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A Comparison of the Efficacy of Individual and Collaborative Music Learning in Ensemble Rehearsals

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Abstract

Collaboration is essential in learning ensemble music. It is unclear, however, whether an individual benefits more from collaborative or individual rehearsal in the initial stages of such learning. In nonmusical domains, the effect of collaboration has been mixed, sometimes enhancing and sometimes inhibiting an individual's learning process. In music, observational studies suggest collaborative rehearsal is indeed effective. In the present study, we compared collaborative and individual rehearsal directly and experimentally. Vocalists studied some pieces alone (with or without accompaniment) and some pieces collaboratively in groups of three. Their immediate performance and memory results indicated that accompaniment in solo sessions enhanced individual learning, and more importantly, collaboration had a detrimental effect. The findings are discussed within the general framework of blocking or free-riding theories.

Keywords

music education, collaboration, learning, rehearsal

A member of a musical ensemble needs to execute his or her own part flawlessly as well as contribute to the overall performance in a manner that helps produce a cohesive, unified sound. The latter component requires working effectively with fellow ensemble members. Each person is expected to be attuned not only to the written notes in the piece but also to the spontaneous performance of the music by the entire group

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(Seddon, 2005). Attaining excellence in ensemble playing thus depends on finding the balance between individual interpretations and collective sound, and to do so, musicians often rehearse individual parts both in and out of context of the ensemble (Lim, 2013). The convention is for individuals to learn their assigned parts prior to group rehearsal (Sawyer, 2006). However, some ensembles have found success in mandating that initial learning be done collaboratively instead so that members may learn their parts in context before individual rehearsal (Seddon & Biasutti, 2009). Indeed, in an observational study, Ginsborg and King (2012) have found such initial collaborative rehearsal to be quite effective and efficient, although they did not compare it to individual rehearsal.

Music ensembles are well-characterized examples of interactive work groups (Young & Colman, 1979). Indeed, ensembles as work groups have been the subject of several studies on group dynamics and group work efficiency in music psychology (e.g., Ford & Davidson, 2003; Ginsborg & King, 2012; Lim, 2013) as well as in business administrative science (e.g., Murnighan & Conlon, 1991; Seddon & Biasutti, 2009) and sociology (e.g., Malhotra, 1981). Collaboration has long been the topic of interest in studying work groups' learning in general. For instance, collaboration has been shown to facilitate individual efforts in intellectual tasks, a phenomenon termed "social facilitation" (e.g., Zajonc, 1965). Further extrapolations from this finding have led to the description of group members as units of a system that engage in collective acquisition, storage, and retrieval of learned information (Larson & Christensen, 1993; Wegner, 1986). Finally, observational research also has found collaboration to be related to more successful work in such realms as product management (Austin, 2003) and classroom instruction (Jackson & Moreland, 2009).

However, collaboration does not always foster the most efficient work environment. For example, interactive work may reduce the individual's motivation to seek outside opinions. Minson and Mueller (2012) showed that when dyads (compared with individuals) were given the opportunity to consult outside opinion to answer trivia questions, they were less likely to utilize this opportunity; in turn, they were less accurate than individuals. Thus, collaboration may create a sense of false confidence while completing a task.

The evidence for the efficacy of collaboration within the realm of learning is also mixed. For instance, Hinsz (1990) showed that students watching a videotaped job interview were better at answering subsequent true/false questions about the interview when working as a group than when working individually. Similarly, Liang, Moreland, and Argote (1995) found that individuals who trained together in how to assemble a transistor radio remembered more of the instructions and made fewer errors compared to those who trained individually before working collaboratively.

However, Weldon and Bellinger (1997) found that participants' memory for words and pictures was worse when they worked in a group than when they worked alone, and Tindale and Sheffey (2002) found that learning trigram, or consonant-vowel-consonant, lists was best when participants learned them independently. Such inhibitory effects have been attributed to "blocked" individual productivity or reduced individual motivation during collaboration, where members might "free-ride" off other members,

assuming their individual contribution to be less valuable than what others can provide (e.g., Davis, 1969; Latane, Williams, & Harkins, 1979; Tindale & Sheffey, 2002). Additionally, as Stroebe and Diehl (1994) suggest, collaborating group members may not be as focused and thus may spend less time learning the material.

In music ensembles, members need to become proficient in playing their individual parts, but there is no empirical evidence or consensus on the most effective rehearsal strategy for optimal individual learning. Given the mixed results in the nonmusical domain, collaboration could enhance or inhibit individual learning. One possibility is that collaboration may not inhibit individual learning in music because the study material is inherently different from those in other domains. For instance, in studies with verbal materials showing collaborative inhibition (e.g., Tindale & Sheffey, 2002), each group member learned the same set of material, a redundancy that could have led to members' blocking each other's acquisition or "free-riding" off others (Stroebe & Diehl, 1994). Musical material is different, however, in that it often contains several different parts that work interactively. Individuals in groups learning this material collaboratively are exposed to each part while learning their own specific part completely rather than learning any redundant information. On the other hand, the interactive nature of musical compositions may, in and of itself, encourage behavior that causes collaborative inhibition. For instance, one ensemble member may demand rehearsal of a certain section of a song, reducing the amount of time that other members have to rehearse parts they find challenging. This theoretically could be a form of production blocking relatively unique to the performing arts. In addition, free-riding may occur when ensemble members rely on note and rhythm cues from other members' parts, never properly acquiring independent cues themselves.

To date, studies on individual differences in music ensemble learning have focused mainly on verbal and nonverbal communication among members and the overall effectiveness of specific rehearsal strategies for ensembles (e.g., Seddon & Biasutti, 2009). There exists very little research into individual outcomes of these various rehearsal tendencies. Recently, Lim (2013) explored the effectiveness of collaboration in vocal musicians by interviewing members of a professional a cappella group about their personal characteristics (e.g., musical training, rehearsal habits, etc.), interpersonal relations (e.g., conflict resolution, friendships, etc.), and mind-set on group organizational structure (e.g., leadership, decision making, etc.). Lim concluded that the convergence of these characteristics led to the musical success of the ensemble, although individual learning outcomes were not included in the comparisons.

The primary aim our research was to test experimentally whether collaboration is beneficial or detrimental to individual learning of music. We hypothesized social facilitation (e.g., Zajonc, 1965) or enhanced communication (e.g., Ginsborg & King, 2012) would predict collaborative learning to be more beneficial, whereas production blocking or free-riding (e.g., Stroebe & Diehl, 1994) would predict collaborative learning to be more detrimental. We should note that in general, the term *collaboration* has been used somewhat loosely in the literature, often referring to it as any interactive processes that occur among the group members during the learning period (e.g., Basden, Basden, Bryner, & Thomas, 1997). This may be because different types of tasks likely

would involve different steps or aspects that could be relevant to collaboration. Consistent with this approach, we also did not limit the definition of collaboration to a particular set of behaviors and accepted any interactive processes relevant to the task during group learning as collaboration.

We compared the same vocalists' acquisition of music in both individual and collaborative learning environments. Of interest was the vocalists' performance as well as memory for the music (i.e., with and without sheet music). Even though in verbal materials learning is often synonymous with memory, in music, it also can refer to the extent to which material can be played or sung fluently with sheet music as a guide. Thus, we tested both physical learning (fluency of performance with sheet music) and mental learning (performance from memory). In addition, we divided the individual learning condition into two types: with or without accompaniment. The purpose was to guard against the possibility that, if collaborative rehearsal did turn out to be more effective, it could not be explained simply by the presence of extra musical information supplied by the other parts (cf. Hinsz, 1990). We also kept track of the participants' learning time to see if any differences between individual and collaborative learning might be attributable simply to the amount of time spent learning (e.g., Metcalfe & Kornell, 2003).

Finally, as a secondary aim, we looked at the relationship between participants' confidence levels after learning and their actual performance. Heath and Gonzalez (1995) demonstrated that participants had greater confidence in their predictions after collaborating with others than when working alone. In the present case, these judgments would be equivalent to judgments of learning (Nelson & Narens, 1990). Of interest was whether such judgments in a learning scenario also would be affected by collaboration and possibly influence learning efficiency (cf. Peynircioglu, Brandler, Hohman, & Knutson, 2013).

Method

Participants

The participants were 48 adults from the community around American University, including 25 undergraduates. In all, there were 15 men and 33 women, with a mean age of 28 (ranging from 18 to 64). Nonstudents were compensated $15 for their participation. Students were given the option of $15 compensation or extra credit in their psychology courses.

All participants were required to have some vocal music experience. Their level of musical accomplishment was assessed through an initial screening in which we evaluated note correctness, a combination of the average of pitch and rhythmic accuracy scores. During this initial screening, participants were sent both sheet music and an audio clip of a short piece (available as online supplemental materials, http://jrme.sagepub.com/supplemental). They were asked to practice this piece and then send back a recording of their rendition of it. The pitch accuracy of each recording was determined by the number of pitches sung correctly out of the total number of written

pitches. A pitch was termed correct if it was within a semitone of the written pitch. Similarly, the rhythmic accuracy of each recording was determined by the number of rhythms sung as intended out of the total number of rhythmic transitions. For example, in one measure containing two notes, there would be one rhythmic transition. A rhythmic transition was termed correct if it was within a 16th note of the written transition. On average, participants scored greater than 99.00% in note correctness (range 93.68% to 100%). The mean reported time to learn was 14.4 min (range 1–60 min).

A postexperimental form assessed for prior musical experience. Overall, the participants had a mean of 13.1 years performing vocal music (ranging from 0–55 years), 6.3 years of formal vocal music training (ranging from 0–22 years), and 5.5 years formal training to read vocal music (ranging from 0–22 years). Thirty-seven participants also played another instrument (for a mean of 6.7 years). Finally, we gathered information about participants' vocal or choral group membership during the recruitment phase to avoid the formation of any groups composed of people who previously had sung with each other. Six university-affiliated vocal groups and 18 professional/adult vocal groups were represented in the study.

Materials

Three novel short pieces of vocal music were written by one of the researchers and were approved by a professional composer with respect to appropriateness and equivalent-part difficulty. The primary purpose was the creation of relatively easy pieces with a few unexpected twists to prevent ceiling effects in performance. The songs had no lyrics and were intended to be sung on the syllable *doo*. Song C was used in the initial screening to determine musicianship and singing level of the participants. Songs A and B were used in the main experiment and had three parts (available at http://jrme.sagepub.com/supplemental). Because of counterbalancing measures that ensured the appearance of both songs in both experimental conditions equally often, no special measures were taken to make the difficulty levels comparable. Generally, a music ensemble is thought of as a group with more than two members. We used three-member ensembles because previous research in nonmusical domains suggests that groups of four or more typically exhibit collaborative inhibition, whereas with groups of three, there is collaborative inhibition as often as collaborative facilitation (e.g., Basden, Basden, & Henry, 2000; Bouchard & Hare, 1970).

In order to gauge the difficulty of our musical samples, we asked six volunteer singers who did not participate in the main experiment to learn one of the vocal parts of Song A or Song B, keeping track of how long it took them to become proficient in singing it. The longest time taken to learn any of the parts was reported to be 27 min, so we set the maximum rehearsal time for all sessions in the experiment at 30 min.

The part arrangements were customized for each session such that female participants were given parts that fell in the range of B3 to C5, and male participants' parts fell in the range of B2 to C4. If the part assigned was still out of a given participant's comfortable vocal range, he or she was encouraged to sing an octave higher or lower depending on preference.

During the initial practice period, audio clips were presented over Beats headphones and, during the learning period, through RadioShack AMX-18 speakers. During learning, the audio stimuli were queued using Windows Media Player on a Dell computer. During the test performances requiring accompanying audio parts, the clips were played on a Samsung Galaxy Tab device. Participants were also given the option of using a Kawai FS630 keyboard for aiding learning. The researcher captured audio recordings of participant performances at the end of each experimental session using Audacity software and a Shure SM 58 microphone. Group sessions were video recorded using a Samsung Galaxy phone.

For this study, we created a simple survey that asked participants to rate their relative enjoyment in learning alone and with others on a 5-point Likert scale, ranging from 1, *not a lot*, to 5, *a lot*. We called this measure "enjoyment of learning" and gave the short survey both prior to and following each experimental session. Given that there is often a strong social benefit of belonging to a choir, separate from a desire to make music (Bailey, 2005), we wanted to see if the main results would be influenced by the participants' attitudes toward group versus individual singing.

"Judgments of learning" (JOL) were assessed after learning but prior to each performance by asking participants to rate how well they expected to perform on a 5-point Likert scale ranging from *poor* to *perfect*. Similarly, confidence was assessed following each performance by asking participants to judge the quality of their performance on a 5-point Likert scale ranging from *poor* to *perfect*.

Design and Procedure

Whether learning occurred individually or collaboratively was a within-subject manipulation, and the amount of information in the individual learning condition was a between-subject manipulation. Each participant was assigned randomly to one of two individual ("solo") session conditions: independent or aided, with 24 participants in each condition. In addition, all participants participated in a collaborative ("group") session. The order of session conditions attended and the order of songs learned were counterbalanced across the participants. Half of the participants attended their solo session first and the group session second and vice versa for the other half. Participants were assigned Song A in one session and Song B in the other session in such a way that half of the participants who attended their solo session first were given Song A in that session and the other half Song B and similarly with the participants who attended their group session first. The assignment of specific vocal lines to participants in each song was random.

Each group comprised three participants who had been assigned to the same solo condition type, the same corresponding song, and the same session order. Participants' prior musical experience, screening score, and outside choir membership also were taken into consideration when forming groups. Details of group composition can be found in Table S1, available online (http://jrme.sagepub.com/supplemental). Prior to attending an experimental session, all participants were screened via e-mail to establish their music learning level. The e-mail prompt contained a brief survey regarding

their singing and other musical experiences. Participants also received Song C (sheet music as a PDF file and an audio clip as a MIDI file) and were instructed to practice the piece until they felt comfortable singing it using the sheet music. Participants then sang and recorded the piece and sent the researcher this recording along with a record of how long it had taken them to learn the piece. We also ensured that the participants assigned to any one group did not have any experience singing together prior to the study because there are mixed results in the literature about how familiarity with other persons affects group-based tasks, some findings suggesting enhancement (e.g., Wegner, Erber, & Raymond, 1991) and others inhibition (e.g., Hollingshead,1998).

During the first session, participants filled out an informed consent form, an audio/video release form, and the preliminary enjoyment-of-learning survey. Then, they began the learning procedure, which differed between the solo and group conditions and which further differed between the solo independent and solo aided conditions. In addition, to ensure that learning indeed was taking place, some participants chosen at random ($n = 18$) completed a baseline test in the beginning of both solo and group sessions. This test consisted of listening to their assigned part once and then performing it one time while looking at the sheet music but without rehearsal and without accompaniment. All participants answered the JOL question prior to the test and the confidence questions after the test.

In solo independent learning sessions, the participants were told that the goal was to learn to sing a musical piece to the best of their ability and to perform it both using sheet music and from memory. They were given the sheet music for a part drawn from either Song A or Song B, and a MIDI audio clip of this part was played once. They then were told that they would be given 30 min for rehearsal and were asked to use as much of the allotted time as needed to rehearse. During rehearsal, they were permitted to replay the MIDI recording as often as they wanted, play notes on an electric keyboard, and read from the sheet music. They were not permitted to use any other instruments or write anything down on the sheet music or separate paper. The researcher remained in the room in case of technical or equipment error but otherwise did not interfere with the learning process. The Samsung Galaxy phone (used to record sessions in the group condition) was placed in the room, but no recording was made in either solo learning condition. After rehearsal, the participant informed the researcher when he or she was ready to proceed to the test. Unbeknownst to the participant, the time taken to learn was recorded by the researcher. If the time limit expired, participants were instructed to stop rehearsal, and 30 min was recorded as the time taken.

Following the learning phase, participants were asked to perform the learned music twice for the researcher. The first performance was with sheet music, and the second performance was from memory. No accompaniment was played during either test. A digital audio recording of the two performances was made for subsequent scoring purposes.

In solo aided sessions, participants were provided with the accompaniment to their assigned part, consisting of the second and third parts of the target song. Participants received sheet music of the entire score, with their assigned part highlighted in yellow. Participants were instructed to focus on the highlighted part, but keep in mind that the

accompanying parts would be played while they performed after learning. During rehearsal, participants were given access to both their own part as a solo MIDI audio clip and a MIDI audio clip that contained all three parts of the song sample, with the accompanying parts at 50% to 75% volume. Participants were instructed to rehearse using the three-part clip at least once since they would be performing with accompaniment. The remaining procedure was identical to that of the solo independent condition.

During the learning phase of group sessions, the three participants were given copies of the sheet music with their assigned part highlighted in yellow and were asked to collaborate. They were told that they would be evaluated individually, however, during the test singing of the assigned part. Then, the participants took turns leaving the room, while one participant stayed and listened to a MIDI audio clip of his or her own part, without background accompaniment. When each participant had listened to his or her part, the group reconvened for learning. The remaining procedure was similar to that of the solo aided sessions, except that all three parts of the audio clip were at the same volume level and the Samsung Galaxy phone video camera was recording the session for future scoring. During the testing period, two participants were asked to step out of the room and were instructed to not practice their parts any further, while one participant remained in the room for the test. Otherwise, the testing procedure was identical to that in the solo aided condition.

Those who participated in the solo conditions first (either independent or aided) returned to participate in the group session an average of 19.9 days later (range: 1–57 days). Those who participated in the group condition first returned an average of 12.8 days later (range: 0–64 days) for the solo session. At the conclusion of the second session, each participant also completed final enjoyment-of-learning and musical experience surveys.

Results and Conclusions

Note correctness scoring (the average of pitch and rhythmic accuracy subscores) was used to quantify physical learning (called the "performance" score, for recordings taken with sheet music) and mental learning (called the "memory" score, for recordings taken while participants performed from memory) for each participant.

Pitch and rhythm scoring were done by one of the researchers and a colleague (blind to learning condition), and the interrater reliability was 93.5%. We also should note that the results of our baseline test conducted with 18 of the participants confirmed that participants' performance improved on average 18% following the learning session, $t(35) = 2.39$, $p < .05$, $d = 1.12$. Thus, performance at the end of the sessions did reflect learning and was not a product of simple sight-singing.

Of main interest were any differences between the solo and group learning conditions as well as between the solo independent and solo aided learning conditions with respect to both performance and memory. There were no effects of song (A or B), vocal part (1, 2, or 3), or session order (solo first or group first) on either performance

Table 1. Mean Percentage Correct in Performance and Memory Tests for Pitch (P), Rhythm (R), and Combined Overall Measure (OVR), as a Function of Learning Condition (Solo or Group) and Learning Type.

Learning Condition	Performance			Memory		
	OVR	P	R	OVR	P	R
Solo						
All	.91	.91	.91	.81	.80	.81
Independent	.90	.91	.90	.72	.71	.72
Aided	.90	.91	.93	.90	.89	.90
Group						
All	.83	.80	.86	.67	.63	.71
Independent	.85	.81	.89	.67	.62	.71
Aided	.80	.78	.82	.67	.64	.70

or memory scores (all Fs < 1), and thus, the results were collapsed across these factors for the analyses.

A 2 × 2 ANOVA with learning condition (solo or group) as a within-subject variable and solo learning type (independent or aided) as a between-subject variable showed a main effect of learning condition on overall performance scores, $F(1, 46) = 8.50$, $p < .01$, $\eta^2 = .16$, as well as on memory scores, $F(1, 46) = 10.61$, $p < .01$, $\eta^2 = .19$, with scores in both cases being higher in the solo condition than in the group condition (see Table 1). These results suggest that collaboration inhibited learning for individuals, in terms of both physical and mental learning. Additionally, there were no main effects of the solo learning type on overall performance or memory scores and no interaction between learning condition and solo learning type for performance scores (all p values > .10). However, there was a significant interaction between learning condition and solo learning type for memory scores, $F(1, 46) = 4.59$, $p < .05$, $\eta^2 = .09$. Aided solo learning led to higher memory scores than group learning, $t(23) = 4.06$, $p < .01$, $d = 1.65$, but independent solo learning did not, $t(23) = 0.46$, $p > .10$, $d = .18$.

When pitch and rhythm accuracy components were analyzed separately, for performance, there emerged an effect of learning condition for pitch, $F(1, 46) = 9.95$, $p < .01$, $\eta^2 = .18$, and an effect approaching significance for rhythm, $F(1, 46) = 3.34$, $p < .10$, $\eta^2 = .07$, with solo performance being better than group performance in both cases. There was no effect of solo learning type for either component and no interactions (all p values > .10). Similarly, for memory, there was also an effect of learning condition for pitch, $F(1, 46) = 16.70$, $p < .01$, $\eta^2 = .27$, as well as for rhythm, $F(1, 46) = 5.32$, $p < .05$, $\eta^2 = .10$, and no effects of solo learning type on either pitch or rhythm (both p values > .10). However, there was a significant interaction between learning condition and solo learning type for rhythm, $F(1, 46) = 5.05$, $p < .05$, $\eta^2 = .1$, such that aided solo learning led to higher memory scores than did group learning, $t(23) = 3.49$, $p < .01$, $d = 1.42$, but independent solo learning did not, $t(23) = 0.04$, $p > .10$, $d = .02$, mirroring the interaction with the overall memory scores. Thus, there was no observable

Table 2. Mean Time Spent (Minutes), Initial and Final Enjoyment Scores (1–5), and Judgments of Learning (JOL) and Confidence Ratings for Performance and Memory Tests (1–5) as a Function of Learning Condition (Solo or Group).

Learning Condition	Time	Enjoyment		JOL		Confidence	
		Initial	Final	Performance	Memory	Performance	Memory
Solo	25.15 (6.25)	4.25 (0.91)	3.25 (0.98)	4.35 (0.96)	3.11 (1.17)	3.88 (1.21)	3.17 (1.37)
Group	25.23 (4.52)	4.79 (0.50)	3.96 (0.97)	3.77 (1.04)	2.64 (1.13)	3.65 (1.31)	2.67 (1.28)

Note. Standard deviations in parentheses.

dissociation between pitch and rhythmic processing in showing the inhibitive effect of collaboration.

We also looked at the role of time taken to learn, to determine if it might have mediated the relationship between our conditions and learning. The results for findings of secondary interest are presented in Table 2. Solo time was the total duration taken to rehearse. Group time was extrapolated from the videos of the group rehearsal sessions by the researcher and a colleague (interrater reliability was 94.9%). For each participant, rehearsal time was defined as the total duration he or she was observed singing the assigned part, plus any time the group rehearsal focused on that part or that person exclusively. Thus, although group participants interacted throughout the collaborative rehearsal, it was possible to extract individual rehearsal times based on to the group's decisions to focus on particular sections or particular parts. An ANOVA as before revealed no main effect of learning condition or of solo learning type on time and no interaction (all Fs < 1). Neither collaboration nor having accompaniment during the solo sessions appeared to affect how long participants spent rehearsing; nevertheless, performance was worse after collaborating than after working alone. This suggests that the inhibitory nature of collaboration was due to some other factor than simply being able to rehearse for a longer period of time in a given condition.

Second, participants' stated enjoyment of learning was higher following group learning than following solo learning, $t(47) = 3.13$, $p < .01$, $d = 0.90$, with no differences between independent and aided solo learning types, $p > .10$. Thus, participants enjoyed the act of learning collaboratively, but this social learning preference did not overcome the observed collaborative inhibition in learning (cf. Bailey, 2005).

Finally, we looked at JOL and confidence ratings to see if participants had good metacognitive skills in being able to realize how well they had learned and also whether individual differences in metacognition might affect learning efficiency. JOL ratings given before each test correlated with both performance and memory scores (for performance, $r = .58$ and .74, $p < .01$, before solo and group participations, respectively; for memory, $r = .52$ and .53, $p < .01$, before solo and group participations, respectively). Similarly, confidence ratings given after the test correlated with both performance and memory scores as well (for performance, $r = .65$ and .80, $p < .01$, after solo and group participations, respectively; for memory, $r = .72$ and .76, after solo and group participations, respectively, $p < .01$). There was thus a robust relationship between both types of

Table 3. Performance and Memory Scores as a Function of Participant Experience for Solo and Group Learning Condition.

Experience	Performance	Memory
Low		
Overall	.81	.67
Solo	.85	.70
Group	.77	.63
High		
Overall	.98	.78
Solo	.98	.90
Group	.96	.66

metacognitive ratings and the actual scores (cf. Peynircioglu et al., 2013). However, there were no differences between the solo and group conditions, suggesting that the inhibition observed in collaboration was not influenced by the participants' JOL ratings or confidence levels (cf. Heath & Gonzalez, 1995).

One other potential factor that can influence the results in any study of music learning is individual differences in prior experience. Thus, participants were separated into three groups according to combined average years of vocal music training, performing experience, and music reading experience. A 2 (learning condition: solo or group) × 2 (experience: more or less) ANOVA using only the participants in the top and the bottom thirds with respect to experience (means shown in Table 3) showed no main effect of experience on memory scores but an effect approaching significance for performance scores, $F(1, 30) = 3.95$, $p < .10$, such that those with greater experience scored higher than those with less experience. This validated our self-report measures to some degree. However, there was no interaction between learning condition and experience (both Fs < 1), suggesting that experience did not influence the inhibitory effects of collaboration in either performance or memory.

Discussion

In this study, we compared the efficacy of learning music individually and collaboratively. Earlier observations related to the qualitative advantages for ensemble musicians to engage first in solo rehearsal or first in collaborative rehearsal had suggested that the communicative and interpersonal relations in a collaborating ensemble could lead to greater success (Ginsborg & King, 2012; Lim, 2013). In the present study, we compared the *relative* effectiveness of individual and collaborative learning directly in an experimental setting by looking at actual performance levels.

There was an advantage for vocalists initially learning their assigned parts individually rather than collaboratively. Thus, consistent with Tindale and Sheffey's (2002) findings in the nonmusical domain using word lists, learning appeared to be inhibited when participants were required to work with others. As Stroebe and Diehl

(1994) suggested in their review of collaboration across various nonmusical domains, both production blocking and free-riding may have led to the collaborative inhibition in group learning in musical rehearsals. Participants were required to learn their part in the presence of two other participants, which, in theory, could have aided learning due to the addition of musical information for encoding as well as through social facilitation (Zajonc, 1965). However, in collaborative rehearsals, although each participant appeared to spend just as much time on his or her part as in individual rehearsals, the quality of attention might have been reduced and freedom of choice for exactly what to rehearse and for how long might have been curtailed. In this sense, interacting with others could have blocked individual production. In addition, with other active singers in the room, some participants may have felt self-conscious and thus perhaps less focused on learning and more focused on not appearing inferior to the other ensemble members, also known as evaluation apprehension (Diehl & Stroebe, 1987). Finally, it was also likely that participants were free-riding or focusing less on the material at hand by assuming that other group members would be more responsible.

Our current design did not allow for identifying whether production blocking in any form or free-riding was responsible for the observed inhibition during group sessions or the relative contribution of either. Nevertheless, free-riding seems less of a possibility than does production blocking given that there were relatively similar rehearsal times across all of the sessions and participants knew from the beginning that their *individual* performances would be tested.

To investigate the specific reasons for collaborative inhibition, future studies could focus on assessing member roles during rehearsal or manipulating the group structure in a systematic way. For instance, one could compare performance of the same person in several different types of rehearsals with the same group. Performance after a rehearsal with an assigned leader from outside the group compared to performance after a rehearsal with no such leader would be informative with respect to any negative effects of a leadership structure on collaborative inhibition. Furthermore, any performance differences between when another group member is assigned the role of leader and when the person himself or herself is assigned the role of leader might be informative with respect to teasing apart free-riding from production blocking. That is, to the extent that there emerge differences, better performance when the person is in a leadership role than otherwise would suggest free-riding when he or she is not the leader, whereas worse performance would suggest production blocking, since as a leader, he or she would be expected to place greater emphasis on the learning of others.

We also examined whether physical learning (performance) and mental learning (memory) would differ in their susceptibility to collaborative influences and found no differences. Both similarly were inhibited during collaborative sessions. Mental learning of music is sometimes required, such as in musical theatre, piano performance, or competitive marching band performance, when the use of sheet music would be considered unprofessional. However, much of musical learning is physical, with both rehearsal and performance involving the use of sheet music, such as in orchestra or choir performances, or informal music-making. Both forms of learning are

challenging, of course, but memorization is challenging in a different way because it is relatively independent of technique and sight-reading skills that enhance physical learning and perhaps even inherently more challenging because, with the additional task of remembering, there is higher cognitive demand. Given that more difficult tasks appear to be more vulnerable to collaborative inhibition than simpler tasks in general (e.g., Basden et al., 1997), and given that collaboration in the present study did indeed produce inhibitory effects, it was less surprising that the effect emerged for the memory task. However, in this case, even basic, physical learning was inhibited during collaboration and to the same extent as in mental learning.

In previous observations of success with collaboration in ensemble learning (e.g., Seddon & Biasutti, 2009), one possibility was that it was the extra information or cues that were present in the form of other parts that enhanced an individual's learning of his or her own part. To tease apart this possible informational advantage from a possible enhancement via collaboration itself, we separated solo learning into two types: with or without similar extra information as is present during ensemble rehearsals. We observed better memory performance in aided solo compared to independent sessions. Thus, extra musical information did enhance individual learning to some extent, likely by providing a richer context in which to fit one's own part and through more elaboration (cf. Segalowitz & Cohen, 2001).

However, memory performance was worse when participants learned in a group than when they learned individually. The similar extra musical information in group sessions was thus either not beneficial because it was delivered in the form of other vocalists' singing, not under the control of the individual, and in the context of social interaction, or the inhibitory effects of collaboration trumped any benefit this extra information could provide. Interestingly, participants in the aided solo condition did not do any better than those in the independent solo condition in terms of physical learning, suggesting that perhaps the task was not difficult enough for the benefit of the extra context to be noticeable or of much consequence.

Finally, the results showed that metacognitive judgments regarding prediction and evaluation of performance were unaffected by participation in solo or group sessions. That is, participants' ratings of their confidence both preceding and following performance were correlated to the same extent with the quality of performance, regardless of learning condition. Thus, the possibility that participants may show overconfidence as a result of collaboration, without the benefit of enhanced performance (e.g., Heath & Gonzalez, 1995), did not materialize. It might be that the overconfidence observed during collaboration in decision making, the focus of Heath and Gonzalez's (1995) study, arose because the main purpose was to consolidate information into one consensus, whereas in the present case the individual acquisition of the information was still important in its own right, independent of the group performance.

In conclusion, we observed that participants learned new pieces of music more successfully when in an individual learning environment than in a collaborative one. Although some previous case studies of musical ensembles had indeed suggested that the optimal rehearsal strategy involves solo learning before collaborative learning (e.g., Sawyer, 2006), this was the first experimental study to corroborate these

suggestions. Unlike the advantages touted by Weldon and Bellinger (1997), learning by collaboration may thus be counterproductive, at least initially, and the most optimal condition might be a compromise of learning alone but with accompaniment that enriches memory processing. This would give the learner more contextual cues to draw upon during performance without the distracting and inhibitive environment fostered by collaboration.

Of course, we examined only a single instance of an ensemble's rehearsal and an ensemble whose members were not familiar with each other. Over time, as ensemble members become familiar with each other, they may gain cohesiveness and develop other strategies for efficiency in initial learning (e.g., Lim, 2013), counteracting any negative effects of production blocking or free-riding. Thus, a more ecologically valid approach to studying collaboration in music might be measuring performance after learning over a series of rehearsal sessions. Another caveat was that we measured the success of individual learning only, even in the collaborative learning condition. It is possible that overall group performance would have been superior after collaborative learning than individual learning, with, say, a stronger member's being able to better anticipate and cover the mistakes of the others or giving extra help in what he or she knew would be a difficult passage. Nevertheless, the current results suggest that musical ensembles should remain mindful that although it is critical to work collaboratively for successful performance, the initial learning of pieces may be the most effective if completed on an individual basis.

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Supplemental Material

Table S1 and the three pieces used in this experiment are available at http://jrme.sagepub.com/supplemental.

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