerge.

Other participants described additional ways in which their personal experience or attitude influenced their approach, and ultimately their particular style. The transfer of skill from other instruments was one such factor. One described that his approach to dealing with constraint was primarily influenced by the way in which he plays his primary instrument: "The one sound, I saw as a limitation. It's not the end of the world, especially for a drummer. You don't need those melodies too much."

3.4 Explicit Assessments of Constraint

At the very end of the interview, participants were asked to describe how they would change the instrument. Most responses were either framed in terms of sound (variation of frequency, timbre and volume) or control (add more buttons, introduce sliders). Surprisingly, several performers expressed an appreciation of the simplicity of the interface. Because of this they did not want to drastically change the instrument and commented that a minor change or addition, such as volume or frequency control, would suffice to substantially increase the musical possibilities of the instrument. One participant said, "I like the simplicity of it. I think it would be neat if it had some sort of velocity sensitivity or something like that... I like the idea of the one-button thing... I would make it something in the touch... If touch controlled timbre... but just with that one button."

4. CONCLUSIONS AND FUTURE WORK

We have observed that performers were able to achieve a significant degree of stylistic diversity with a constrained musical instrument. In analysis of patterns of variation across a number of performance attributes, a normative style emerged with the distribution of variations appearing to decay roughly exponentially. Stylistic variation was manifested within the constraints of the instrument, by developing variations using the immediately apparent affordances of the instrument. A different kind of variation

emerged through exploration of "non-obvious" affordances. This emerged in some participants as an explicit response to perceived problems presented by the constraint. Others sought to explore all the possibilities the instrument made available. To this end, participants used diverse approaches and achieved significantly varied results. This suggests that the individual approaches and attitudes of performers contribute significantly to the development of style. With a constrained instrument, we have observed that performers developed stylistic variations both in spite of and because of the constrained design.

The implication that the performer's contribution to the interaction is an important factor in style should not be surprising, but it provides an opportunity to reflect back on the concept of virtuosity. There has been a tendency to describe the potential for virtuosity in terms of properties of the device [11], but our data shows that some performers see enormous potential in "simple-to-use" devices. One participant even stated, "there are always people that can achieve a greater level of virtuosity with a given instrument, simple or complex as it might be." Other participants certainly did reflect on exhausting the musical potential of the instrument, and therefore while stylistic diversity was developed with the instrument in this study, it may not prove to be meaningful for spectators in a musical context. However, the participants tended to suggest that it would only take a very small amount of increased complexity in order to effect a significant increase in the diversity of activities and musical potential.

This study examined the relationship between constraint and style on the part of performers, but did not look at the effects on spectators' ability to recognize style or structure. A follow-on study will therefore elicit spectator perceptions of style and structure when watching performances with a constrained interface. Future experiments will also look at the development of style with less constrained instruments.

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