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Examination of a MIDI Wind Controller for use in wind performance research

Laura A. Stambaugh

Georgia Southern University

ABSTRACT: MIDI wind controllers (MWCs) have existed for over 20 years, but their use as a tool in wind instrument research has received little attention. The purpose of this investigation was to examine the validity and practicality of using an MWC in wind performance research. Validity was examined by determining the consistency between performances on an MWC and on a clarinet or saxophone. Practicality was assessed by determining the duration of practice time by single reed players on an MWC. Following a pilot study involving four clarinettists and two saxophonists, nine participants practised and performed warm-ups, scales, and a melodic excerpt on an MWC for four days. Performances were analysed for warm-up time, practice time, pitch accuracy, and duration. Warm-up and practice times were reasonable relative to total study session durations. Results indicated MWCs are a practical and valid proxy in research for saxophonists. For clarinettists without saxophone experience, appropriate musical tasks are limited to playing passages in the key of C. Areas of research that could benefit from the use of MWCs are dynamics, micro-timing, and music-motor learning.

KEY WORDS: MIDI, wind controller, wind instrument, contextual interference, practice

Wind instruments reflect the time period they were constructed in, from the simple bone flutes of prehistoric times, to the MIDI wind controllers of the current digital age. The development of the MIDI keyboard about 20 years ago represents the earliest use of MIDI technology (MIDI Manufacturer's Association, n.d.). At that time, Wilson (1992) challenged the music research community to use new technologies as tools for exploring aspects of expert piano performance and instrumental skills. It has since become commonplace to use MIDI keyboards in research on piano performance and motor skills in music-making. Although MWCs were also developed at that time, they remain largely unexamined as a tool for research on the playing of wind instruments. The purpose of the present study was to determine the extent to which MWCs can be useful in research on wind performance. While applied research is "usually conducted to effect positive and immediate results for a

particular person or situation" (Madsen & Madsen, 1997, p. 17), the present study is intended to inform future research and is therefore more closely aligned to basic research, the findings of which can have implications for practice.

The most widely used MWCs are manufactured by Akai and Yamaha. They use a recorder or saxophone/clarinet style mouthpiece with a manufacturer-designed synthetic reed. Measuring about 600 mm/24 inches long, they weigh approximately 520 grams/1.2 pounds. The key configuration is Boehm-system and can be set to saxophone or flute fingerings. A true electronic instrument, the MWC generates no tone but is connected instead to a sound-generating module. For research purposes, the controller and the module need to be connected to computer software, which records the digital performance data. When using an MWC in this way, the researcher can collect data about pitch, duration and breath pressure (volume).

A starting point for determining the extent to which MWCs are suitable tools for research is to examine how MIDI keyboards became accepted by researchers on piano performance. Salmon and Newmark (1989) saw the potential for MIDI performance data to be used as a way of discriminating between performers and "[to] provide information otherwise undetectable to performer or listener" (p. 25). Furthermore, they found that it was possible to export MIDI data files into other software programs for statistical analysis. They concluded that MIDI technology offered a high level of timing resolution, multiple data sources could be recorded simultaneously for multiple variables, and post-recording options included playback, transcription, and statistical analysis. In the same year, Lee (1989) showed that it was possible to use a MIDI keyboard and computer to measure pitch, duration, articulation, and dynamics. In addition it could be used to diagnose performance problems and measure subsequent changes more objectively than by ear.

An early example of the use of MIDI data to reveal subtle differences between performers was reported by Palmer (1989b). Six pianists performed an excerpt from a Mozart piano sonata, recording MIDI data in milliseconds so that the researchers could analyse differences between performers in terms of timing asynchronies, patterns of rubato, and articulation. Wilson (1992) explored pitch, duration, and articulation in MIDI output from repeated performances by pianists. When a second expert performed the same tasks, MIDI output revealed subtle differences between the performances of the two pianists.

While many studies using MIDI output examined keyboard performance, few studies have used MWCs to learn about wind instrument performance. The Yamaha WX5 has a saxophone-style mouthpiece with a synthetic reed, allowing the performer to adjust intonation by changing jaw pressure on the reed. Guillemain, Kergomard, and Voinier (2005) explored this aspect of performance, as well as breath pressure, which is used to vary dynamics. Scavone and da Silva (2005) investigated the use of breath pressure particularly in extended techniques such as flutter tonguing on several electronic wind instruments. More recently, the Yamaha WX5 was used by Barthet, Guillemain, Kronland-Martinet, and Ystad (2010) to generate stimulus tones for a study of perception. This limited body of work has begun to explore how MWCs may be applied in perceptual and theoretical paradigms. However, there are compelling reasons for examining other aspects of MWCs in order to identify their potential for behavioural research.

First, computer-monitored musical instruments can be used to collect objective data, uncontaminated by the inevitable, albeit unintentional, perceptual biases of human beings (Large, 1993; Lee, 1989). Second, the resolution of MIDI data enables measurement to be undertaken at levels that would be impossible by listening alone. The software used in the present study, Cubase LE4, has a temporal resolution of .001 seconds and can be set to a resolution of 24-960 pulses per crotchet (quarter note). Third, MWCs collect data for parameters such as breath pressure that cannot be measured in conventional wind performance. While other tools measure loudness in decibels, air speed can serve as a proxy for dynamics. Breath pressure also functions as a 'cushion' for tone production, and the MWC could be a valuable feedback tool for showing developing performers when their use of air speed is inconsistent.

Fourth, sequencing software used in conjunction with MWCs provides a rich array of information about performance in both numeric and graphic formats. Individual pitches can be named or indicated by frequency, and duration is indicated in milliseconds. These pitches can then be compared with the printed music score (Salmon & Newmark, 1989). Graphic computer outputs enable analyses to be performed in ways not available with conventional methods. Palmer (1989a) noted that analysis using traditionally notated music "cannot display the number of dimensions or the precision of each dimension adequately for research on musical performance" (p. 266) but graphic outputs permit multiple, concurrent excerpts to be compared, temporally evolving performance to be represented in its entirety, and details of performance that are not easily heard to be examined. Finally, data generated by MWCs take much less time to prepare for analysis than acoustic sound files. In research on wind performance using conventional methods involving the 'scoring' of performances, the sound files must first be randomised. Next, expert listeners must be trained to use the scoring criteria. Then they have to listen repeatedly to each performance so as to achieve the highest possible level of accuracy, and the researcher must determine the reliability of scorers' reports. When studies are based on the scoring of thousands of acoustic files (e.g., Stambaugh, 2011, 2013), this is a very time-consuming process. As we have seen, sequencing software generates lists of numbers representing pitch, duration, and dynamics in numerical formats, significantly reducing researchers' labour time.

The purpose of the present study was to examine the validity and practicality of using an MWC in research on wind performance. It addressed four questions informed by the process of validating MIDI methods for research on keyboard performance and by the specific needs of research on wind performance.

1) How long does it take for a single-reed player to adapt to using an MWC and what does the adaptation involve?

2) Which musical parameters can be measured reliably using an MWC?

3) Can data generated by an MWC be used to discriminate subtle performance nuances, and if so, which ones?

4) To what extent can performance on an MWC substitute for performance on a saxophone or clarinet?

METHOD: PILOT STUDY

Design

The pilot study was designed to test the materials, apparatus and procedure to be used in the main study. Comparison would be made of clarinettists' and saxophonists' performances on their own familiar acoustic instruments and on the unfamiliar MWC, to examine the following parameters: adaptation to the MWC (i.e., length of time used for warming up and practising), accuracy (measured by the number and type of errors made), and length of time taken to play a musical excerpt. Breath pressure (loudness) would also be examined but is not reported for the pilot study.

Participants

First, two participants, an oboist (the researcher) and a professional saxophonist, played the Yamaha WX5 to generate the tasks to be used in the pilot study. Next, six pilot participants were recruited: undergraduate and postgraduate music majors (median age 22 years, range 19-31) at a large university in the southeast United States. Four of the participants were clarinettists (three female, one male); the other two were saxophonists (both male). They all gave their informed consent to take part in the study.

Materials and Apparatus

The Yamaha WX5 MIDI Wind Controller was used in this study. It retails for about 700 US dollars. It has two styles of mouthpiece: clarinet/saxophone with a composite reed, and recorder. Although it is lightweight, it has a neck strap. It can be powered by an AC adaptor, batteries, or phantom power. Several performance parameters may be adjusted, including sensitivity to jaw pressure, sensitivity to wind pressure, and fingering mode (three saxophone systems and one flute system). The most obvious difference between the way the keys are set up on the WX5 and on the conventional clarinet or saxophone is that the WX5 has four octave keys operated by the left thumb (see Figure 1) and fewer keys played by the little fingers than a clarinet. While the WX5 is MIDI-compatible in that it can be connected to any MIDI device, it was connected in the present study to a virtual acoustic tone generator, the Yamaha VL70-m. This was connected in turn to a MacBook Pro laptop using a USB MIDI Interface (UM-1G from Cakewalk, which retails for about 40 US dollars) running Cubase LE4. In both the pilot study and the main study, the tone generator was set to the 'AirSax' sound.
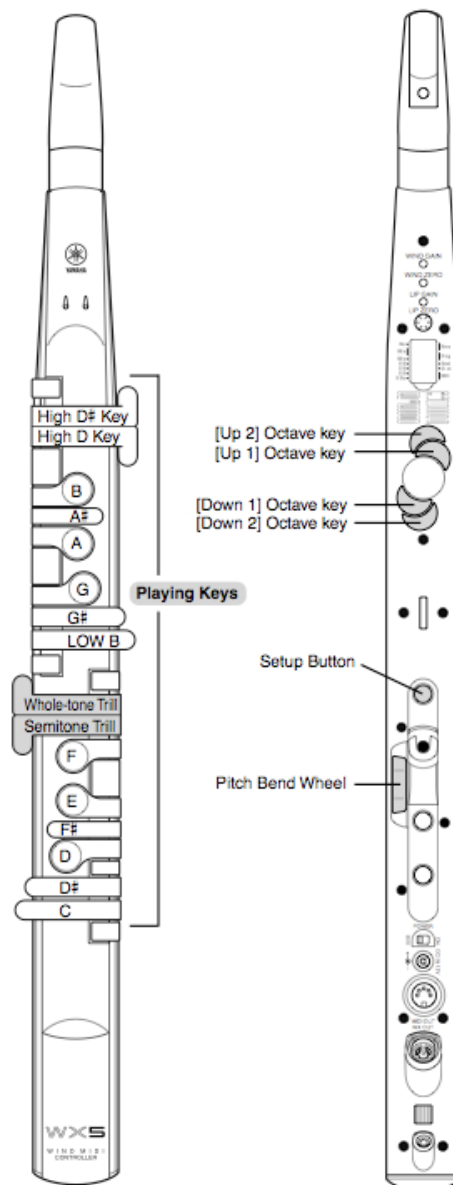
Figure 1. Yamaha WX5 Fingering Chart (Yamaha, 1998), p.12.

The first playing tasks were to warm up by playing a series of minims (half notes) at various dynamics to familiarise participants with the feel of the embouchure and wind resistance, and octave leaps to gain facility with the left-hand octave keys. The second set of playing tasks consisted of three scales in two octaves, up and down, starting on C4, D4 and E flat 4 at 88 beats per minute (bpm) using the rhythm shown in Figure 2. C major was chosen because it uses the simplest fingering pattern; E flat major because it has flats, necessitating the use of right- and left-hand side keys, and left-hand palm keys in its extended range; and A major because it has sharps and uses left-hand side keys.

Figure 2. The rhythm of the scale participants were asked to play at 88 bpm.

Instrumentalists must be able to play more than scales, so a brief musical excerpt was chosen as the third task (see Figure 3, the Violin I part from Mozart's Divertimento No. I, K. 136). As this work was composed for a string instrument, it was unlikely to be familiar to the wind players. The excerpt uses note-values from semibreves (whole notes) and minims (half notes) to semiquavers (sixteenth notes). Some fingerings would be consistent with and others would be different from those used traditionally when playing the clarinet and saxophone.

Figure 3. Excerpt as performed in pilot study.

Procedure

Participants played both their acoustic instrument and the MWC in the course of a session lasting about 45 minutes. To control for order effects, half of the participants in each instrument group were asked to perform on their acoustic instrument first and the other half on the MWC first. They were provided with headphones for use with the MWC. The researcher showed participants how to hold the MWC, produce a sound, and read the fingering chart. Next, they spent as much time as they desired on the warm-up minims and octave leaps. They then practised the C, E flat, and A scales until they could play each scale at 88bpm. Finally, they were asked to practice the excerpt in any manner of their choosing until they could play it "as well as possible, including pitch, rhythm and dynamics." They were then asked to perform it. The part of the session in which they played the MWC was recorded as one continuous file in Cubase LE4. The researcher was present in the room but could not hear the sound of the MWC performance through the participants' headphones.

The procedure was the same when participants played their saxophone or clarinet, except that they began warming up without preliminaries. The range of the instrument is such that saxophonists could play only the upper octave of the A scale (this was addressed in the main study). The part of the session in which participants played their acoustic instruments was recorded using a QC1 microphone with Audacity software.

Scoring

A timeline was created for each sound file identifying the times when warming up, practising and performing each scale and excerpt began and ended. Each segment of the timeline (e.g., practice time for C scale, including pauses and repetitions while practising) was highlighted in Cubase or Audacity, and the internal timer in the software was used to calculate the duration of the segment to .01 of a second. The duration of each performance task (e.g., the performance of the C scale) was measured from the onset of the first pitch to the onset of the last pitch, as in previous research (Palmer & Meyer, 2000). Timestamps provided by Cubase were used to calculate the durations of performances on the MWC. For example, in the two-octave C major scale, the onset of the first C4 at 1:00.15 to the onset of the second C4 at 1:09.30 yielded a duration of 9.15 seconds. For performances on the acoustic instruments, the researcher highlighted the onset of the first through last notes played in each segment of interest (e.g., two-octave C scale) and used the internal timer in Audacity to calculate the duration of the segment. Accuracy of pitch on both acoustic instruments and the MWC was scored using a method similar to that employed in previous research involving acoustic instruments only (Stambaugh, 2013; Stambaugh & Demorest, 2010). Potential full scores of 29 and 107 were allocated for each scale and the musical excerpt respectively, and 1 was deducted for each wrong note, omitted note, repeated note, or extra note. In addition, the MWC produces graphs of MIDI output representing the performer's breath pressure for each note played and a numerical output representing loudness on a scale from 0 (silence) to 127. These are not reported for the pilot study but are reported for Experiment 2, below.

RESULTS: PILOT STUDY

Given the small number of participants in the pilot study, analysis was conducted at the level of descriptive statistics. Preliminary examination of the timelines indicated that the least experienced clarinettist practised much longer on the MWC than the other participants but the data obtained from this participant were nevertheless included in the descriptive statistics presented below.

As shown in Table 1, participants warmed up and practised longer on the MWC than on their acoustic instruments. Scale practice on the MWC lasted between 13 seconds (C scale, experienced saxophonist) and 22 minutes (E flat scale, least experienced clarinettist). Many more pitch errors were made on the MWC than on the acoustic instruments. Octave errors were anticipated to be most prevalent because of the difference between the keys used to produce them on the MWC and the two kinds of instrument, known as the octave key on the MWC and saxophone, and the register key on the clarinet. However, 37.5% of the total errors made on the MWC were extra notes, followed closely by repeated notes (34.1%). More errors were made in the lower (13.7%) than the upper octave (12%). Very few notes were omitted (1.7%) or played at the wrong pitch (1%). Similar lengths of time were taken to perform the C scale, but not the other two scales, and musical excerpt on the MWC and acoustic instruments. The mean durations of each note of the C scale played on the MWC and acoustic instruments respectively were 0.327 and 0.317 seconds.

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Table 1. Comparison of practice, warm-up and performance on MWC and acoustic instruments (pilot study)

		Mean (Range)	
		MIDI Wind Controller	Clarinet/Saxophone
Practice time in seconds	Warm-Up	181.5 (89-339)	26.3 (5-40)
	C scale	135.5 (13-484)	5.2 (0-12.7)
	E flat scale	308.1 (36 - 1366.2)	3.5 (0-14)
	A scale	74.1 (35-141)	12.8 (0-37)
	Excerpt	253 (79.7-461.5)	360.3 (36-1127)
Number of pitch errors	C scale	6.3 (4-9)	0.3 (0-1)
	E flat scale	15.7 (7-24)	0.2 (0-1)
	A scale	3.5 (3-9)	0.3 (0-2)
	Excerpt	35.5 (24-40)	3.4 (0-7)
Performing time in seconds	C scale	9.5 (7.5-11.1)	9.2 (5.5-11)
	E flat scale	18.2 (11.2-25.8)	8.8 (5.8-10.3)
	A scale	5.6 (3-9)	8.1 (4.4-10.8)
	Excerpt	39.6 (32.3-45.37)	37.3 (31.2-45.5)

MAIN STUDY

Three experiments were conducted over the course of four days, the first experiment on Day 1 and the second two on Days 2, 3 and 4. The apparatus tested in the pilot study, described above, was used in each of the three experiments. The participants and materials are described below, and the design, procedure, scoring, analysis and results for each experiment are reported and discussed for each of the three experiments separately.

EXPERIMENT 1: METHOD

Participants

Nine participants were recruited (median age = 22 years, range 19-31 years), all members of large instrumental ensembles. Eight were undergraduate and one was a postgraduate music majors at a large university in the southeast United States. Three of the participants were clarinettists (two female, one male); the other six were saxophonists (one female, five male). One male saxophonist had participated in the pilot study. Given that eight months lapsed between the single-session pilot study and the main study, it was decided to include him in the main study. They all gave their informed consent to take part in the study and received financial compensation of US $40.

Materials

The following changes were made to the materials used in the study, based on the results of the pilot study. The scale of D major replaced the A scale so that both octaves could be played on the saxophone. The excerpt was shortened by 5 bars to 8 bars (see Figure 4) so as to reduce the amount of practice time likely to be required by less experienced performers.

It was also transposed into the key of C to eliminate the need to use left-hand palm keys, observed to be a source of errors in the pilot study.

Figure 4. Excerpt as performed in main study.

Design

The following research questions were addressed by this experiment:

1) How long does it take for a single-reed player to adapt to using an MWC and what does the adaptation involve?

2) Which musical parameters can be measured reliably using an MWC? and

3) To what extent can performance on an MWC substitute for performance on a saxophone or clarinet?

The independent variable was instrument, played by each participant: MWC and clarinet or saxophone. The dependent measures were lengths of time taken for warming up, practising, and playing a musical excerpt; performing time for scales and the excerpt; number and type of errors made; and breath pressure (loudness).

Procedure

One change was made to the procedure following the pilot study. In order that the sound produced by the MWC would be audible to the researcher, so she could ensure participants were following instructions correctly, an amplifier was used instead of headphones. Four participants played their own instrument first.

Scoring

A potential full score of 55 to represent pitch accuracy was allocated to the musical excerpt, since it had been shortened. Data representing loudness were obtained only for performance on the MWC and a Cubase setting was used to delete all non-note events so as to limit the data to loudness at each note onset.

Analysis

While lengths of time taken for warming up, practising, and playing a musical excerpt were normally distributed, histograms indicated that scores representing pitch accuracy were not, so they were transformed logarithmically. Repeated-measures ANOVAs were conducted with a Bonferroni adjustment to control for Type I error such that the significance level was set at .017 per comparison.

EXPERIMENT 1: RESULTS

Table 2 shows the mean practice time for the warm-up, scales, and excerpt on the MWC and acoustic instruments, as well as pitch accuracy and performing time for the scales and excerpt.

Table 2. Comparison of practice and performance on MWC and acoustic instruments (Experiment 1)

		Mean (*SD*)	
		MIDI Wind Controller	Clarinet/Saxophone
Practice time in seconds	Warm-Up	247 (82.20)	66.44 (91.55)
	C scale	52.90 (62.60)	10.56 (19.67)
	D scale	65.30 (62.40)	8.78 (14.96)
	E flat scale	196 (120.00)	8.44 (14.77)
	Excerpt	236 (102.80)	60 (69.30)
Number of pitch errors	C scale	7.11 (5.73)	0.56 (0.88)
	D scale	8.44 (6.41)	0.22 (0.67)
	E flat scale	9.33 (5.66)	0.56 (1.01)
	Excerpt	16.63 (5.04)	3.22 (5.40)
Performing time in seconds	C scale	11.64 (3.89)	9.86 (1.70)
	D scale	12.12 (1.47)	9.60 (1.86)
	E flat scale	14.59 (4.03)	9.73 (1.78)
	Excerpt	19.41 (11.23)	21.32 (1.98)

Table 3. Results of repeated measures ANOVAs comparing performance on MWC to performance on acoustic instruments

	df	*F*	*η2*	*p*
Pitch accuracy				
C scale	1, 8	7.833	.08	.023
E flat scale	1, 8	16.116	.49	.004*
D scale	1, 8	10.000	.36	.013*
Performing Time				
C scale	1, 8	1.712	.09	.227
E flat scale	1, 8	7.810	.41	.023
D scale	1, 8	7.403	.38	.026

Note. *p* < .017 per dependent variable with Bonferroni adjustment for multiple comparisons.

For the excerpt, pitch accuracy was greater on acoustic instruments (M = 94.2%) than on the MWC (M = 69.8%). Volume outputs were examined for individual performers. The graphic output in Figure 5a displays pitch, duration, and volume. This display made it easy to see how volume changed in relation to pitch and throughout the excerpt. Figure 5b shows the numeric volume output available from Cubase.
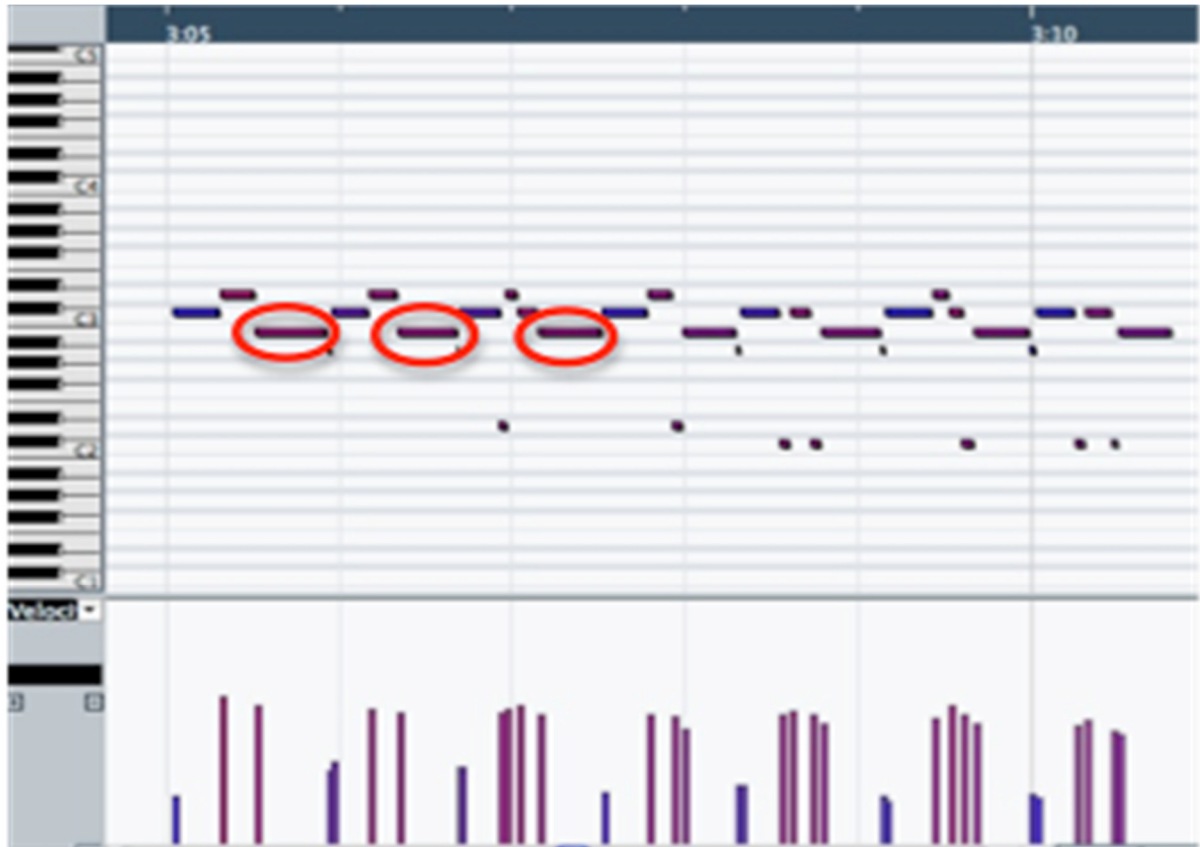

Figure 5a. Graphic view of the volume output for the excerpt. This section corresponds to Measure 3 in Figure 3. The columns at bottom of the figure indicate volume, with red indicating louder and blue indicating quieter playing. The red ovals correspond to the yellow boxes in Figure 5b (Experiment 1).

Type	Start	End	Length	Pitch	Volume
♩ Note	3.05.933	3.05.952	0.019	A2	37
♩ Note	3.05.951	3.06.171	0.22	C3	42
♩ Note	3.06.170	3.06.340	0.17	D3	70
♩ Note	3.06.339	3.06.680	0.341	B2	68
♩ Note	3.06.679	3.06.698	0.019	A2	39
♩ Note	3.06.697	3.06.929	0.232	C3	39
♩ Note	3.06.928	3.06.965	0.037	D2	68
♩ Note	3.06.964	3.07.032	0.068	D3	70
♩ Note	3.07.031	3.07.151	0.12	C3	72
♩ Note	3.07.150	3.07.524	0.374	B2	67
♩ Note	3.07.523	3.07.781	0.258	C3	26
♩ Note	3.07.780	3.07.930	0.15	D3	67
♩ Note	3.07.929	3.07.989	0.06	D2	66
♩ Note	3.07.988	3.08.299	0.311	B2	60
♩ Note	3.08.298	3.08.320	0.022	A2	30
♩ Note	3.08.319	3.08.548	0.229	C3	30
♩ Note	3.08.547	3.08.607	0.06	C2	67
♩ Note	3.08.607	3.08.729	0.122	C3	69
♩ Note	3.08.728	3.08.790	0.062	C2	67
♩ Note	3.08.789	3.09.136	0.347	B2	63
♩ Note	3.09.136	3.09.158	0.022	A2	24
♩ Note	3.09.157	3.09.425	0.268	C3	21
♩ Note	3.09.425	3.09.525	0.1	D3	65
♩ Note	3.09.524	3.09.603	0.079	C3	72
♩ Note	3.09.602	3.09.664	0.062	C2	67
♩ Note	3.09.663	3.09.993	0.329	B2	63
♩ Note	3.09.992	3.10.021	0.029	A2	25
♩ Note	3.10.020	3.10.254	0.234	C3	23
♩ Note	3.10.253	3.10.310	0.057	C2	62
♩ Note	3.10.309	3.10.471	0.162	C3	64
♩ Note	3.10.470	3.10.500	0.03	C2	59
♩ Note	3.10.499	3.10.819	0.32	B2	57

Figure 5b. Numeric view of volume output for the excerpt. The yellow boxes correspond to the red circles in Figure 5a (Experiment 1).

EXPERIMENT 1: DISCUSSION

The first research question asked how long it would take for clarinet and saxophone players to adapt to playing an MWC. Participants spent less than eight minutes warming up on the MWC at their first practice session, and they spent less than two minutes practising each scale. While the results for accuracy suggest that participants should probably have spent more time warming up and practising, the warm-up and practice data indicate that participants must have become accustomed to playing the MWC within one 45-minute study session.

The second research question asked which parameters could be reliably measured on an MWC. Pitch, rhythm, and volume outputs were available in graphic and numerical outputs. The graphic output clearly showed pitch errors of very short duration that occurred when a player's fingers were not perfectly synchronised.

The final research question asked the extent to which performance on an MWC could substitute for performance on a saxophone or clarinet. Participants performed rhythms using note-values from semiquavers to semibreves. To determine which pitch sets were most appropriate for short-term research studies using MWCs, Experiment 1 included one scale requiring simple fingerings (C major) and two requiring more complex fingerings (D major and Eb major). The pitches of the C scale were performed on the MWC and acoustic instruments in the same length of time and at a similar level of accuracy.

EXPERIMENT 2: METHOD

Design

Experiment 2 also addressed research questions 1) how long does it take for a single-reed player to adapt to using an MWC and what does the adaptation involve, and 4) to what extent can performance on an MWC substitute for performance on a saxophone or clarinet? In addition, it asked 3) can data generated by an MWC be used to discriminate subtle performance nuances, and if so, which ones? A repeated measures design was used. The study session for Experiment 1 served as Day 1 of four days. The dependent variables were length of time taken for warming up, practising, and performing, and accuracy measured by calculating the number of pitch errors made while playing the excerpt and subtracting it from the total number of notes played.

Procedure

As described in Experiment 1, participants practised and performed the excerpt on the MWC and on their own instrument on Day 1. On Days 2, 3 and 4, participants played only the MWC. They warmed up at their own discretion using minims, octave leaps, and tonguing exercises. They practised the excerpt until they decided they could perform it as indicated, and then gave a complete performance of the excerpt.

EXPERIMENT 2: RESULTS

A different aspect of the performances given by the nine participants on each of the four days is presented in each of the graphs comprising Figures 6a-d, below. Participants spent significantly less time warming up on Day 2 (M = 100.33 seconds; SD = 84.58) than they did on Day 1 (M = 247 seconds, SD = 82.24: $F[1,8]$ = 62.976, p < .001). Practice time on the excerpt also decreased by 393% from Day 1 (M = 236 seconds; SD = 102.77) to Day 4 (M = 56 seconds; SD = 50.48: $F[1,8]$ = 65.07, p < .0001). The time taken to give the last performance of the excerpt on Day 1 decreased from Day 1 (M = 24.81 seconds, SD = 4.15) to Day 4 (M = 22.11 seconds, SD = 2.03: $F[1,8]$ = 3.276, p = .113) on Day 4. Accuracy increased from a mean of 69.8% on Day 1 to 76.7% on Day 4, $F[1,8]$ = 1.619, p = .244.
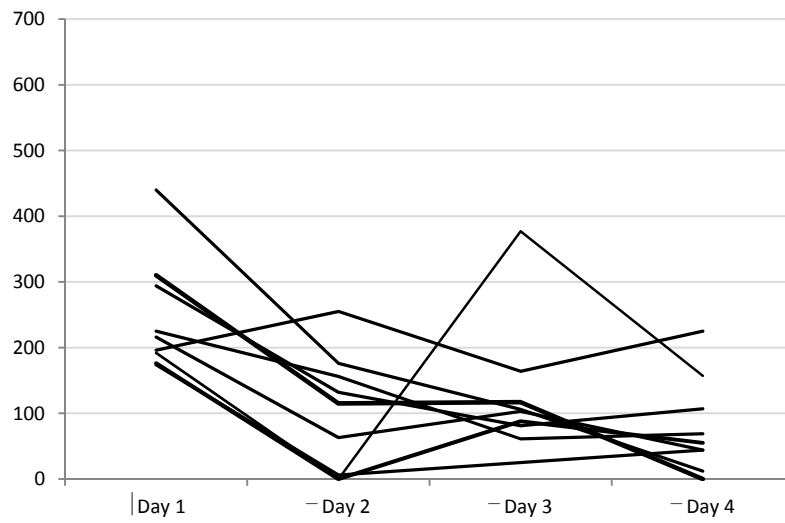
Figure 6a. Warm-up time played on MWC during Days 1-4. Each line represents an individual participant.
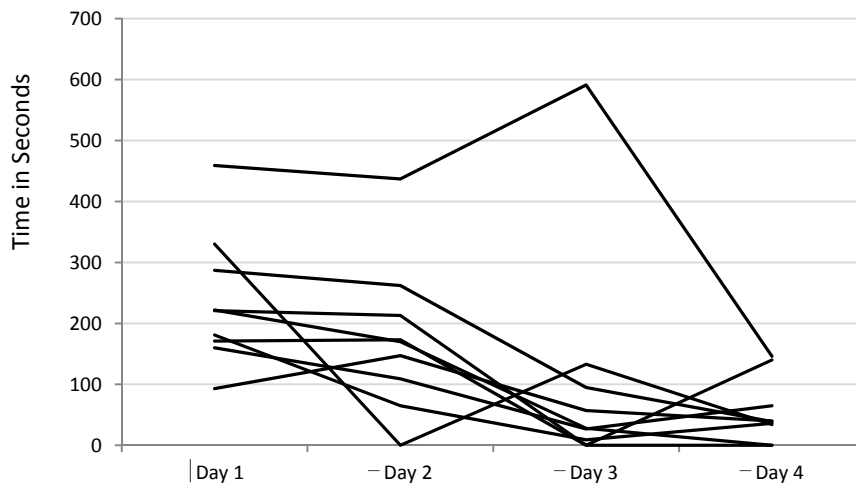

Figure 6b. Practice time for excerpt played on MWC on Days 1-4. Each line represents an individual participant.
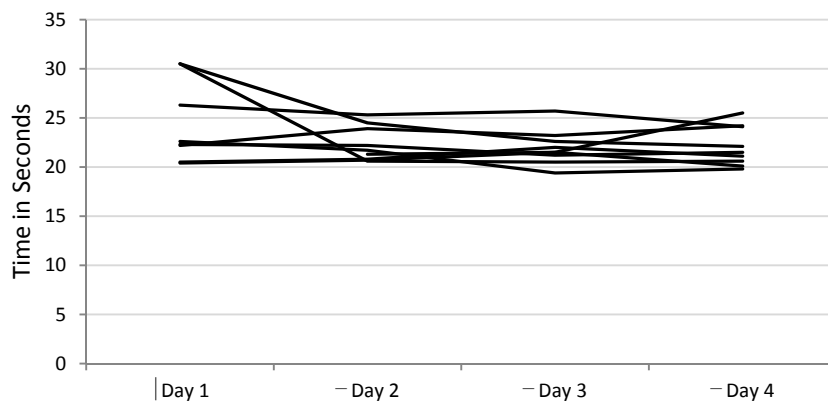

Figure 6c. Performance time for excerpt played on MWC on Days 1-4. Each line represents an individual participant.
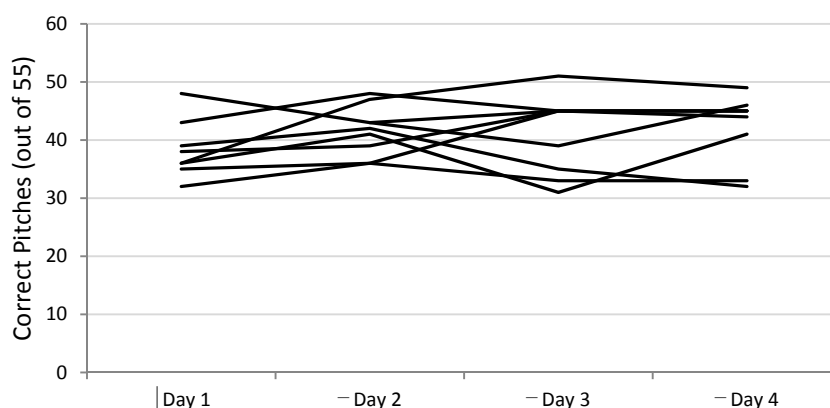
Figure 6d. Pitch accuracy for excerpt played on MWC on Days 1-4. Each line represents an individual participant.

Certain sections of the excerpt were selected for more in-depth analysis. Measure 5 (see Figure 4), with pitches falling under the right hand fingers, had a mean error rate of 0.12 errors. In this section, played by the participants with a high rate of accuracy, temporal evenness was consistent across the four study sessions. For example, the mean pitch duration calculated for one saxophonist was 0.19 seconds on Day 1 and 0.18 seconds on Day 4. Measure 3 (see Figure 4) consists of semiquavers that should all have the same durations, but it is clear from the graphic output for a different saxophonist (Figure 5a) that some notes, circled in red, lasted longer than others. Their actual durations are highlighted in Figure 5b, where it can be seen that the mean duration of the red-circled notes lasted 0.229 seconds while the mean duration of the remainder was only 0.168 seconds.

EXPERIMENT 2: DISCUSSION

The first research question addressed in Experiment 2 asked how long it would take for a single-reed player to adapt to using an MWC and what the adaptation involved. Participants spent less time warming up on Day 4 than on Day 1, although four of them did warm up for longer on Day 3 than Day 2. Pitch accuracy increased from Day 1 to Day 4, indicating that participants continued to adapt to the different tonguing required and to the feel of the keys on the MWC. However, the accuracy rate of 76.7% on Day 4 was still quite low by standards of public performance, especially when compared to the 94% accuracy rate on Day 1 of the performances on acoustic instruments. It may be that longer periods of warm-up and practice are required to overcome the challenges of playing the difficult passages in the excerpt, which included octave breaks and the use of side keys.

The second research question asked if data generated by an MWC could be used to discriminate subtle performance nuances, and if so, which ones? In-depth examination of graphic and numeric data from two sections of the excerpt revealed timing differences within and between performers. Such data could be used as a teaching aid: it could be valuable for students who have difficulty hearing unevenness in their playing to see it represented in graphic form, or to demonstrate the use of tempo changes within a single phrase, for example, by expert performers for expressive purposes. Furthermore, data from the MWC can be used to highlight changes in breath pressure, which are heard as changes in volume.

The fourth research question sought to determine the extent to which performance on an MWC could substitute for performance on a saxophone or clarinet. On the basis of the results of Experiment 2, the MWC could substitute for clarinet and saxophone provided the pitch range is confined to D-B (in any octave, depending on which of the octave keys is chosen and/or on the sound setting). Figure 5a shows that Measure 3 was a source of many of the errors made on the MWC. The pitch sequence B-C-D-C requires players repeatedly to cross an octave break.[1] While the fingering for this sequence is the same on the MWC and saxophone (although not the clarinet), the micro-timing needed for 'clean' playing is different. By contrast, all participants were able to play Measure 5 accurately since only one hand is needed to operate the keys. It is therefore recommended that the music used in future MWC research minimises the need for saxophonists to negotiate the B to C octave break.

EXPERIMENT 3

One way of determining the validity of a new technology for research purposes is to use it in the replication of a previous study (Collyer et al., 1997). Experiment 3 replicated the music-motor paradigm of blocked and random practice for short technically-challenging passages (Stambaugh, 2011, 2013). When a performer has several such passages to practise, *blocked* practice denotes playing all the trials of one passage before starting to practise the next passage. *Random* practice means changing the order in which the passages are practised in a single session. The contextual interference hypothesis predicts that blocked practice produces superior performance immediately following practice, while random practice produces superior learning when retention is tested after a delay (Battig, 1966; Shea & Morgan, 1979). While this hypothesis has been supported by the findings of some studies but not others (for a review, see Merbah & Meulemans, 2011), it has been confirmed by Stambaugh (2011, 2013) in woodwind players, both young beginners aged nine, and advanced university students.

EXPERIMENT 3: METHOD

Design

Like Experiment 2, Experiment 3 addressed the fourth research question, the extent to which performance on an MWC can substitute for performance on a saxophone or clarinet in relation specifically to blocked versus random practice. Participants were randomly assigned to one of two groups. The independent variable was practice (blocked or random), and the dependent variables were pitch accuracy, calculated as in Experiments 1 and 2, and the time taken to play each measure of the passages to be learned, calculated as in the pilot study.

Materials

The passages to be learned are shown in Figure 7. They were adapted from those used in

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[1] The WX5 has several fingering options. It is possible to choose a set of fingerings to play sequences such as B-C-D-C without crossing an octave break. Participants in this study were not taught these alternate fingerings, but these options may be useful in future studies.

Stambaugh (2013), composed by the researcher. Two kinds of tests were used: retention and transfer. Retention means performing that which has been practised; Measures 1, 2 and 3 were used for this purpose. Transfer tasks are used to test a practised ability in a novel context and Transfer 1 and Transfer 2, similar to Measures 1, 2 and 3 but with some different intervals, tested transfer.
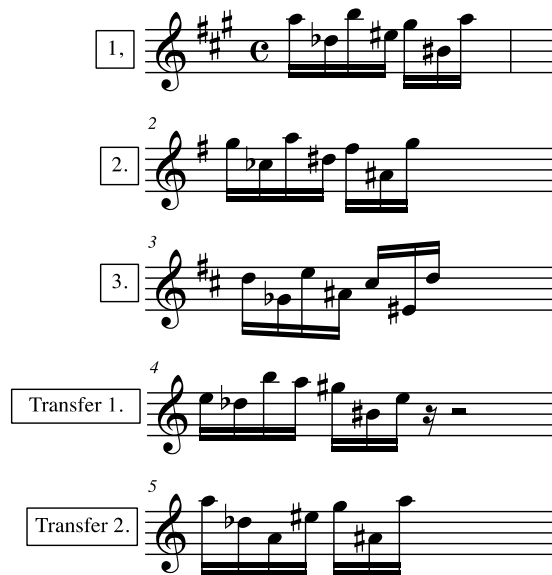

Figure 7. Passages practised in Experiment 3.

Procedure

On Days 2 and 3, the participants warmed up and undertook the tasks required for Experiments 1 and 2. Next, they were given a checklist stating the order in which they were to play each of the three measures shown in Figure 7 nine times in either blocked (1 1 1…2 2 2…3 3 3) or random order (1 2 3 2 1 3…), as accurately and quickly as possible. Having done so, on Day 4, after undertaking the tasks for the first two experiments, their retention was tested as follows: they played the three measures three times each in serial order (e.g., 1 2 3 1 2 3…). Finally, they played the two transfer measures in alternating order. These orders were used because they were unfamiliar to both practice groups.

Scoring

The following trials were analysed: the last three trials of Measures 1, 2 and 3 played by each participant on Day 3 (Acquisition), the retention trials on Day 4 (Retention), and the transfer trials on Day 4 (Transfer). The Cubase files for each trial were ordered randomly and numerical outputs generated. Pitch accuracy and time taken to play each measure were calculated as described in the Design sub-section, above. Given the small number of participants in each practice group (blocked, $n = 4$; random, $n = 5$), analysis was conducted at the level of descriptive statistics.

EXPERIMENT 3: RESULTS

Table 4 shows the means and standard deviation for practice groups at Acquisition, Retention, and Transfer. Several trends were consistent with the contextual interference hypothesis. The blocked group played faster than the random group at the end of practice

(Acquisition) but slower at Retention than Acquisition; the random group played faster than the blocked group at Transfer and faster at Retention than Acquisition. Other trends were inconsistent with the contextual interference hypothesis. The random group performed more accurately than the blocked group at Acquisition, the blocked group performed more accurately than the random group at Transfer, and the blocked group performed more accurately at Retention than it did at Acquisition.

Table 4. Means and standard deviation for Experiment 3 at Acquisition, Retention, and Transfer

		Mean (SD)		
		Acquisition	Retention	Transfer
Blocked Practice (*n* = 4)	Accuracy	3.17 (1.48)	3.95 (.64)	4.46 (1.13)
	Speed	1.58 (.61)	1.67 (.46)	2.37 (.94)
Random Practice (*n* = 5)	Accuracy	3.47 (.78)	3.33 (1.56)	3.69 (1.30)
	Speed	2.03 (.30)	1.80 (.27)	2.28 (.64)

EXPERIMENT 3: DISCUSSION

Experiment 3 demonstrated that participants were able to complete the tasks used in previous woodwind research while performing on an MWC. However, the results of the study are inconclusive because it was not possible, with the small sample size, to analyse the data using tests of statistical significance. It was noted that some participants experienced difficulty playing the test and transfer measures accurately, possibly because they crossed octave breaks and involved the use of side keys.

GENERAL DISCUSSION

The purpose of this study was to examine MIDI wind controllers as a tool for wind performance research. The validity and practicality of the Yamaha WX5 was investigated through four research questions. A one-session pilot study informed the main study, which consisted of three experiments conducted over a period of four days. The pilot study showed that it was possible to collect pitch, duration, and loudness data in both numeric and graphic formats. In Experiment 1, participants' performances of the C scale on the MWC and acoustic instruments were similar but their performances of the other scales and a musical excerpt were played with greater accuracy on their own instruments. In Experiment 2, participants gave MWC performances of the excerpt on successive days, two segments of which were examined for potential, subtle differences. Pitch accuracy improved, to a limited extent, and micro-timing differences were evident within and between performers for one segment but not for the other; indeed the data revealed that for one participant, at least, high levels of accuracy of pitch and consistency of timing could be achieved in the latter. In Experiment 3 the MWC was used in an exploratory comparison of blocked and random practice, replicating previous research with woodwind players performing on acoustic instruments.

Research question 1) How long does it take for a single-reed player to adapt to using an MWC, and what does the adaptation involve?

Warm-up times for all four study sessions were less than eight minutes and decreased across days. Practice times for scales on Day 1 varied widely, likely because of the wide range of skill levels among participants, who ranged from the first-year (freshmen) students through postgraduate-level players. Overall, the results of this study indicate that saxophonists should be able to adapt their playing to the MWC comparatively quickly, but this is likely to be so for clarinettists only if they also play the saxophone; otherwise the music they are asked to play should stay within the range D-B and they should be given time to accustom themselves to using the left hand palm keys. Tonguing also presents challenges. Even though the MWC has a saxophone-like mouthpiece and synthetic reed, saxophonists and clarinettists alike must adapt the way they tongue. Warm-up materials should include tonguing exercises on repeated and different notes.

Research question 2) Which musical parameters can be measured reliably using an MWC?

Pitch, rhythm, and loudness can be measured reliably. Pitch and duration outputs are available in numeric and graphic formats. Loudness data is presented numerically on a scale of 0 to 127 and graphically using columns of different colours. Another musical parameter that could be measured is articulation, as with MIDI keyboard data (Lee, 1989; Palmer, 1989b). Participants in the present study used legato tonguing. Staccato attacks could be shown by spaces between the offset of one note and onset of the next note in the graphic output. Accents could be identified by examining loudness at note onset and subsequent control messages representing an immediate decrease in volume. These parameters reflect only a fraction of those varied in the course of expressive performance.

Research question 3) Can data generated by an MWC be used to discriminate subtle performance differences, and if so, which ones?

The evidence presented in this study suggests that MWC data can be used to discriminate the temporal aspects of performance such as the variations of timing that contribute to rubato and thus expressive performance. Loudness and temporal data are shown simultaneously, enabling the researcher to track changes in loudness precisely over the course of a single performance. Perhaps the most useful application of the MWC's capacity for high-level pitch discrimination is to identify the fleeting pitch errors associated with 'awkward' intervals attributable to the lack of synchronization between key presses (see C2 in Figure 5a). In addition, the Yamaha WX5 does have a pressure-sensitive mouthpiece enabling the performer to 'bend' notes up and down, but this feature was not examined in the present study; it should be investigated in future research.

Research question 4) To what extent can performance on an MWC substitute for performance on a saxophone or clarinet?

The MWC may be most suitable for investigating fingering accuracy, precise timing, and the interaction between timing and dynamics in wind performance. Performances on the MWC and acoustic instruments were most similar when the music played did not present challenges such as octave breaks and the use of left hand palm keys. No problems were encountered with playing at different dynamics. While participants were able to use both

tongued and slurred articulations, the data provided by the MWC do not distinguish between these, so – unlike legato and staccato articulations – they cannot be compared. Finally, participants spent significantly less time warming up on the MWC on the second than the first day of the study, suggesting that they felt more comfortable and confident playing the MWC on the second day; this should be borne in mind for future research.

Limitations of the present study

First, the sample of participants was small, including only nine participants, but this was typical also of early MIDI keyboard studies using between one and seven participants (Collyer, et. al, 1997; Lee, 1989; Palmer, 1989b; Salmon & Newmark, 1989, Wilson, 1992). Second, the present study used one model of MIDI wind controller, but other manufacturers and models are commercially available, and are equally suitable for testing in future research. Third, the participants were not professional musicians; as college musicians, they were still developing and refining their skills on their primary acoustic instruments. Future research should include more advanced players. Fourth, additional aspects of performance on the MWC remain to be investigated. Future research should involve participants besides single-reed players, examine jaw pressure feature, and use a wider range of musical tasks. Finally, the parameters of performance capable of being studied using the MWC reflect only a fraction of those used in artistic, expressive performance. 'Tone' is only one of the subtleties varied by expert performers on their own instruments that cannot be explored by studying MWC performance.

Wilson (1992) responded to his own question, "Can MIDI-based studies assist in a search for answers to the pedagogic and scientific questions [of music performance]?" (p.93), in the affirmative. The present study shows that while MIDI research paradigms cannot be used to answer every question, they do help researchers solve some of the problems of undertaking research in the field of wind performance arising from the use of acoustic instruments. When used with appropriate musical tasks, the use of MWC data can provide precise levels of measurement for specific musical parameters, remove human bias from the scoring process, and make the scoring process less time-consuming. It thus contributes to the goal of improving the use of technology in the interests of advancing research and practice in pedagogy, which in turn can lead to superior musical performance.

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LAURA A. STAMBAUGH is Director of Music Education and Associate Professor at Georgia Southern University in the U.S., where she teaches undergraduate and graduate courses in music education and music cognition. Her research interests include examining instrumental learning through motor learning and cognitive paradigms, and the development of error-detection skills by pre-service teachers.