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Seeing Red: Effects of Practice Interventions on Woodwind Students' Accuracy in Performing Articulation

Laura A. Stambaugh[1] and **Carolyn J. Bryan**[1]

Implications for Music Teaching and Learning

- Woodwind players may be more attentive to performing articulation when they trace in red over articulation or use notation with colored articulation markings.
- Teachers at all levels should direct woodwind players' attention to accent and staccato markings.
- Students should use color in a deliberate way, rather than highlighting every dynamic, articulation, and text marking.
- If beginning woodwind students learn to give equal attention to pitch, rhythm, and articulation, they may carry this holistic approach into their more advanced performance.

Abstract

Music reading is a central part of most band programs, yet research about music reading has rarely included articulation markings. The purpose of this study was to explore the effect of four experimental practice conditions to a control condition on woodwind players' performance of slur, accent, and staccato markings. A secondary purpose was to examine the role of working memory in performing articulation. The practice conditions used visual and kinesthetic approaches: colored notation, tracing over articulation marks, and speaking syllables. University woodwind players ($N = 26$) practiced short etudes on 1 day, and they returned approximately 24 hours later for retention testing. Participants' working memory was strongly related to playing articulation on the first day of practice. Woodwind players prioritized playing slurs over accents and staccatos, and there was some support for tracing with color to support accurate performance of articulation.

Keywords

articulation, music reading, practice, woodwinds, working memory

It is no simple task to decode music notation, translate that visual information into movements, and produce a beautiful sound from those movements. Accordingly, many teachers, performers, and researchers have devoted significant attention to music reading. A close look at this body of work shows much attention has been afforded to reading pitch and rhythm. However, musicians also have to decode and perform other markings, such as articulation. In this study, we address a noticeable gap in the music reading literature: observation of articulation marks. Researchers are not the only people who may overlook articulation markings. Developing instrumentalists may overlook performing articulation markings when playing (Rosenthal et al., 1988; Yarbrough et al., 1993).

Many beginning band method books start with long tones to build embouchure and teach fingerings/slide position, and then introduce slow rhythms in half and quarter notes (e.g., Lautzenheiser et al., 2004). Students have to tongue in order to start playing the whole notes, but there is no marking in the notation to indicate that default beginner articulation. It is only several pages later that students are introduced to articulation markings. At this point, the student has been shown a sequence for decoding music notation: pitch, then rhythm, then articulation. Given our experience teaching woodwinds and results of previous research presented next, it seems many

[1]Georgia Southern University, Statesboro, USA

Corresponding Author:
Laura A. Stambaugh, Georgia Southern University, PO Box 8052, Statesboro, GA 30460-1000, USA.
Email: lstambaugh@georgiasouthern.edu

woodwind players continue this hierarchical approach to learning their repertoire. A theoretical basis for this approach is cognitive load theory, which considers the intersection of a learner's previous knowledge and the difficulty of the task at hand (Stambaugh, 2013; Sweller, 1988). A potential negative outcome of this learning sequence is that more experienced students continue to place a low priority on attending to articulation markings. The question we explore in this study is, "How can experienced woodwind players become more attentive to articulation markings in their music?"

Related Literature

Woodwind Pedagogy

Professional instrumentalists have written extensively about the mechanics of how to play various articulations. In his treatise *On Playing the Flute*, Quantz (1752/1985) wrote about the use of the tongue-strokes *di*, *ti*, and *diri*, but not about reading articulation in notation. *The Art of Saxophone Playing* (1963) contains an entire chapter devoted to the physical aspects of playing staccato and another chapter to articulation in general. In a series of articles in the *Saxophone Journal* (Bongiorno, 1995a, 1995b, 1996a, 1996b), Bongiorno described aspects of air stream, tongue placement, and syllable use for developing general tonguing and staccato articulation. Likewise, clarinet pedagogy has discussed how the shape of the oral cavity is different when playing staccato in the chalumeau register compared with the clarion and altissimo registers: "the harmonic structure . . . is different, and is liable to be upset by the impact of the tongue, leading to 'quacks' and even squeaks" (Brymer, 1976, p. 181). More recently, researchers have employed advances in technology, such as fiber optic cameras (Zimmer, 2002), to further our understanding of how the inner oral cavity changes when performing different articulations. Despite this wealth of discourse and tradition about how and why to play articulations, researchers have not examined the visual cues (notation) or aural cues (imagined model) that prompt the performance of articulation.

Music Reading

Music teachers and researchers have written widely on the topic of reading music, but they often neglect expressive markings such as articulation (for a comprehensive review, see Gudmundsdottir, 2010). Even research using contemporary technology continues to focus on pitch and rhythm reading. Eye tracking and neuroscience tools further our understanding of reading music pitch and rhythm, but rarely isolate articulation markings (Penttinen et al., 2013; Schön & Besson, 2002). In this literature review, we focus on literature that (a) presents a broad theoretical perspective for music reading, (b) specifically addresses articulation, and (c) examines the use of color in music reading.

One of the earliest theoretical perspectives is the sequence of "sound before sight," which is commonly attributed to Pestalozzi (1746–1827; McPherson & Gabrielsson, 2002). More contemporary approaches to "sound before sight" are found in the writings of psychologist James Mainwaring (1951) and music psychologist Edwin Gordon (2001). Mainwaring (1951) wrote, "[a musical] name or symbol should have an immediately recallable empirical content" (p. 108). If a student has no aural image of what an accent sounds like, they are unlikely to perform it in a genre-appropriate way. The act of music reading and performance has also been considered as perception (Sloboda, 1984) and through cognitive lenses. Expert sightreaders were found to look further ahead in their music than less-skilled sightreaders, perhaps because they could *chunk* patterns of pitches and rhythms (Chase & Simon, 1973; Goolsby, 1994).

Recent theoretical perspectives attempt to more clearly define the process of music reading and performance. Gudmundsdottir (2010) suggested that we use two separate component skills: reading notation and producing the sound. Reading notation can be facilitated by familiarity with music structures, such as scales, arpeggios, and phrases (Sloboda, 1984). Producing the sound may be related to information processing and psychomotor speed (Kopiez et al., 2006). Drai-Zerbib et al. (2012) suggested the process either is a cross-modal *conversion* of visual notation being converted to motor output, or a cross-modal *integration*, with visual information encoded at a conceptual level and then becoming motor output. Based on results of their eye-tracking study with expert children and adult pianists, and nonexpert children, they found that experts used the integration model. The authors also suggested the experts may have used an aural image to prime the motor system in order to perform the articulations printed in the music. Simoens and Tervaniemi (2013) investigated if music notation is stored in working memory as a visual image or if notation is immediately translated into an aural image. They asked professional male musicians to perform two-pitch sequences while also attending to either a visual or aural distractor. The visual distractor did not interfere with reaction time to play the target pitch sequence, but the aural distractor did slow performance reaction time. The authors interpreted this result to mean the professional musicians translated the written notation into an aural image for storage in working memory before they produced the sound.

The last theoretical perspective we will address is memory. The act of reading and performing music

places several demands on memory. Many aspects of performance, such as an experienced flutist playing the fingering for E4, become automated with practice. However, other aspects change with each piece of music, each phrase, and even each pitch, such as articulation and dynamics. These localized demands are temporarily stored in working memory. *Working memory* is used for information that needs to be retained for a short period of time and it has a limited capacity for how many pieces of information it can store (Baddeley, 1986). Researchers from a variety of fields are interested in how working memory capacity may affect the ability to do tasks requiring attention (Sala & Gobet, 2017; Seidler et al., 2012). In music, learning to play new repertoire is a task that requires working memory. If the phrase uses only one type of articulation, less working memory is needed than if the articulation changes for each pitch. Yet the relationship between working memory and playing articulation has not been a topic of previous research.

Articulation in Music Research

A limited number of studies include articulation performance as an outcome measure. Working with pianists and nonpianists, Drai-Zerbib and Baccino (2005) manipulated the presence of slurs in notation and aural models to test how input modality affected subsequent performance from notation. Results of their eye-tracking study indicated that expert music readers were more attentive to the aural slurring model than the printed slurs in notation. However, less skilled readers were very dependent on the visual notation. Likewise, Bishop et al. (2013) asked expert, intermediate, and novice pianists to complete a series of performance tasks focused on the ability to imagine articulation and dynamics. The authors hypothesized that skilled musicians have an aural image of their anticipated performance and this anticipation primes the motor system to produce that image. The most important findings from this study were articulation can be imagined during performance and this ability was positively related to expertise.

College band students were asked to prepare a short excerpt using one of five conditions: modeling (listen to a recording of a violinist while watching the score), singing for 3 minutes with access to a keyboard, silent analysis for 3 minutes, free practice with continuous playing for 3 minutes, or a control condition of practicing an unrelated piece of music for 3 minutes (Rosenthal et al., 1988). Although the modeling group had the highest rate of accuracy for articulations and the control group had the lowest rate, there were no statistically significant differences among practice conditions. However, in other studies, college piano majors (Sharp, 1988) and child and adolescent pianists (Yarbrough et al., 1993) did find an aural model useful. Their aural model matched their instrument, perhaps enabling them able to successfully imitate recorded models of articulation, though sometimes at the expense of performing dynamics.

Articulation is often taught with reference to spoken syllables such as “tah” or “too.” Some pedagogues advocate using the same set of syllables for all woodwinds (Kohut, 1973; Westphal, 1985), whereas others (Griswold, 2008) pair certain syllables with certain instruments or certain registers (Guy, 2010). Sullivan (2006) compared the effectiveness of using mono-syllabic (e.g., “tah”) and multiple-syllabic (e.g., “tah,” “dah,” “tut,” and “taht") approaches with high school woodwind players. After 7 days of learning in one of these conditions, students performed articulations for both sightread and rehearsed music more accurately after having studied in the multi-syllabic approach.

Color and Writing on Music

A common pedagogical practice is asking students to write on their music with a pencil or highlighter. This custom has largely been overlooked by researchers, with the exception of some self-regulated practice studies that counted instances of students writing in their music. Miksza et al. (2012; Miksza, 2015) found that writing on music was related to effective practice. However, they did not provide details about what kinds of writing were being done, such as circling whatever a student missed, underlining dynamic markings, or adding breath marks.

One way to draw attention to specific markings in notation is to use color. Researchers and teachers have created alternative notation systems that use color to emphasize relationships among formal or structural elements (Kuo & Chuang, 2013; Wilmer, 1995). Although there are a number of historical and commercial systems for applying color to reading music (for a review, see Kuo & Chuang, 2013), we could only locate a few studies in which researchers empirically investigated the effectiveness of using color in reading and performing music. Adolescent beginning wind players were assigned to either a color-coded notation group, where each pitch was highlighted consistently in its own color, or to a plain, no-color notation lesson group for 12 weeks (Rogers, 1991). Even though students did prefer the color-coded notation, Rogers found no significant differences in music reading and performance skills between groups. In a follow-up study, Rogers (1996) taught first and second grade students for 23 weeks using either plain rhythm notation or notation drawn with colored chalk. The rhythms did not have a fixed color coding; the colors

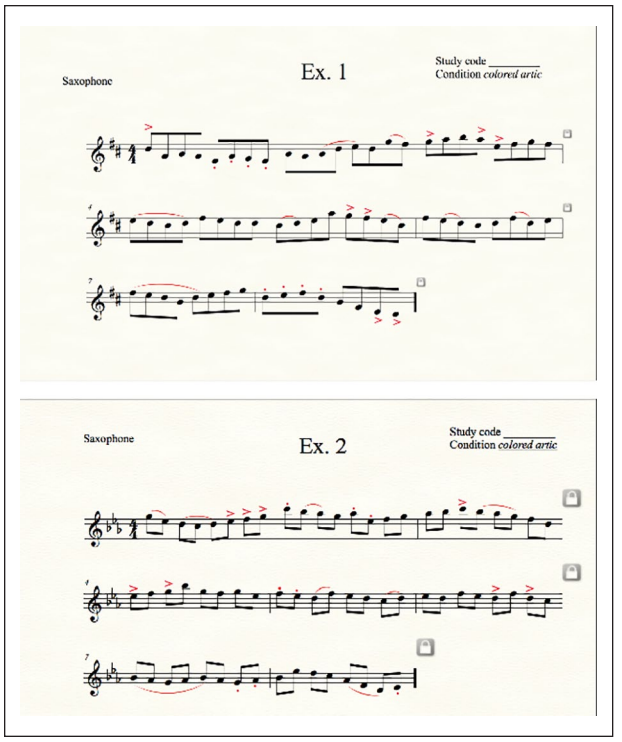

Figure 1. Sample music examples for saxophone players articulation is printed in red.
Note: Articulation was printed in red for the "Red Articulation" condition. Articulation was printed in black for all other conditions.

changed from week-to-week. After 23 weeks of instruction, Rogers found no significant difference between groups for reading plain notation. Last, students in one middle school band were found to play more expressively when using parts that included highlighted key signatures, articulation, and dynamics as compared to parts that only highlighted tempo, instrument part, and a spoken phrase in the piece (Banister, 1994).

We have reviewed the literature about woodwind pedagogy, music reading, and the use of color in notation in order to examine what is already known about reading and playing articulation marks. Although each area of literature raises questions about the process of reading and playing articulation, overall, this topic has been overlooked (Bishop et al., 2013). Therefore, the purpose of this study was to explore the effects of practice strategies on accuracy for performing slurs, accents, and staccatos. Our research questions were as follows:

Research Question 1: What are the effects of color, tracing, and saying syllables on articulation performance accuracy?
Research Question 2: What is the relationship between working memory and articulation performance accuracy?

Method

Pilot Study

The function of the pilot study was to assess the difficulty levels of the music items (see Figure 1) and the appropriateness of the experimental protocol, which was similar to Rosenthal et al. (1988). Three undergraduate music education majors, one each on flute, clarinet, and saxophone, were recruited through convenience sampling. Participants completed the protocol described in the Full Study section, using the music notation described in the Materials section. Participants were debriefed after each playing condition. We asked if each music example was too difficult to learn in two minutes. Participants indicated they were comfortable with the difficulty level of the examples and the amount of practice time. The examples were challenging enough to require practice in order to play all the notes, rhythms, and articulations correctly at a moderate tempo. We made no revisions between the pilot study and the full study.

Full Study

Sample. We chose to limit the sample to woodwind players for two reasons. First, both authors are woodwind players, which would assist in developing the music examples and in interpreting results. Second, Sullivan (2006) found no significant differences between instrument studies using flute, clarinet, and saxophone. We would be able to collapse our data across instruments, leading to more generalizable teaching implications.

Participants ($N = 26$; female, $n = 17$; male, $n = 9$; other designation, $n = 0$) were members of university ensembles. Twenty-three participants were music majors (flute, $n = 6$; clarinet, $n = 11$; nd saxophone, $n = 9$). They were all undergraduate students ($M_{age} = 19.8$ years; $SD = 1.19$ years) recruited through convenience sampling from two universities in the southeast region of the United States. All participants completed the university approved informed consent process, and they received no compensation for their participation.

Design. We used a repeated-measures design. The independent variable was practice condition, which had five levels: Control, Red Articulation, Draw Red Articulation (Draw Red), Draw Black Articulation (Draw Black), and Speak Syllables. The dependent variables were accuracy of performed accents, staccatos, and slurs, and they were measured on two consecutive days (Day 1, Day 2) with approximately 24 hours between sessions (Duke & Davis, 2006; Stambaugh, 2013). Two orders of the practice conditions were determined by a random number generator (www.randomizer.org/). One order was

Practice Example, Example 1/Control, Example 4/Draw Red, Example 2/Red Articulation, Example 3/Draw Black, and Example 5/Speak Syllables. The other order was Practice Example, Example 2/Control, Example 5/Draw Black, Example 4 Speak Syllables, Example 3/Draw Red, and Example 1/Red Articulation. Participants were randomly assigned to one of the two orders and they used the same order on Day 1 and Day 2.

Materials. In order to create music examples that would not be familiar to any of the instrumentalists at both universities, we used the website Sight Reading Factory (Gracenotes, 2019). This online tool allowed us to set parameters for length of example (16 measures), meter (common time), key signature (two examples each in A Major, D Major, and Eb Major), and rhythm values (all eighth notes). We had it generate six unique music examples (see Figure 1, for two examples). One example was designated as the Practice Example and the other five were used in the experimental conditions. The notes and articulation markings were printed, as is customary, in black for the Practice, Control, Draw Red, Draw Black, and Speak Syllables conditions. However, in the Red Articulation condition, the notes were printed in black, whereas the articulation markings were printed in red. We chose the color red because it is a high contrast to black and white and because of its use in previous research (Silvey et al., 2017).

The second author, a professional saxophonist, added the following articulation markings to each example: slurs encompassing 20 to 25 notes, eight staccatos, and eight accents. These examples were used with saxophonists. To make the examples more suitable for flute and clarinet ranges, we adjusted the octaves up or down. To further account for content validity, we sent the music examples to two university performance faculty on each instrument. All faculty agreed the music examples were appropriate for undergraduate students to practice within a limited time period. To control for threats to internal validity, we created two orders of practice conditions.

To measure working memory, we used a digit span forward test (Richardson, 2007). The test can be administered in less than 10 minutes and has long history of use in research and health settings, including as part of the Wechsler Intelligence Scale (Wechsler, 1997; Woods et al., 2011). The researcher reads aloud a group of single numbers (e.g., 6, 3, 5, and 1). The participant repeats back the numbers in the same order they were given. This process is repeated, and the list of single numbers grows longer until the participant reaches a failure threshold.

Procedure. Participants completed individual study sessions in a faculty office with the first author present, to ensure adherence to the protocol. First, they filled out a background questionnaire to document their musical background, provide demographic information including age and year in school, and indicate if they were color blind ($n = 0$). Next, they completed the forward digit span test. After that, they warmed up on their instrument until they decided they were ready to begin. To test the recording software Audacity (Team Audacity, 2019) and microphone (Samson QU1), participants played a one or two octave scale at a comfortable tempo and volume. The recording software continued to record the entire study session. A pencil and countdown timer were on the music stand, and a metronome was on a table next to the participant.

Next, the first author told the participant that the purpose of the study was to test different practice techniques, with the goal of playing accurate pitches, rhythms, and articulations. The participant was asked to practice the Practice Example (see Figure 1). The researcher then read aloud,

> You will have two minutes to practice this excerpt, however you want to practice it. Your goal is to be able to play the pitches, rhythm, and articulations as accurately as possible. You may use the metronome or write on your music, if you like. While a suggested tempo is listed, you should choose a tempo that allows you to play the music correctly. Please try to practice in the way you usually would, in a practice room by yourself.

At the end of the 2 minutes, the researcher asked the participant to play the example all the way through without stopping. The researcher reminded the participant to "play all the pitches, rhythms, and articulations as correctly as possible." Then, the researcher asked the participant if they had any questions about the study procedures.

Having become familiar with the study procedures, the participant worked through the five practice conditions in their assigned order. In each practice condition, the participant had a total of 2.5 minutes of contact time with the example and then they played a complete runthough. "Contact time" is clarified by explaining the practice conditions.

In the Control condition, the notation was in black ink. Participants were told the same directions as indicated for the Practice Example, except that they had 2.5 minutes to practice instead of 2 minutes. In the Red Articulation condition, the articulation was printed in red ink and the notation was printed in black ink. Participants were told the same directions as in the Control condition.

In the Draw Red condition, participants were told, "Please use this red pencil to trace over all the articulation markings in the example," which took about 30 seconds, and then "You now have 2 minutes to practice as you usually would. Your goal is to be able to play the pitches,

rhythm, and articulations as accurately as possible. You may use the metronome or write on your music, if you like." In the Draw Black condition, participants received the same instructions as the Draw Red condition, except they used a black marker to do the tracing. In the Speak Syllables condition, participants were told, "Please chant through the notation using any syllables you want to show the articulation." Then the researcher modeled the first three measures using the syllables "ti" and "ta." Once the participant did that, they were told to practice for 2 minutes, using the same directions as in the Practice Example. Between conditions, the researcher chatted for 10 to 30 seconds with the participant. Participants were also told they could take a longer break (up to 2 minutes) between examples, if they wanted a longer rest break. If so, they had to engage in a nonmusic-related activity, such as checking email on their phone. At the end of practicing in all conditions, participants were asked to try not to practice those specific examples overnight (they did not take their music with them). They were permitted to practice other music and play in rehearsals as their schedule demanded.

Approximately 24 hours after the first testing session, participants returned for retention testing. Delayed retention is important in learning studies because performance immediately after practice may not reflect more long-term learning (Duke & Davis, 2006; Stambaugh, 2013). Participants again warmed up and played a major scale to test the microphone level. The microphone was placed in approximately the same location as the previous day. Following instructions to "play all the pitches, rhythms, and articulations as accurately as possible," they played through the Practice Example. Then they recorded each of the other five examples without practicing before the run-through recordings. Examples were recorded in the same order as they had been practiced in the previous day.

Scoring. The dependent variables were number of correct slurs, accents, and staccatos performed in each condition. A challenge in scoring articulation performance is individual differences between performers. One clarinet player's staccato may sound different than another clarinet player's staccato. We limited this confound by scoring files for one participant at a time. First, we scored their Practice Example to gain familiarity with the individual player's articulation style. However, the Practice Example score was not included in analysis. Then we scored the experimental conditions in the order they had performed them, although we were blind to performance day and practice condition.

We created a printed score book with enough copies of all the music examples for 2 days of performances and we marked articulation errors on the notation. To ensure interrater reliability, both researchers participated in scoring the audio files through a series of four rounds of scoring. We started with one set of recordings from each instrument (e.g., clarinet participant #1, Day 2, all five practice conditions). Together, we listened to each sound file (e.g., clarinet participant #1, music example #3) without knowing the practice condition or day of performance and we discussed whether each articulation in the example was performed. In our scoring books, we marked errors of missed or wrong articulation on the corresponding note. In the second round of scoring, we independently scored the same three sets of recordings. We then met again to further discuss refining the scoring. In the third round of scoring, we independently scored another three sets of files and then met to discuss any remaining scoring questions. Cronbach's alpha was used to calculate interrater reliability, which was deemed acceptable ($\alpha = .80$) for 34.6% of recordings. In the final round of scoring, we split the remaining files to score independently.

Results

Our first research question addressed the effect of color, tracing, and spoken syllable practice conditions on the accuracy of articulation performance. After determining means and standard deviations (see Table 1), we conducted preliminary analyses (see Supplemental Document, available online: Full Statistics Report) and determined there was no effect of song ($p = .529$) or order of practice conditions ($p = .63$). The mean accuracy rate for slurs approached a ceiling effect on Day 1 ($M = 94.7\%$ accuracy, $SD = 10.2\%$) and Day 2 ($M = 95.6\%$ accuracy, $SD = 6.4\%$). Therefore, we did not include slur accuracy in further analysis. Due to the small sample size and violations of normality, we conducted a nonparametric analysis using Friedman's analysis of variance with number of accent errors Day 1, accent errors Day 2, staccato errors Day 1, and staccato errors Day 2. This omnibus test indicated a statistically significant difference, $\chi^2(4) = 59.723$, $p < .001$. Follow-up Wilcoxon Signed Ranks Tests indicated significantly more accents were missed than staccatos on each pairwise comparison ($p < .001$). However, there were no significant differences in number of errors from Day 1 to Day 2 for accents ($p = .192$) or staccatos ($p = .969$). Musicians generally retained accuracy levels from Day 1 to Day 2.

We selected four follow-up pairwise comparisons based on differences in means (see Table 1). For playing staccatos on Day 2, the Draw Red condition resulted in significantly fewer errors than the Speak Syllables condition (Wilcoxon Signed Ranks Test, $Z = -2.648$, $p = .008$). The Red Articulation condition on Day 2 also resulted in fewer staccato errors than the Speak Syllables condition, although not at the level of significance set for

Table 1. Mean and Standard Deviations for Articulation Percent Correct by Practice Condition.

	Day 1 acquisition			Day 2 retention		
Conditions	Slur, *M* (*SD*)	Accent, *M* (*SD*)	Staccato, *M* (*SD*)	Slur, *M* (*SD*)	Accent, *M* (*SD*)	Staccato, *Mean (SD)*
Control	93.3 (14.1)	47.0 (37.2)	65.5 (36.1)	95.4 (5.1)	56.0 (40.5)	69.0 (40.0)
Draw Black	92.2 (14.4)	45.3 (39.3)	60.9 (40.4)	95.3 (7.8)	46.9 (36.9)	65.6 (40.8)
Draw Red	96.1 (5.6)	57.0 (38.2)	71.0 (41.1)	95.6 (6.4)	59.0 (35.5)	76.5 (38.8)
Red Articulation	95.5 (7.0)	47.5 (37.0)	68.5 (39.7)	95.8 (6.2)	47.0 (35.2)	71.5 (36.0)
Syllables	96.5 (6.3)	56.3 (38.1)	66.1 (41.8)	96.8 (5.9)	51.0 (42.0)	59.4 (43.3)

Note. Underlined percentages are the highest scoring condition.

Table 2. Kendall's tau-b Correlations Among Articulation Accuracy and Working Memory.

Variable	1	2	3	4	5	6	7
1. Working Memory	—						
2. Slurs on Day 1	.271**	—					
3. Accents on Day 1	.223**	.164*	—				
4. Staccatos on Day 1	.262**	.324**	.446**	—			
5. Slurs on Day 2	.008	.336**	.250**	.333**	—		
6. Accents on Day 2	.020	.043	.536**	.291**	.304**	—	
7. Staccatos on Day 2	.062	.123	.387**	.576**	.382**	.458**	—

*$p < .05$. **$p < .01$. Two-tailed.

this analysis ($Z = -2.236$, $p = .025$). Comparison of the Day 1 Draw Red versus Day 1 Draw Black condition was not significant ($p = .049$), nor was it significant on Day 2 ($p = .114$).

Our second research question addressed the relationship between working memory and the ability to accurately play articulation. The mean number of items remembered in the forward digit span was 5.6 items ($SD = 1.0$; range 4–7). We used Kendall's tau-b correlation to analyze these relationships, and those results are presented in Table 2. Digit span was significantly related to percent correct slurs, accents, and staccatos on Day 1 ($p = .002$) but not on Day 2 ($p = .407$).

Discussion

To study the learning of reading and performing articulation, we compared the effects of four experimental practice conditions to a Control condition. The college woodwind players in this study were most attentive to playing slurs, staccatos, and accents, respectively. We found some evidence to support the use of tracing with color when learning articulation in new music. In addition, we examined the role of working memory in reading and performing articulation. Working memory was significantly related to articulation accuracy on the first day of practice but not on the second day of practice.

Our first research question was, "What are the effects of color, tracing, and saying syllables on articulation performance accuracy?" Overall, our results indicated that tracing in color or seeing red articulation markings may improve performance accuracy. This evidence was mixed, however, as tracing or seeing red articulation did not always result in superior performance in comparison with noncolored conditions. The effect of speaking syllables was neutral for playing slurs and inconsistent for playing accents and staccatos.

When participants traced in red over the articulation markings, that condition led to the highest accuracy rates for staccatos and accents on Days 1 and 2, although only one pairwise comparison was statistically significant. This positive result from marking music is consistent with findings from some self-regulated practice research (Miksza, 2015; Miksza et al., 2012), although it is not known if students used color in those studies. In the present study, drawing in red (but not in black) and seeing red articulation may have engaged students' working memory and attention for articulation marks. Although the colored conditions were not always statistically better than the non-colored conditions, the mean accuracy scores for accents and staccatos were best in the Draw Red condition. This result may have meaning in classroom or audition settings. The differences between mean accuracy rates shown in Table 1 could easily separate students who earn certain grades on a playing test or seats in an honor ensemble. Middle school band students benefitted from color highlighting in their music, even though they did not do the highlighting themselves (Banister, 1994). Color-coding was not found to be helpful with elementary students who were learning rhythm or pitch

names (Rogers, 1991, 1996). It is presumptuous to draw conclusions among these studies because of the differences in ages, music experience, and skill/concept being tested. Future research could separate these variables. We only used the color red in this study because it stands out well on a white page of black notation. Colors that do not contrast well against black and white, such as yellow or pastels, may not be as effective. Future researchers could examine the effect of letting students choose their own color.

Our second research question was, "What is the relationship between working memory and articulation performance accuracy?" Working memory is needed to hold information being used in the present (Baddeley, 1986). As a musician reads a staff of music, the pitches, rhythms, and expressive markings flow into and out of working memory. Because working memory has a limited capacity, it may follow that musicians with a larger working memory capacity are able to play more marks on the page than musicians with a smaller working memory. Similar to results of a sightreading study (Meinz & Hambrick, 2010), our results showed this was true on the first day of practice but not on the second day of practice. This difference may be due to increasing familiarity with the music. On the first day of practicing, each element is new—key signature, pitch sequences, rhythms, and expressive marking—resulting in a high load for working memory (Maes et al., 2015). By the second day of practice, participants may not have thought about the rhythm because they knew it was all eighth notes. They had likely started to chunk groups of notes into arpeggio or other patterns (Chase & Simon, 1973; Goolsby, 1994; Sloboda, 1984), and they were more accustomed to playing in the key signature of each exercise. By not having to pay attention to so many individual elements of performance, they had more working memory available to pay attention to the articulation markings. Although this explanation makes theoretical sense, it is only partially supported by our results. The accuracy rates for accents and staccatos on Day 2 ranged from 46.9% to 76.5%. Some participants were still not able to use working memory to play accents and staccatos.

The design of our study did not allow us to investigate whether the musicians had an inner aural model of the exercises. We expect that college instrumentalists would have an aural model for an accented note, as recommended by Mainwaring (1951), but it is not known if a general model for an accent is sufficient. An inner aural model that is complete with all articulations may be needed in order to perform all the nuances of a specific notated exercise (Bishop et al., 2013; Drai-Zerbib et al., 2012; Rosenthal et al., 1988; Simoens & Tervaniemi, 2013). Given that participants had less than 3 minutes with each excerpt, they may not have had time to fully form such a representation. Future research could explore how the fidelity of a musician's inner model relates to their accuracy in performing notation.

Results of this study raise a number of questions about college woodwind players performing articulation. These college musicians prioritized playing slurs over staccatos and accents. Could this be an artifact of beginning method books, which often introduce slurs before other articulations? Alternatively, had their previous teachers given more feedback about slurs than about staccatos and accents? Perhaps the size of the articulation is a critical factor, as slurs are simply bigger than staccatos? Did participants need more than one day of practice with each strategy? Next, this study only included woodwind players whose ability levels enabled them to participate in college music ensembles. Future research using a similar design with string, brass, and percussion players of varying ages and ability levels could reveal similarities and differences in the effects of visual and kinesthetic practice conditions.

Recommendations for Practitioners

For many beginning school band students, commercial method books are the primary written materials they use. The first printed articulation in band books is usually the slur. Several pages later, staccatos or accents make their debut (Lautzenheiser et al., 2004). It is logical that method books limit the amount of new information presented at any one time because too much new information can impede learning (Sweller, 1988). One way to manage cognitive load in beginning students while still introducing articulations is to first have students play through the pitches and approximate rhythm of a new piece. Next, have them trace over the articulation markings using a bright color. Tracing may be more effective than a highlight swipe because tracing requires the student to give more attention to the shape of the articulation. Next, have students play sections of pitches with the correct articulation but with each note at the same duration. As practice or instruction continues, the goal is to work toward playing the correct pitch, rhythm, and articulation. After students are fluent with the exercise, give them other versions of the exercise that have the same pitches and rhythms, but different articulation. Alternatively, songs early in method books can first be learned as printed. Next, students draw in instances of one type of articulation. When they can play that version of the exercise, they should draw in another kind of articulation. This learning sequence is for beginners who have high levels of cognitive load simply from producing sound, finding fingerings or slide positions, and playing rhythm. As these basic skills become automated, articulations should be included from the first attempts to practice new music.

In order for students to be successful at reading music, the level of difficulty needs to be appropriate to their skill level (Gudmundsdottir, 2010). The use of developmentally appropriate repertoire allows experienced students to play pitches, rhythms, and articulations from early on in practice, rather than waiting to add articulation after the pitches and rhythms are learned. Students should focus on playing a holistically correct note (pitch, rhythm, articulation, and dynamics) in order to develop the correct inner aural model (Drai-Zerbib et al., 2012). Without the correct inner aural model, students will not be able to detect their own performance errors (Schmidt, 1975, 2003).

Finally, encouraging beginning and experienced woodwind players to perform all elements of the notation can be challenging. When students are in rehearsal or at their lessons, teachers can remind students about articulation or demonstrate how articulation brings music to life. Teachers have much less impact on the time students spend practicing alone. Therefore, introducing color as a practice strategy may help students improve their performance accuracy when playing at home. In this study, we used color in purposeful applications, rather than telling students to indiscriminately highlight every marking on the page. The most effective strategy was for students to trace over the articulation markings with color before they started physical practice. This targeted approach to using color may minimize limitations on working memory, thereby enabling students to incorporate articulation earlier and more permanently in the learning process.

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ORCID iD

Laura A. Stambaugh https://orcid.org/0000-0002-7459-5890

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References

Baddeley, A. D. (1986). *Working memory*. Oxford University Press.

Banister, S. (1994). The effects of highlighting on the musicality of middle school band students' performance. *Contributions to Music Education*, *21*, 64–72.

Bishop, L., Bailes, F., & Dean, R. T. (2013). Musical imagery and the planning of dynamics and articulation during performance. *Music Perception: An Interdisciplinary Journal*, *31*(2), 97–117. http://doi.org/10.1525/mp.2013.31.2.97

Bongiorno, F. J. (1995a). Developing saxophone articulation: Part I, starting the tone. *Saxophone Journal*, *20*(2), 60–61.

Bongiorno, F. J. (1995b). Developing saxophone articulation: Part II, speed and control. *Saxophone Journal*, *20*(3), 68–69.

Bongiorno, F. J. (1996a). Developing saxophone articulation: Part III, advanced techniques. *Saxophone Journal*, *20*(4), 40–41.

Bongiorno, F. J. (1996b). Playing on both sides of the fence: Performing classical and jazz saxophone, Part II. *Saxophone Journal*, *20*(6), 30–31.

Brymer, J. (1976). *Yehudi Menuhin music guides: Clarinet*. Schirmer Books.

Chase, W. G., & Simon, H. A. (1973). Perception in chess. *Cognitive Psychology*, *4*(1), 55–81. https://doi.org/10.1016/0010–0285(73)90004–2

Drai-Zerbib, V., & Baccino, T. (2005). L'expertise dans la lecture musicale: Intégration intermodale [Expertise in music playback: Intermodal integration]. *L'année Psychologique*, *105*(3), 387–422. http://doi.org/10.3406/psy.2005.29702

Drai-Zerbib, V., Baccino, T., & Bigand, E. (2012). Sight-reading expertise: Cross-modality integration investigated using eye tracking. *Psychology of Music*, *40*(2), 216–235. http://doi.org/10.1177/0305735610394710

Duke, R. A., & Davis, C. M. (2006). Procedural memory consolidation in the performance of brief keyboard sequences. *Journal of Research in Music Education*, *54*(2), 111–124. https://doi.org/10.1177/002242940605400203

Goolsby, T. W. (1994). Eye movement in music reading: Effects of reading ability, notational complexity, and encounters. *Music Perception: An Interdisciplinary Journal*, *12*(1), 77–96. https://doi.org/10.2307/40285757

Gordon, E. E. (2001). *Preparatory, audiation, and music learning theory*. GIA.

Gracenotes, LLC (2019). *Sight reading factory* [Computer software website]. https://www.sightreadingfactory.com/

Griswold, H. G. (2008). *Teaching woodwinds*. Pearson.

Gudmundsdottir, H. R. (2010). Advances in music-reading research. *Music Education Research*, *12*(4), 331–338. http://doi.org/10.1080/14613808.2010.504809

Guy, L. (2010). Setting the stage for our current topic: Articulation. *Clarinet*, *38*(1), 24–27.

Kohut, D. (1973). *Instrumental music pedagogy: Teaching techniques for school band and orchestra directors*. Prentice-Hall.

Kopiez, R., Weihs, C., Ligges, U., & Lee, J. I. (2006). Classification of high and low achievers in a music sight-reading task. *Psychology of Music*, *34*(1), 5–26. https://doi.org/10.1177/0305735606059102

Kuo, Y. T., & Chuang, M. C. (2013). A proposal of a color music notation system on a single melody for music beginners. *International Journal of Music Education*, *31*(4), 394–412. https://doi.org/10.1177/0255761413489082

Lautzenheiser, T., Higgins, J., Menghini, C., Lavender, P., Rhodes, T. C., & Bierschenk, D. (2004). *Essential*

elements for band: Bb tenor saxophone book 1. Hal Leonard Corporation.

Maes, P.-J., Wanderley, M. M., & Palmer, C. (2015). The role of working memory in the temporal control of discrete and continuous movements. *Experimental Brain Research*, *233*(1), 263–273. https://doi.org/10.1007/s00221–014–4108–5

Mainwaring, J. (1951). Psychological factors in the teaching of music. *British Journal of Educational Psychology*, *21*(2), 105–121. https://doi.org/10.1111/j.2044–8279.1951.tb02789.xC

McPherson, G. E., & Gabrielsson, A. (2002). From sound to sign. In R. Parncutt & G. E. McPherson (Eds.), *The science and psychology of music performance: Creative strategies for teaching and learning* (pp. 99–115). Oxford University Press.

Meinz, E. J., & Hambrick, D. Z. (2010). Deliberate practice is necessary but not sufficient to explain individual differences in piano sight-reading skill: The role of working memory capacity. *Psychological Science*, *21*(7), 914–919. https://doi.org/10.1177/0956797610373933

Miksza, P. (2015). The effect of self-regulation instruction on the performance achievement, musical self-efficacy, and practicing of advanced wind players. *Psychology of Music*, *43*(2), 219–243. https://doi.org/10.1177/0305735613500832

Miksza, P., Prichard, S., & Sorbo, D. (2012). An observational study of intermediate band students' self-regulated practice behaviors. *Journal of Research in Music Education*, *60*(3), 254–266. https://doi.org/10.1177/0022429412455201

Penttinen, M., Huovinen, E., & Ylitalo, A. K. (2013). Silent music reading: Amateur musicians' visual processing and descriptive skill. *Musicae Scientiae*, *17*(2), 198–216. http://doi.org/10.1177/1029864912474288

Quantz, J. J. (1985). *On playing the flute*. (E. E. Reilly, Trans.; 2nd ed.). Schirmer Books. (Original work published 1752).

Richardson, J. T. E. (2007). Measures of short-term memory: A historical review. *Cortex*, *43*(5), 635–650. https://doi.org/10.1016/S0010–9452(08)70493–3

Rogers, G. L. (1991). Effect of color-coded notation on music achievement of elementary instrumental students. *Journal of Research in Music Education*, *39*(1), 64–73. http://doi.org/10.1104/pp.110.167569

Rogers, G. L. (1996). Effect of colored rhythmic notation on music-reading skills of elementary students. *Journal of Research in Music Education*, *44*(1), 15–25. http://doi.org/10.2307/3345410

Rosenthal, R. K., Wilson, M., Evans, M., & Greenwalt, L. (1988). Effects of different practice conditions on advanced instrumentalists' performance accuracy. *Journal of Research in Music Education*, *36*(4), 250–257. http://doi.org/10.2307/3344877

Sala, G., & Gobet, F. (2017). Does far transfer exist? Negative evidence from chess, music, and working memory training. *Current Directions in Psychological Science*, *26*(6), 515–520. https://doi.org/10.1177/0963721417712760

Schmidt, R. A. (1975). A schema theory of discrete motor skill learning. *Psychological Review*, *82*(4), 225–260. https://doi.org/10.1037/h0076770

Schmidt, R. A. (2003). Motor schema theory after 27 years: Reflections and implications for a new theory. *Research Quarterly for Exercise and Sport*, *74*(4), 366–375. http://doi.org/10.1080/02701367.2003.10609106.

Schön, D., & Besson, M. (2002). Processing pitch and duration in music reading: A RT–ERP study. *Neuropsychologia*, *40*(7), 868–878. https://doi.org/10.1016/S0028–3932(01)00170–1

Seidler, R. D., Bo, J., & Anguera, J. A. (2012). Neurocognitive contributions to motor skill learning: The role of working memory. *Journal of Motor Behavior*, *44*(6), 445–453. https://doi.org/10.1080/00222895.2012.672348

Sharp, M. D. (1988). *Relationships among model performances and performances by piano majors: Articulation and dynamics in selected Bach fugal excerpts* (Publication No. 303583563) [Doctoral dissertation, The Louisiana State University and Agricultural and Mechanical College]. ProQuest Dissertations & Theses A&I.

Silvey, B. A., Montemayor, M., & Baumgartner, C. M. (2017). An observational study of score study practices among undergraduate instrumental music education majors. *Journal of Research in Music Education*, *65*(1), 52–71. https://doi.org/10.1177/0022429416688700

Simoens, V. L., & Tervaniemi, M. (2013). Auditory short-term memory activation during score reading. *PLOS ONE*, *8*(1), e53691. https://doi.org/10.1371/journal.pone.0053691

Sloboda, J. A. (1984). Experimental studies of music reading: A review. *Music Perception: An Interdisciplinary Journal*, *2*(2), 222–236.

Stambaugh, L. A. (2013). Differential effects of cognitive load on university wind students' practice. *Psychology of Music*, *41*(6), 749–763. https://doi.org/10.1177/0305735612449505

Sullivan, J. (2006). The effects of syllabic articulation instruction on woodwind articulation accuracy. *Contributions to Music Education*, *33*(1), 59–70.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science*, *12*, 257–285. https://doi.org/10.1207/s15516709cog1202_4

Team Audacity (2019). *Audacity* (Version 2.3.1) [Computer software]. https://audacityteam.org/

Wechsler, D. (1997). *Wechsler Adult Intelligence Scale* (3rd ed.). Psychological Corporation.

Westphal, F. W. (1985). *Guide to teaching woodwinds*. Wm. C. Brown Publishers.

Wilmer, C. (1995). Color-encoded music scores: What visual communication can do for music reading. *Leonardo*, *28*(2), 129–136. https://doi.org/10.2307/1576134

Woods, D. L., Kishiyama, M. M., Yund, E. W., Herron, T. J., Edwards, B., Poliva, O., Hink, R. F., & Reed, B. (2011). Improving digit span assessment of short-term verbal memory. *Journal of Clinical and Experimental Neuropsychology*, *33*(1), 101–111. https://doi.org/10.1080/13803395.2010.493149

Yarbrough, C., Speer, D., & Parker, S. (1993). Perception and performance of dynamics and articulation among young pianists. *Bulletin of the Council for Research in Music Education*, *118*, 33–43. https://www.jstor.org/stable/40318591

Zimmer, S. J. (2002). *A fiber optic investigation of articulation differences between selected saxophonists proficient in both jazz and orchestral performance styles* (Publication No. 250880570) [Doctoral dissertation, Arizona State University]. ProQuest Dissertations & Theses A&I.