# Emotional Ornamentation in Performances of a Handel Sonata

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ORNAMENTATION IS ONE ASPECT OF MUSIC ASSOCIATED with emotional affect in Baroque music. In an empirical study, the relationship between ornamentation and emotion was investigated by asking a violinist and flutist to ornament three melodies in different ways to express four emotions: happiness, sadness, love, and anger. The performers adapted the type of ornaments to the instructed emotion as well as the characteristics of the ornaments. The flutist specifically varied the duration, timing, and complexity of the ornamentation, while the violinist varied the complexity, density, and sound level of the performances. The ability of the performers to communicate the emotions was tested in a listening experiment. Communication was found to be generally successful, with the exception of the communication of happiness. This success was not due to general consensus about the expression of emotions through ornamentation. Rather the listeners were sensitive to a performer's specific use of ornamentation.

THE AIM OF THE PRESENT STUDY WAS TO investigate the relationship between variations in melodic ornamentation and perceived emotion in the context of modern performances of a Handel sonata. The research aimed to contribute to the understanding of the attribution of emotional qualities to music and the communication of emotion using music. The questions asked were: What musical qualities relate to perceived emotions, and, specifically, what is the role, if any, of ornamentation in the communication of emotion for modern day musicians? These questions are distinct from the question of how listeners come to experience emotions in response to music. Listeners' experience of emotions may be more subjective and socially dependent than their perception of emotion (see for discussions Gabrielsson, 2001/2002; Scherer, 2004; Scherer & Zentner, 2001). Previous research has shown that listeners are quite consistent in labeling music with an emotional quality, especially where it concerns basic emotions (Gabrielsson & Juslin, 2003). This research has started to distinguish relevant musical features that are responsible for labeling music with a specific emotional category. Perhaps not surprisingly, almost every musical feature, including aspects of the performance, may influence the perception of emotions; this may include harmony, rhythm, melody, tempo, dynamics, timbre, vibrato, and articulation (see e.g., Gabrielsson & Juslin, 1996, 2003; Hevner, 1935; Sundberg, Iwarsson, & Hagegård, 1995). Some of these features are apparently more important than others. For example, tempo and mode are both salient features, but, when contrasted, tempo can overrule the effect of mode to distinguish happy from sad sounding music (Gagnon & Peretz, 2003).

The exact influence of musical features on the perception of emotions is, however, not always clear and consistent. In their overview of musical variables and their emotional connotations, Gabrielsson and Lindström (2001) noted that musical features are often associated with many (even contrasting) emotions, and interactions between features are often found. For example, the effects of melodic contour and rhythm interact when judging melodies as sounding happy or sad.

To explain relationships between emotion and music, at least two theories have been offered: (1) a theory based on musical cues, and (2) a theory based on extended musical structure (for summaries, see Gabrielsson & Juslin, 2003; Sloboda & Juslin, 2001). The theory that associates perception of emotion with musical cues emphasizes the communication of specific emotions, such as happiness and sadness, based on local and global characteristics of the music. Cues may be either acoustic or structural. Acoustic cues include speed, loudness, pitch, timbre, attack, and decay of events, while structural cues include tonal mode (major or minor), melodic contour, and harmonic and melodic intervals.

Cues may have an origin in vocal expressions of emotions in speech (Juslin & Laukka, 2003) and in infant directed nonverbal communication ('motherese,' e.g., Trehub & Nakata, 2001/2002). Cues may also have a biological basis, which is the case for dissonance, which is innately disliked (Trainor & Heinmiller, 1998). In addition, cultural cues are established within a tradition and include, for example, the different meanings of scales (see Balkwill & Thompson, 1999, for a clear differentiation between cultural and psychoacoustic cues). Cultural cues are associational, rather than iconic (a distinction made by Sloboda & Juslin, 2001), meaning that cultural cues and emotions are related by convention rather than by similarity.

The other theory concerned with musical structure is related to the theories of emotion of Meyer (1956) and Langer (1963). It emphasizes the temporal structure of music, i.e., how music unfolds over time, and its analogy with the temporal structure of emotions. To give a very short outline, according to Meyer, music may arouse emotions by setting up expectations that are rewarded, violated, or suspended. This parallels the cognitive framework for emotions when an individual's goals are frustrated or rewarded (Mandler, 1975; Oatley, 1992). Very briefly, in Langer's theory, patterns of ebb and flow in music evoke emotions by analogy to general forms of feeling. No specific emotional categories are communicated, but rather patterns of tension and release.

A few empirical studies have provided evidence for these theories. Krumhansl (1996) and Lerdahl and Krumhansl (2007) related perceived tension in music to points of tension and relaxation, mostly harmonic in nature, in line with Meyer's theory. More generally, the fluctuations in tension and emotionality as recorded with continuous response methods suggest the importance of temporal structure for the affective impact of musical events (see e.g., Krumhansl, 1998; Schubert, 2001; Sloboda & Lehmann, 2001).

These two types of theories are rather different from each other and they may well tap into two distinct processes. While the first is concerned with the recognition of an emotional character based on acoustic or cultural cues, the second concerns emotional tension build-up and release over time. Another difference is that the cue-based theory does not consider structural context. Recognition of an emotion depends on an addition of cues; which emotion is recognized depends on which emotion gets most evidence, as in Juslin's adaptation of the Brunswikian lens model (Juslin, 2000). In this summation, the kind of cues may partly depend on participants' (cultural) background, but the interpretation of cues is fixed within a certain context. For example, loud sounds will generally increase the evidence for anger and decrease the evidence for sadness. The interpretation of cues is established within a stable framework of emotional connotations of sounds and musical elements. This contrasts with Meyer's account that makes the meaning of events primarily relative to structural context and relationships with other events (embodied musical meaning in Meyer's terms, 1956).

The issue central to the current study concerned the possible role of ornamentation in the communication of emotions in music. Ornaments are notes that can be added to a melody as a kind of melodic variation. Ornaments are often tied to a melody note to which they belong and which they elaborate. For Western classical music, ornamentation was an important part of performance practice within the Baroque era. Several treatises from that time contain elaborate sections on ornamentation and describe what performers should and should not do (for summaries see Donington, 1963; Wessel, 1979). In some of these, a relation between ornamentation and emotion is suggested. For example, Carl P. E. Bach (1753/1949) wrote that for each affect, be it happy or sad, 'ornaments will lend a fitting assistance.' And Mattheson (1739/1981) observed that 'it is necessary that [a singer] knows how to perform a precomposed melody with much grace, ornament and artistry: [This] is reading with expression and good style' (p. 265). Mattheson included ornaments among the means that were used to emphasize words or notes. And the aim of 'emphasis' is to point 'toward the emotion, and illuminate the sense or meaning of the performance' (p. 370).

These treatises provide some suggestions that specific ornaments may express one affect and not another, but clear predictions are difficult to draw from this literature. Therefore, our predictions for the relationships between ornaments and emotions are based on the emotion theories summarized above. First of all, we expected that ornaments function as cultural cues, which means that they are a stylistic convention: specific types of ornaments, such as an appoggiatura or trill, are associated with specific emotions, such as sadness or happiness. Secondly, ornamentation is a way of varying the local characteristics of a melodic line. For example, variation of the number of notes or the duration of the ornament varies local tempo, while variation of the pitch of the ornament may make a passage more dissonant. In this way, ornaments function as acoustic cues. Finally, ornamentation is a melodic variation at a certain structural position. The ornament adds an

aspect of surprise and unexpectedness. The structural position of this variation is one factor that influences the strength of surprise. For example, violations of expectancies may be more salient for strong metrical positions and for structural positions later in a phrase. In this way, the structural position of an ornament may influence its meaning.

We report two studies that explored these three ways in which ornaments may influence perception of emotion in modern day practice. In the first study, two performers, experienced with ornamenting Baroque music, were asked to ornament four musical fragments taken from a Handel sonata to express different emotions: mild and intense happiness, mild and intense love, mild and intense anger, and mild and intense sadness. Love differs from the other emotions, because it is not generally considered to be a basic emotion category. However, it is an important emotion in theories of Clynes (1977) and Ortony, Clore, and Collins (1988), and is important in many musical contexts. Furthermore, these emotions were chosen to vary valence, activity, and intensity systematically.

According to the circumplex model of emotions (Russell, 1980), emotions differ along the two dimensions of valence and activity. Valence distinguishes negative emotions, such as sadness and anger, from positive emotions, such as happiness and love. Activity distinguishes emotions with higher levels of arousal, such as anger and happiness, from emotions with lower levels of arousal, such as sadness and lovingly (the term used in the instructions for the participants). Additionally, emotions may vary in intensity (e.g., Ortony, Clore, & Collins, 1988). The intensity of an emotion may distinguish cold anger from hot anger, or mild from intense sadness. Several studies have suggested the usefulness of these dimensions for the interpretation of emotions perceived in music (e.g., Ilie & Thompson, 2006; Juslin & Laukka, 2001, Schubert, 2001; Sloboda & Lehmann, 2001). Moreover, happiness, sadness, and love are emotions that are often mentioned in music treatises, when examples of affects are given (for a list of common affects and terminologies, see Wessel, 1979).

In our study, we asked the performers to ornament musical fragments with a variety of emotional expressions. This procedure is taken from speech research in which actors are asked to read a text aloud in different ways (see e.g., Kramer, 1964; Scherer, Banse, Wallbott, & Goldbeck, 1991). The mode of expression is not related to the meaning of the text. Instead a factual text without emotional meaning is often used to easily separate the influence of the actors' reading from the influence of the meaning of the text. In music research, this procedure is

also used, asking musicians to perform melodies with different emotional expressions (for an overview, see Juslin & Laukka, 2003). Although it may be possible that melodies are emotionally "neutral," it is more likely that most melodies have some emotional connotation that influence the perception of emotions. We took this possible effect of musical fragment into account and separated it from the effect of performance.

The two performers ornamented the music according to their own ideas and intuition. Despite this freedom, we expected that the applied ornamentation would fall within the conventions of Baroque music and can be classified according to the categories distinguished by performance practice treatises of that time, such as appoggiaturas, trills, and turns. More specifically, in the analysis of the ornamentation, we first classified the ornaments according to categories distinguished by Bach (1753/1949) and then analyzed the characteristics of the ornaments, such as the melodic and harmonic relationships of the ornament to the main note and chord, again following Bach's distinctions. The structural location of the ornament included its serial position and metrical position within the musical fragment. Finally, we examined the relations between these analyzed characteristics of the ornamentation and the instructed emotions of the performances.

In the second study, listeners' perception of emotions in the recorded performances was examined. Musically trained participants (not specialists in Baroque music) indicated perceived emotions by rating the presence of the four emotions on separate unipolar scales. We then related their ratings to the intended emotions and to the analyzed characteristics of the ornamentation.

In this way, the performers' strategies to express emotions could be distinguished from listeners' attribution of emotional qualities to music. Mode and tempo were fixed by the musical fragment that was ornamented and by asking the performers to play along with a pre-recorded accompaniment. This excluded these relatively salient cues to perceived emotion and allowed us to focus on the effects of ornamentation. However, other cues such as dynamics, timbre, and articulation could still be varied. Average sound level was therefore analyzed as an additional potential acoustic cue for emotions. The other additional cues were not considered in this study due to the complexity of the acoustic analyses that would have been required.

To summarize, the questions of this study were: (1) Do performers instructed to convey different emotions via ornamentation adopt consistent strategies in doing this? (2) Do performers and listeners with similar backgrounds share knowledge about communication of

emotion through ornamentation? (3) How does this knowledge fit the hypothesized relationships between perceived emotion and type, characteristics, or position of ornamentation?

## Study 1: Performers' Ornamentation of Melodies

METHOD

*Materials.* Materials for the performances were the opening bars of the first (bars 1-5), second (bars 1-16), third (bars 1-7), and fourth movement (bars 1-13) of Handel's sonata HWV360 in G minor for recorder and basso continuo (Op. 1, No. 2). This is an early sonata of Handel, composed between 1724 and 1726. The approximate tempo was 78 eighth notes per minute for fragment 1 (F1), 96 quarter notes per minute for fragment 2 (F2), 58 half notes per minute for fragment 3 (F3), and 112 quarter notes per minute for fragment 4 (F4).

Scores of F1, F3, and F4 are given in Figure 1. F2 is not shown, since it was excluded from the analysis (see below). The last chord of F3 is omitted in the figure to save an extra line. Complete scores were given to the performers.

Additional material for exemplification of the intended emotions to the performers was collected from two CDs with performances of Handel's solo sonatas.[1] These performances of a variety of sonatas and our recordings of the piano accompaniment of sonata HWV360 were put on CD. Track information is listed in the Appendix.

*Performers.* A female flutist and a male violinist performed the solo part of the fragments from the Handel sonata. They are both professional musicians who perform regularly on instruments of the Baroque period as well as on modern instruments. A highly skilled pianist from the Northwestern University School of Music performed the basso continuo of the music.

*Procedure.* Three recording sessions were organized in a 450-seat concert hall of Northwestern University. In the first recording session, the accompaniment of the Handel sonata was recorded. The pianist was instructed to perform the basso continuo of the entire sonata with neutral expression, approximately at an indicated tempo,

though with small, musically appropriate variations in tempo.

In the second and third sessions, the ornamented melodies were recorded. Three weeks before these recordings, scores, written instructions, and a CD with audio tracks (see Appendix) were sent to the performers with the following instruction: "Please prepare the beginnings of each fragment [bars and tempi for each fragment were indicated] first of all without any additions of ornaments or changes of the score and secondly, with different ornamentation in order to express the following eight emotions: Happy mild (gayement) and intense (brillant), loving mild (cantabile) and intense (con brio), sad mild (doloroso) and intense (lagrimoso), and angry mild (ardito) and intense (furioso). The choice of ornamentation is left to your taste and interpretation." In addition, a practice procedure was suggested that included four steps: (1) choosing a mood and fragment to perform, (2) listening to the track that exemplifies an expression of the emotion, (3) imagining the performance of the Handel sonata, and (4) performing the fragment along with the piano accompaniment.

The Italian and French indications of the moods and sounding examples of the moods were included in addition to emotion words to help make the instructions more natural for musicians. Sounding examples eliminated potential doubt about the possibility of expressing the instructed moods in music. The examples did not contain much ornamentation and therefore should not have influenced the performances in this respect.

Separate recording sessions were held for the flutist and the violinist. At the recording session, the respective soloist performed each version of each fragment as often as needed to achieve a satisfactory performance. In most instances, the first performance was sufficiently satisfying. The soloist performed the music along with the accompaniment, which he/she heard over a headphone that covered only one ear. Headphones were used in order to be able to record the soloist separately from the accompaniment.

The order in which the versions were recorded was fixed. The recording session started with the neutral version of F1, followed by the mild and intense happy version of this fragment, the mild and intense loving version, the mild and intense sad version, and the mild and intense angry version. The same order was followed for F2, F3, and F4.

The best performance was selected from the performances of the versions that were recorded more than once. This was generally the last version, or whichever

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[1]CD: George Frideric Handel (1685-1759) Complete Wind Sonatas, Philips Classics Production 446 563-2 (1995), Printed and made in U.S.A. Original recordings 1/1981 (CD1 track 9&11), 5/1983 (CD2). Performed by Academy of St. Martin in the Fields: F major (HWV363a) and C minor (HWV366)—Neil Black Oboe, George Malcolm harpsichord, Graham Sheen bassoon; C major (HWV365)—Michala Petri recorder, George Malcolm harpsichord, Denis Vigay cello; B minor (HWV376)—William Bennett flute, Nicholas Kremer harpsichord, Denis Vigay cello.

had best satisfied the performer. This led to a collection of one performance by the flutist and one performance by the violinist of the nine conditions of the four fragments, a total of 72 performances (2 performers × 9 versions × 4 fragments).

### ANALYSIS

As preparation for the analysis of the ornamentation, we first made a transcription of the performances and separated ornamental notes from structural (notated) notes. All notes that were present in the transcription but were not present in the original score were defined as ornaments. Secondly, we identified the main note for each ornamental note. The main note was defined to be the first structural note following the ornamental note(s).

These steps and the following steps of the analysis were done as closely in agreement with Baroque performance practice and music theoretical literature as possible. However, sometimes a systematic approach was preferred above a historical-musicologically oriented interpretation. For example, the rule that all notes that do not occur in the score are ornamental and all score notes are structural could have had exceptions, when analyzed music-theoretically. Nevertheless, we felt that the rule suits the current study well, since the score is the starting point for the performers.

*Type of ornament.* To classify the ornaments used by the performers, we took the ornament types distinguished by Bach (1753/1949): the appoggiatura, turn, mordent, trill, slide, the compound appoggiatura, and the slide. In addition, Bach distinguished the snap, which is not usually considered as a separate category, but rather as a variant of the mordent, so we did not include this distinction (Donington, 1963). The ornaments we considered may be understood as follows (see also Figure 2):

- A single appoggiatura is a one-note ornament that is tied to the following main note.

- A double appoggiatura consists of two notes that both fall or rise to the following main note.
- A trill is a rapid alternation of the main note and a note a semitone or whole tone above the main note. The trill often starts from the upper note and ends on the main note.
- A turn ornaments the main note by playing around it: one note above the main note, the main note, one note below and a return to the main note.
- A mordent is an alternation of the main note with a neighboring note that starts with the main note: main note, one note above or below the main note, and a return to the main note.
- A slide fills a melodic interval by stepwise intervals in one direction. In the analyses, the slide should have at least three tones going up or down in the same direction to be recognized as such.

To these classes, we added the substitute and the arpeggio. An ornament is a substitute when the main note is eliminated and replaced by the ornamental note. An ornament is an arpeggio when it consists of broken chords or intervals larger than a whole tone.

Figure 3 gives examples of transcribed performances and labeled ornaments. For example, the first line gives the first bars of F1 in the "Intense Happy" condition as performed by the flutist. She introduced arpeggios and a trill in these first two bars. Arrows indicate the main notes that immediately follow the ornaments. The second line gives the first bars of F1 for the "Intense Lovingly" condition for the flutist. In this condition, she introduced a mordent that precedes a slide, which in turn precedes a slide towards the main note. This ornamentation is repeated in a shortened version (mordent followed by one slide towards the main note). At the end of bar one, we distinguish two single appoggiaturas and, in bar 2, we distinguish a trill, a double appoggiatura and a slide.

The classification of these ornaments was not always straightforward, as it depended on the identification of
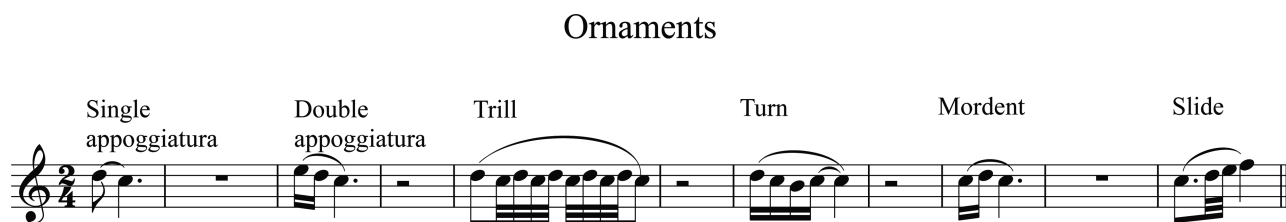
## Ornaments



FIGURE 2. Examples of the different types of ornaments distinguished.

main notes and on the grouping of notes as one ornament. We applied three rules as consistently as possible: (1) the main note is the score note at its original position or delayed and shortened by an ornament; (2) the notes preceding the main note that are not score notes are ornamental notes; and (3) ornamental notes are grouped into traditional categories where possible.

*Characteristics of the ornaments.* For the characterization of each ornament, we also took into account distinctions made in performance treatises. Bach (1753/1949), Quantz (1752/1966), and Donington (1963) differentiate between long and short appoggiaturas, ascending and descending appoggiaturas, appoggiaturas stealing time from the main note and sparing the main note,

and between consonant and dissonant appoggiaturas. These characterizations of appoggiaturas can also be applied to the other ornaments.

- A long appoggiatura should be at least half the duration of the main note, otherwise it is short. Compare, for example, the second long with the first short appoggiatura in the third line of Figure 3.
- In an ascending appoggiatura, the ornament ascends to the following note. In a descending appoggiatura, the ornament descends to the following note. Compare, for example, the second ascending with the first descending appoggiatura in the seventh line of Figure 3.



FIGURE 3. Examples of the ornamentation used in this study. All examples show the first two bars of F1 and are taken from the intense version of an emotion.

- An appoggiatura that steals time from the main note shortens and shifts the main note. This type of timing of the ornament is referred to as "on-main" and is often "on the beat." An appoggiatura that spares the main note precedes the main note and leaves the onset timing of the main note unaffected.[2] This type of timing is referred to as "pre-main." This manner of timing is often, but not always, "before the beat." Compare, for example, the second pre-main with the first on-main appoggiatura in the seventh line of Figure 3.
- The consonance or dissonance of an appoggiatura is determined by the interval of the appoggiatura with the root of the chord that is performed at the same time. If this interval is an octave, prime, perfect fifth, major or minor third or sixth, it is consonant; otherwise it is dissonant. Compare, for example, the appoggiatura and substitute in bar 1 of the seventh line of Figure 3, which are consonant tones, with the two appoggiaturas in bar 2 of this performance, which are dissonant tones.

To these characteristics, we added complexity and density. Complexity distinguishes simple ornaments that consist of only one note (the single appoggiatura and the substitute) from compound ornaments that consist of more than one note (the turn, mordent, slide and double appoggiatura). Density is simply the number of ornaments added in a musical fragment.

*Average sound level.* The average sound pressure level per performance in dB was calculated using PRAAT (Boersma & Weenink, 2006).[3]

*Structural position of the ornaments.* Three dependent variables related to structural position were defined: metrical position, bar position, and position within the fragment. Metrical position defines the position of an ornamental note within a metrical hierarchy, while bar and position within the fragment define the serial position of an ornamental note within a bar or fragment.

Five metrical levels were distinguished: the bar level, the first division of a bar in two or three, the beat level, the half beat level, and the quarter beat level. The metrical weight of a specific metrical position was defined as the sum of the levels at that position, which is highest for the first beat of a bar (5) and lowest for the smallest subdivision (1).

Two bar positions were distinguished: first half or second half of the bar. Three positions within fragments were distinguished: first third, second third, and last third of the fragment. Note that these structural characteristics are simple distinctions that do only partial justice to the theories of Meyer (1956) and Langer (1963). Our tests for the effect of structural position can therefore only be seen as a first step.

Figure 4 gives an overview of the analysis procedure: It shows the successive steps of: (1) transcription, (2) comparison with the original score to distinguish ornaments from structural notes, and (3) classification of the ornaments, characterization of the ornaments, and the definition of the position of the ornaments. It also shows the summaries per condition that were used in the further analyses of the ornaments: The number of ornaments of a certain type and with a certain character were summed per condition and this number was divided by the total number of ornaments per condition, which gave the percentage of ornaments of a certain type and character per condition. This made all variables irrespective of the number of ornaments. The total number of ornaments was included as a separate variable ("density").

To examine the relationship between emotion and ornamentation, the effect of fragment on the use of ornaments needed to be distinguished from the effect of emotion instructions. The fragments are rather different from each other and influence the ornamentation that can be applied. For example, F4 is relatively fast and therefore contains relatively many single appoggiaturas and fewer compound appoggiaturas such as turns and slides. To eliminate such effects of fragment, the average percentage per fragment was calculated. This average was subtracted from the average per performance to obtain percentage deviations that were then analyzed further.

To determine the association between the instruction of an emotion (coded as 1 in the target performances and 0 in the other performances) and the presence of an ornament in performance, correlations were calculated between the coded instructed emotions and the percentage deviations for ornaments. These correlations were based on 24 data points: 3 fragments × 8 instructions per performer. A similar procedure was used to calculate correlations with the activity of the instructed emotion (coded as 0 or 1) and with the valence of the instructed emotion (also coded as 0 and 1). A separate analysis was conducted to determine the effect of emotional intensity.

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[2]According to Bach, appoggiaturas always take something from the duration of the main note, although this might be very little if the ornament is short.

[3]A web-link to PRAAT and explanatory texts can be found at www.fon.hum.uva.nl/praat/.

**Transcription**   **Comparison with original score**

Recorded performance — Transcribed performance — List of ornaments per performance

**Analysis of each ornament**

*Type*   *Character*   *Position*

Appoggiatura?
Trill?
Turn?
Mordent?
Slide?
Substitute?
Arpeggio?

Duration? l/s
Direction? u/d
Timing? on/pre
Harmony? c/d
Dotting? y/n
Single or compound? y/n
Density? #

Bar Position?
Form Position?
Metrical Position?

**Summary per condition**

Per condition: # of each type

Per condition: # of each character

Per condition: Average position

*Division by total # of ornaments*   *Division by total # of ornaments*

Per condition: % of ornaments has type x

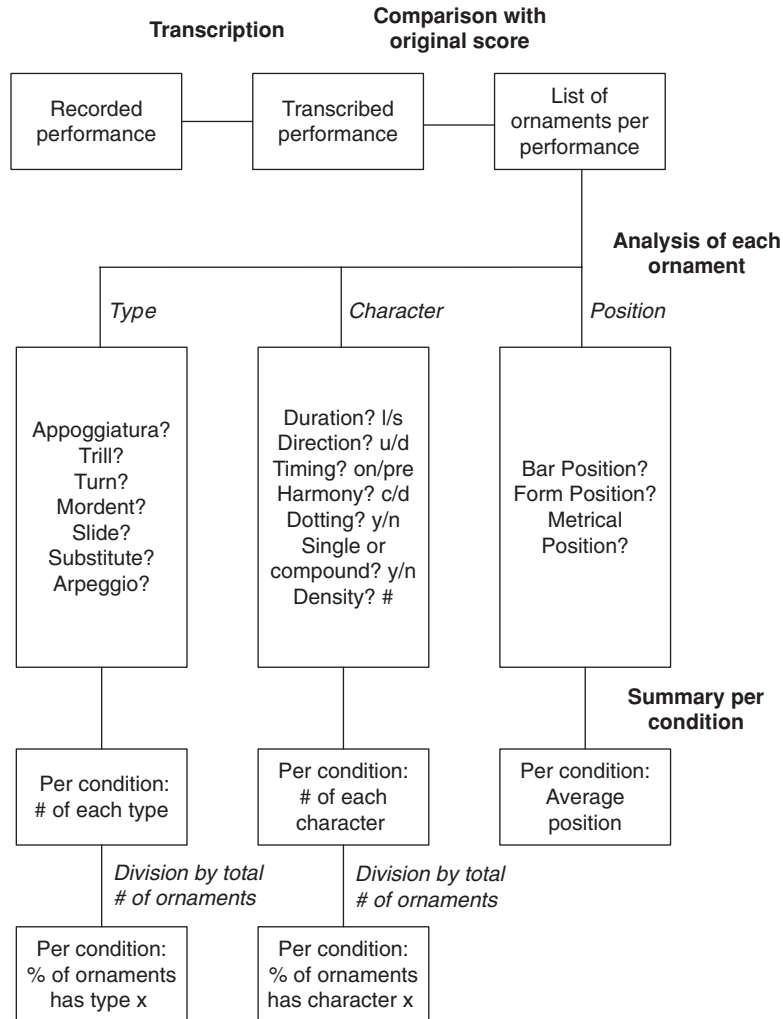Per condition: % of ornaments has character x

FIGURE 4.  Schematics of analysis procedure of the ornamentation added by the performers to the original music of the Handel sonata.

The neutral version of all fragments and all performances of F2 were excluded from analysis. The tempo of the F2 accompaniment turned out to be too slow to be comfortable for the performers, so that there were difficulties of synchronization between soloist and accompaniment.

*Results*

*Flute: Type of ornamentation.* The top rows of Table 1 list the significant correlations with the type of ornament for the flute performances. As can be seen, happy performances showed a positive correlation with the presence of turns, while loving performances showed a positive correlation with the presence of slides. Sad performances correlated negatively with the presence

of trills and arpeggios, and positively with the presence of single appoggiaturas, while angry performances correlated negatively with the presence of single appoggiaturas, and positively with arpeggios. High activity performances showed more trills, arpeggios and fewer single appoggiaturas than low activity performances, while performances with positive valence showed more slides than performances with negative valence.

*Flute: Characteristics of ornamentation.* The middle rows of Table 1 show the significant correlations between instructed emotions and characteristics of the ornamentation. These characteristics included complexity, density, timing, duration, direction, and harmony. Each of these characteristics correlates significantly with at least one instructed emotion. Sad performances had, in contrast to happy performances, relatively many

**TABLE 1.   Correlations for Flute Performances Between Emotions (Columns) and Ornamentation (Rows).**

| Emotion* | i-H | i-L | i-S | i-A | i-Act | i-Val | r-H | r-L | r-S | r-A |
|---|---|---|---|---|---|---|---|---|---|---|
| Single | −.09 | −.02 | **.59** | **−.48** | **−.49** | −.09 | **−.42** | **.53** | **.70** | **−.62** |
| Double | −.27 | −.03 | .11 | .18 | −.07 | −.26 | .13 | −.01 | .07 | .03 |
| Trill | .17 | .13 | **−.60** | .30 | **.41** | .26 | .30 | **−.44** | **−.66** | **.54** |
| Turn | **.41** | −.35 | −.10 | .05 | .39 | .05 | .10 | −.19 | −.16 | .12 |
| Mordent | .05 | −.23 | −.12 | .29 | .30 | −.15 | −.05 | −.31 | −.21 | .39 |
| Slide | .00 | **.55** | −.17 | −.38 | −.33 | .47 | .14 | .32 | −.05 | −.17 |
| Arpeggio | .08 | −.11 | **−.42** | **.45** | **.46** | −.03 | .22 | **−.50** | **−.55** | **.41** |
| Substitute | .08 | .04 | −.28 | .17 | .21 | .10 | .08 | −.26 | −.19 | .04 |
| Complexity | .07 | .01 | **−.55** | **.46** | **.46** | .08 | **.41** | **−.49** | **−.68** | **.62** |
| Density | −.25 | **.42** | −.27 | .10 | −.13 | .15 | **.56** | .08 | −.27 | −.05 |
| On-timing | **−.41** | −.28 | **.48** | .21 | −.17 | **−.60** | −.22 | −.07 | .35 | .09 |
| Duration | −.32 | .17 | **.61** | **−.46** | **−.67** | −.13 | −.25 | **.57** | **.64** | **−.48** |
| Direction | .18 | .25 | .02 | **−.45** | −.24 | .37 | .00 | **.55** | .25 | **−.59** |
| Harmony | −.02 | .20 | **−.55** | .38 | .31 | .15 | −.36 | **−.45** | **−.56** | **.52** |
| Sound level | .02 | .17 | −.10 | −.10 | −.06 | .17 | .11 | .06 | −.13 | .18 |
| Meter | **−.42** | −.32 | **.79** | −.05 | **−.41** | **−.64** | **−.47** | −.20 | **.62** | .21 |
| Form pos | −.03 | −.17 | **.41** | −.22 | −.21 | −.17 | −.19 | .18 | .33 | −.14 |
| Bar pos | .28 | −.29 | .04 | −.04 | .22 | .00 | .03 | −.11 | −.17 | .05 |

*Emotions are instructed (i-H, i-L, i-S, i-A, i-Act, i-Val) or rated (r-H, r-L, r-S, r-A). Significant correlations are in bold ($N = 24$, $p < .05$).

ornaments occurring at the original time of the main note (on-main). Sad performances had relatively many long ornaments, fewer complex ornaments, and more dissonant harmony than the other performances. Angry performances had fewer long ornaments, more complex ornaments, and more downward ornaments. Activity of emotions was negatively associated with duration and positively associated with the complexity of ornaments. Positive compared to negative valence of emotions was associated with pre-main timing rather than on-main timing. This indicates an association between the activity of emotions and duration and between the valence of emotions and timing.

*Flute: Sound level of performance.* There were no significant correlations between instructed emotion and sound level of the performances, indicating that sound level was not a deliberately manipulated parameter for the expression of intended emotions.

*Flute: Structural position of ornaments.* The only significant correlations between instructed emotion and structural position were with metrical position. As can be seen in Table 1, bottom row, happy ornaments showed a negative correlation with metrical weight and sad ornaments showed a positive correlation. Both valence and activity of instructed emotion were negatively associated with metrical weight: More ornaments fell on weak beats in conditions with positive and active emotions. These relationships may have different origins: The ornaments at weak beats in positive emotions relate to the ornaments timed relatively often pre-main, given that the main note was often timed on the beat, while the ornaments at weak beats in active emotions relate to the greater complexity of ornaments in performances with active emotions.

*Violin: Type of ornamentation.* Significant correlations for the violin performances between instructed emotions and type of ornaments are reported in the top half of Table 2. There was a positive correlation between happy performances and the presence of trills, and between loving performances and the presence of single appoggiaturas. Sad performances were negatively associated with double appoggiaturas and positively associated with substitutes. Angry performances were positively associated with the presence of double appoggiaturas.

Activity of emotions was negatively associated with the presence of single appoggiaturas and positively associated with the presence of double appoggiaturas, while positive valence of emotions was associated with the presence of trills. Thus, the violinist's use of trills was different from the flutist, for whom the use of trills was associated with high activity emotional performances.

*Violin: Characteristics of ornamentation.* The middle rows of Table 2 show the significant correlations between instructed emotions and characteristics of the

TABLE 2.   Correlations for Violin Performances Between Emotions (Columns) and Ornamentation (Rows).

| Emotion* | i-H | i-L | i-S | i-A | i-Act | i-Val | r-H | r-L | r-S | r-A |
|---|---|---|---|---|---|---|---|---|---|---|
| Single app. | −.28 | **.43** | .11 | −.26 | **−.47** | .13 | −.39 | .18 | .26 | −.14 |
| Double app. | .39 | −.23 | **−.58** | **.43** | **.70** | .13 | .23 | −.37 | **−.48** | .36 |
| Trill | **.64** | −.11 | −.29 | −.25 | .34 | **.47** | .34 | .12 | −.08 | −.16 |
| Turn | −.19 | .11 | −.19 | .27 | .07 | −.07 | **.53** | −.07 | −.27 | .22 |
| Mordent | .01 | −.09 | −.11 | .19 | .17 | −.08 | .35 | −.06 | −.23 | .14 |
| Slide | .19 | −.19 | −.19 | .19 | .33 | .00 | .14 | −.18 | −.18 | .24 |
| Arpeggio | .08 | −.13 | .03 | .02 | .09 | −.05 | −.15 | −.04 | −.19 | .02 |
| Substitute | −.24 | −.08 | **.55** | −.23 | −.40 | −.28 | −.27 | .16 | **.48** | −.29 |
| Complexity | .19 | −.26 | **−.47** | **.54** | **.63** | −.06 | **.57** | −.34 | **−.53** | **.44** |
| Density | .12 | −.04 | **−.53** | **.45** | **.49** | .07 | .16 | **−.42** | **−.67** | **.54** |
| On-timing | .04 | .19 | .32 | **−.55** | **−.44** | .20 | −.10 | **.39** | **.46** | **−.41** |
| Duration | .11 | −.26 | .21 | −.06 | .04 | −.13 | .05 | −.08 | .09 | −.02 |
| Direction | −.08 | −.02 | −.03 | .13 | .04 | −.09 | .12 | −.09 | .08 | .04 |
| Harmony | .03 | .28 | −.17 | −.13 | −.09 | .27 | .04 | .08 | −.01 | .09 |
| Sound level | .03 | .02 | **−.76** | **.71** | **.64** | .04 | **.42** | **−.61** | **−.70** | **.74** |
| Meter | −.09 | .23 | **.46** | **−.60** | **−.60** | .12 | −.14 | **.42** | **.51** | **−.47** |
| Form pos | **.45** | −.18 | −.25 | −.02 | .37 | .24 | .27 | −.02 | .04 | −.10 |
| Bar pos | −.10 | −.27 | .29 | .08 | −.03 | −.32 | .07 | −.11 | .01 | .02 |

*Emotions are instructed (i-H, i-L, i-S, i-A, i-Act, i-Val) or rated (r-H, r-L, r-S, r-A). Significant correlations are in bold ($N = 24$, $p < .05$).

ornaments. The only significant relationships are with sad and angry performances, which are the most passive and the most active emotion, respectively. Sad performances were negatively associated with complexity and density, while angry and high activity performances were positively associated with complexity and density of ornaments. Additionally, angry and high activity performances showed more pre-main timing than on-main timing. This correlation with timing is different from that found in the flute performances, which showed a relationship between timing and valence. The correlations observed for the violin may relate to the higher density of ornaments for active emotions, because there is a restriction on the ornaments that can be timed on-main. Therefore, if more notes are added, relatively many will occur before the original time of the main note (pre-main).

*Violin: Sound level of performances.* The average relative sound level of a performance was negatively associated with sad performances, and positively with angry and high activity performances (see but last row in Table 2). This indicates that the violinist used sound level as a significant parameter for signaling intended emotion, in contrast with the flutist, whose performances did not show any significant correlations with sound level.

*Violin: Structural position of ornaments.* As was the case with the flutist, the only significant correlations between instructed emotion and structural position were with metrical position (see last row in Table 2). Metrical position was positively associated with sad performances and, negatively with angry performances and activity. This is somewhat different from the flutist, who also showed correlations with valence and happiness. The correlations between metrical position and sad, angry and activity for the violinist may again be related to the larger density of ornaments for the active emotions: When more short notes are added, more of these notes fall on weak beats.

*Flute and Violin: Effect of emotion intensity.* In the analyses above, no distinction was made between mild and intense emotions. To explore the effect of intensity, a principal components analysis was performed using correlations between the characteristics of the ornamentation in each of the 24 conditions (4 emotions × 2 intensities × 3 fragments). Only the characteristics that showed a significant effect of emotion in the earlier analyses were included (see Tables 1 and 2). The two main components with an eigenvalue greater than 1 were selected for rotation. Figure 5 shows the scores of each performance on the first two rotated factors.

For the flutist, the first two dimensions accounted for 55% of the variance. Dimension 1 was most strongly correlated with the presence of single appoggiaturas
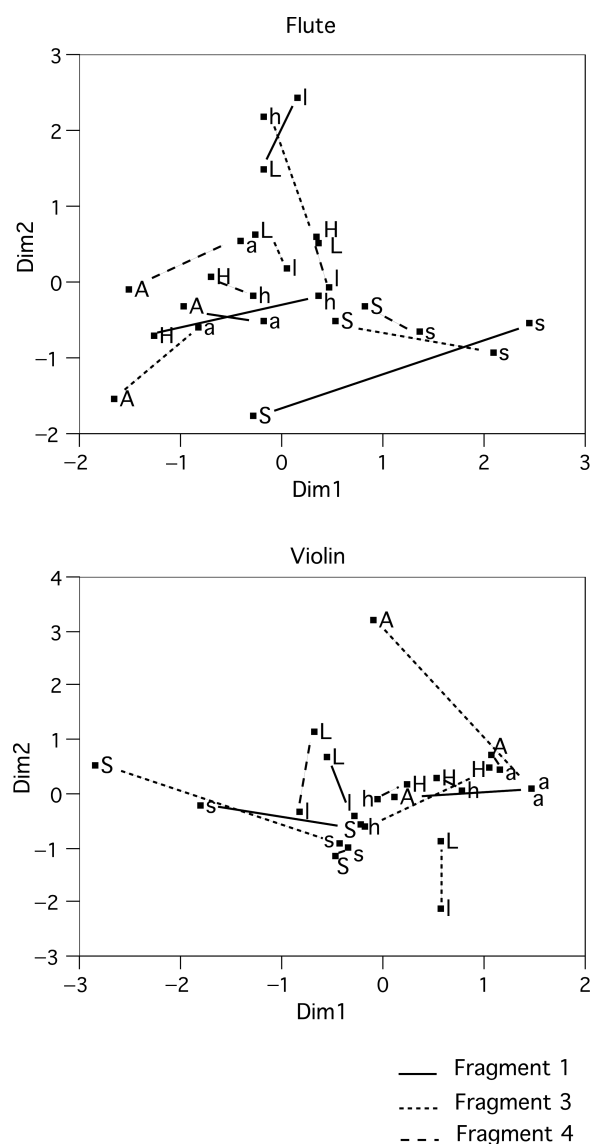
FIGURE 5. Multiple dimensional scaling plot of the flute performances (top) and violin performances (bottom). Instructed emotions are indicated by initials. Capital initials indicate intense emotions and lower case initials indicate mild emotions. Lines connect mild and intense versions of a performance. Different line types indicate the different fragments.

and negatively correlated with the complexity of ornaments ($r = .94$ and $-.93$, $N = 24$, $p < .0001$), while dimension 2 of the flutist most strongly correlated with the presence of slides and pre-main rather than on-main timing ($r = .84$ and $.81$, $N = 24$, $p < .0001$).

As can be seen in the top panel of Figure 5, the four emotions tended to occupy different spaces: Sad performances loaded high on dimension 1 and low on dimension 2. Loving and happy performances scored in

the middle of dimension 1 and high (loving) or medium high (happy) on dimension 2. Finally, angry performances loaded low on both dimensions. The intense and mild versions of a performance were not always grouped closely together. Overall, there was a tendency for the intense version to score lower on dimension 2 than the mild version, which means that intense versions tended to have fewer slides and more pre-main timing than mild versions.

For the violinist, the first two components accounted for 57% of the variance. Dimension 1 was most strongly negatively correlated with timing (higher scores have more pre-main than on-main timing) and with the metrical position of ornaments ($r = -.84$, and $-.82$, $N = 24$, $p < .0001$), while dimension 2 was most strongly negatively correlated with the presence of single appoggiaturas, and positively with the presence of turns and complexity ($r = -.79$, $.78$, and $.78$, $N = 24$, $p < .0001$).

As can be seen in the bottom panel of Figure 5, also for the violinist, the four emotions tended to occupy different spaces. Sad performances scored lowest on dimension 1, followed by loving and happy performances. Angry performances scored highest on dimension 1. The scores on dimension 2 were generally intermediate with some exceptions. Angry performances scored relatively high on dimension 2, and sad relatively low, although the loving version of fragment 3 scored lowest. Overall, there was a tendency for intense versions to score higher on dimension 2 than mild versions of an emotion, which indicates that intense versions tended to have more complex ornaments, more turns, and fewer single appoggiaturas. Additionally, for the negative emotions, intense versions tended to score lower on dimension 1 than mild versions, which indicates that they had relatively more on-main timing on heavier beats.

## Study 2: Perception of Emotion in Ornamented Melodies

Our second study consisted of a listening experiment. In this experiment, the communication of emotion from performer to listeners was investigated. We examined the recognition of the emotions by the listeners as well as the relationship between listeners' responses and applied ornamentation. Participants were not Baroque specialists, but had considerable musical training in Western classical music. Participants rated the presence of the four emotions—happiness, love, sadness, and anger—on a seven-point rating scale. Unipolar scales were used to allow for ambiguous and relatively open responses (e.g., both happy and sad

might be perceived to be present to some extent in a performance, or none of the emotions might be perceived to be strongly present). No differentiation was made between mild or intense emotions, in order to keep the rating task simple. Instead, we expected that an emotion would be perceived to be more strongly present in performances of intense emotions than performances of mild emotions.

METHOD

*Materials.* The variously ornamented performances of fragments 1, 3, and 4 that were analyzed in Study 1 were used in the listening experiment. The recordings of these performances were overdubbed with the recordings of the piano accompaniment and presented as a mixed monotrack file to both ears. Because the solo performances and the piano performances were recorded in the same hall and with the same recording set up, the resulting sound mix was of very high quality and convincingly realistic; the fact that it was produced by overdubbing was not noticed by the listeners.

*Participants.* Twenty-four music students participated in the experiment. They were divided into two groups of twelve, the violin and the flute groups. The majority were second year music undergraduates, but some higher-level students participated as well. They were paid a small amount for their participation. The average age was 24 for the flute group and 23 for the violin group. The average age of the violin group is given excluding one elderly undergraduate music student (age 66). The average number of years of instrumental practice was 10 for the flute group and 14 for the violin group. Participants performed a variety of instruments. The flute group consisted of one string player, three wind instrument players, four voice majors, two keyboard players, a harpist and a composer. The violin group consisted of four string players, four wind instrument players, one voice major, and three keyboard players.

*Procedure.* The participants were tested individually. Assignment to the flute or violin group was done in alternation. The participants in the flute group listened to the flute performances in random order and the participants in the violin group listened to the violin performances in random order. The participant was seated at an iBook Macintosh computer and was given instructions to read. Some practice with the task was provided, after which the real experiment would begin. The practice trials consisted of one expressive and one neutral performance of each fragment. After the practice trials, there was some time for questions and feedback. The duration of the entire experiment was less than an hour.

A user interface with a play button and four vertical seven-point rating scales with verbal labels of the emotions on top, designed in POCO (Honing, 1990), was used to play the musical material and record the ratings. The order of the four emotions in the interface was counterbalanced over participants. The music was presented over Sony dynamic stereo professional headphones (model MDR-7506) at a comfortable volume.

The instruction to the participants was to listen carefully to the performances and the ornaments that the performer used, and to judge the extent to which the emotions happy, loving, sad, and angry were perceived to be present in the performance. Participants were asked to rate the presence of each emotion independently. They were free to rate the emotions in any order and could change the rating until they pressed the ok/save button. They were asked to try to listen to each performance only once, although it was possible to listen to it again if needed by pressing the play button again.

*Results*

*Rating of the presence of the emotions.* Two measures of percent correct are reported here. The target emotion may be said to be correctly identified by the listener when that emotion is rated as more strongly present in the target performance than the other emotions. The rating of the target emotion is than absolutely highest. However, a target emotion may also be said to be correctly identified when that emotion is rated to be more strongly present in the target performance than in the other performances of a fragment. The rating of the target emotion is relatively high for the target performance.

Table 3 shows the mean percent correct scores for the relatively judged emotions, per emotion and per fragment, for the flute and the violin performances. The absolute percent correct scores are given in parentheses.

The values in Table 3 should be compared to a chance level of 25%. This is the chance probability that a target emotion is the highest rated emotion. It can be seen that happy was not always recognized above chance, but the other emotions generally were; their relative percentages correct were at least 50% and for some conditions close to 80% or even 90%. These results do not distinguish between conditions where the instruction was to express a mild or intense version of the emotions. The difference in percentage correct was small between the versions, although there was a tendency for the intense emotions to be better recognized than the mild emotions.

TABLE 3. Average Percentage of Participants that Gave the Relatively Highest (or in Parentheses, Absolutely Highest) Rating to the Target Emotion.

| | Flute | | | Violin | | |
|---|---|---|---|---|---|---|
| | F1 | F3 | F4 | F1 | F3 | F4 |
| Happy | 21 (17) | 38 (8) | 46 (54) | 42 (8) | 21 (4) | 63 (46) |
| Loving | 50 (42) | 54 (58) | 75 (58) | 50 (58) | 54 (46) | 50 (21) |
| Sad | 67 (75) | 88 (79) | 58 (21) | 50 (79) | 71 (88) | 54 (50) |
| Angry | 63 (50) | 58 (33) | 54 (50) | 92 (67) | 92 (50) | 79 (83) |

The differences between the relative and the absolute percentages highlight the influence of the fragments. For example, F4 was generally judged to be happy in character, while F1 and F3 were generally judged to be sad in character. This is suggested by the absolute percentage correct. Such trends, related to the characteristics of the fragments, are cancelled out in the relative percentage correct.

It is noteworthy that all relative percentages are higher than the absolute percentages, except for some loving and sad conditions, which is likely a result of an interchanging of loving and sad, as we will see next.

Correlations were used to examine the association between perceived emotions and between perceived and instructed emotions. Data was averaged over participants. Before averaging, however, the effect of fragment on the emotion rating was separated from the effect of performance by subtracting the average emotion rating of a fragment from the emotion rating of a performance. Instructed emotions were coded as 0 or 1, while ratings of perceived emotions varied between 1 and 7. Tables 4 and 5 show the significant correlations for the flute and violin performances, respectively.

For both the flutist and the violinist, significant positive correlations existed between the ratings of love and sadness, and between instructed and perceived anger, instructed and perceived love, instructed and perceived sadness, and between instructed sadness and perceived love (for the flute performances) or instructed love and perceived sadness (for the violin performances). In other words, sadness and love confounded, and happiness was not reliably communicated. Additionally, anger and love as well as anger and sadness correlated negatively. In contrast to what might be expected, happiness and sadness correlated negatively only in a few instances (e.g., instructed sadness and perceived happiness).

*Relation between performances and ratings.* To explore which of the analyzed characteristics of the performances may have influenced the listeners' ratings of emotions, correlations between analyzed characteristics and average ratings per performance were calculated. This was done for each characteristic and rated emotion separately, and separately for the flutist and violinist. As before, the effect of fragment on the emotion rating was first separated from the effect of performance by subtracting the average

TABLE 4. Correlations Between Rated Emotions (Rows) and Rated or Instructed Emotions (Columns) for the Flute Performances.

| | Rated | | | Instructed | | | |
|---|---|---|---|---|---|---|---|
| | Happy | Loving | Sad | Happy | Loving | Sad | Angry |
| Happy | | | | .32 | .30 | −.59 | −.04 |
| Loving | .06 | | | −.13 | **.50** | **.44** | **−.80** |
| Sad | **−.48** | **.69** | | −.27 | .09 | **.78** | **−.60** |
| Angry | −.03 | **−.89** | **−.70** | .01 | −.39 | **−.42** | **.79** |

*Note:* Significant correlations are in bold ($N = 24$, $p < .05$).

TABLE 5.  Correlations Between Rated Emotions (Rows) and Rated or Instructed Emotions (Columns) for the Violin Performances.

|        | *Rated* | | | *Instructed* | | | |
|--------|-------|--------|------|-------|--------|------|-------|
|        | Happy | Loving | Sad  | Happy | Loving | Sad  | Angry |
| Happy  |       |        |      | .34   | .15    | **−.47** | −.02 |
| Loving | .26   |        |      | .20   | **.41** | .26  | **−.88** |
| Sad    | −.14  | **.70** |      | .02   | **.70** | **.55** | **−.75** |
| Angry  | −.07  | **−.93** | **−.83** | −.27 | −.23 | **−.40** | **.91** |

*Note:* Significant correlations are in bold (*N* = 24, *p* < .05).

emotion rating of a fragment from the emotion rating of each performance. This was done for participants individually, before averaging the rating data.

All analyzed characteristics of the ornaments per performance were taken into account, which included the different types of ornaments, the ornament characteristics, the sound level of the performance, and the structural position of the ornaments. Tables 1 and 2 (right columns) show the correlations that were significant (*p* < .05). Generally, they confirm the relationships observed in the analyses of the performances, with some exceptions. For example, some effects that were observed in the performances were not recognized reliably by the listeners, such as the association between the presence of slides and loving for the flutist, or the presence of trills and happy for the violinist.

## Discussion

In this study, we investigated the communication of emotions in modern performances of a Handel sonata by means of ornamentation. The recognition of the performers' intentions by musically trained listeners was successful on the whole. Sadness, anger, and love were communicated well above chance level. The recognition of happiness was, however, less successful and was above chance level for some fragments only. In the ratings of the presence of the four emotions, sadness and love were correlated, and instructed sadness and love were perceived as expressing both love and sadness. No such correlations between the two negative or the two positive emotions were observed, nor were the two active emotions confused. In other words, the performers communicated distinguishable categories of emotions with the exception of the low-activity emotions studied here—sad and loving.

Despite this observation of communication of discrete emotions, we also observed certain strong correlations between characteristics of ornaments and the activity of emotions. Ornament density and complexity were positively related to active emotions for both performers. Additionally, the violin performances showed a correlation between activity of emotions and sound level and the flute performances showed a correlation between activity of emotions and the use of trills, arpeggios, and short as opposed to long durations. In contrast to what might be expected based on previous literature (Balkwill & Thompson, 1999), complexity was a factor related to activity of emotions rather than to the valence of emotions.

Only a few relationships with valence were observed. The flutist used more slides and timed the ornaments with more anticipation, and more often on weak beats in the performances of positive emotions than in performances of negative emotions. The violinist used more trills in positive emotion conditions.

Sometimes specific ornaments were related to specific emotional intentions. For example, the flutist used slides specifically in the loving conditions and turns in the happy conditions, while the violinist used trills in the happy conditions and substitutes (to lower pitch ranges) in sad performances. However, most of the results were in line with our hypothesis that ornaments can function as acoustic cues for emotions; the characteristics of the ornaments such as density, duration, sound level, and timing mattered, rather than the type of ornament or the position of the ornament within the melody. Notably, most of these characteristics are not unique to ornaments, but could just as well be characteristics of other melody notes or the musical composition in general.

Some evidence was found for the relevance of the structural position of the ornaments. The structural

position of the ornaments was examined to include an aspect of the theories of Meyer (1956) and Langer (1963), which emphasize the relevance of how music unfolds over time for the emotional characteristic of music. The only significant effect that was found was a significant variation of the metrical position of ornaments with instructed and perceived emotion. For both performers, sadness was associated with ornaments at heavy metrical positions, which corresponds to a frequent use of on-main appoggiaturas in this condition. Ornaments at weak metrical positions were, on the other hand, associated with the presence of happiness and positive emotions for the flutist, and with the presence of anger and active emotions for the violinist. Apparently, the performers applied weak-beat timing in distinct ways, possibly related to the tendency of the flutist to time ornaments pre-main in positive emotion conditions, and the tendency of the violinist to add more ornaments in high activity emotion conditions.

From the observed relationships between expressed or perceived emotion and ornamentation, it should not be concluded that there was strong evidence for shared knowledge between performers and listeners about the expression of emotion through ornamentation. The means to express the emotions through ornamentation were different for the two performers and, thus the cues to infer emotions were different for the two groups of listeners. Expressed emotions could be recognized, although not all varied characteristics of ornaments were effective in conveying the performers' intentions. The disagreement in means of expression between the performers coupled with a fairly accurate communication between performer and listeners suggest that conventions concerning communication of emotion through ornamentation are not strong (at least nowadays), but that does not preclude communication. It seems that, although 18th century musicians may have had stronger associations between types of ornaments and their emotional meanings, modern musicians do not clearly possess this.

It should be noted that this study was exploratory and needs corroboration. For example, in the reported experiments, articulation and timbre may have played a role in the communication of emotions and may have helped participants to infer emotions correctly. To assess the contribution of ornamentation more strictly, performers may be asked, in a follow-up study, to perform the ornamented versions without knowledge about the intention to express different emotions, after which listeners rate the perceived emotions. The observed associations between ornamentation and emotions should therefore be taken as suggestive only.

Moreover, the results of this study relied heavily on only two performers and were probably to some extent specific to the musical style of the Handel sonata. A larger-scale study with more performances with fewer ornamentations per fragment may be needed here, also to examine whether some of the differences between the performers have greater generality for their respective instruments.

Although the performers were generally comfortable with their task, they did mention that it was a bit awkward to impose an emotion that contrasted with the mood of the original music. Specifically, the violinist found it odd to perform the music angrily, when originally there was no anger in the music. Nevertheless, the communication of instructed anger was most successful.

These and related issues of ecological validity complicate systematic research, but nevertheless need careful consideration. The use of both systematic variation of variables and examples from existing music may provide a solution in future research.

Given certain restrictions, our study showed that modern musicians are able to reliably use ornamentation for the communication of emotion and suggested how this communication might work. It emphasized performers' varying strategies to express emotions, the predominance of communication of activity, and the predominance of cue-like communication. Even though the strategies of ornamentation may have limited generality, communication still functioned properly.

## Author Notes

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